Geology and Coal Resources of the Buffalo-Lake De Smet Area Johnson and Sheridan Counties Wyoming

By WILLIAM J. MAPEL

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Description of sedimentary rocks and reserves of coal in part of the Bighorn Mountains and the adjacent west side of the Powder River Basin

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GEOLOGY AND COAL RESOURCES OF THE BUFFALO LAKE DE SMET AREA, JOHNSON AND SHERIDAN COUNTIES, WYOMING

By William J. Mapel

ABSTRACT

The Buffalo-Lake De Smet area includes about 640 square miles in Johnson and Sheridan Counties, north-central Wyoming. The area lies on the eastern flank of the Bighorn Mountains and the western margin of the Powder River Basin. It includes most of the northern and central parts of the Buffalo coal field.

Sedimentary rocks exposed in the area have an aggregate thickness of about 17,500 feet and range in age from Cambrian to Quaternary. Igneous and metamorphic rocks of Precambrian age, mainly granite and gneiss, underlie this sedimentary sequence unconformably. The Precambrian rocks are exposed along the western border of the area in the core of the Bighorn Mountains. Rocks of early Paleozoic age crop out in a narrow, northward-trending band along the mountain front. Rocks ranging in age from early Mississippian to Paleocene are exposed adjacent to the mountain front. Rocks of Eocene age cover most of the area east of the foothills. Surficial deposits of Quaternary age, including terrace and pediment deposits, alluvium, colluvium, and landslide material, occur locally.

The oldest sedimentary formation in the Buffalo-Lake De Smet area is the Flathead sandstone of Middle Cambrian age. It is about 345 feet thick and consists mainly of light-brown crossbedded sandstone interbedded with some green shale. The undifferentiated Gros Ventre and Gallatin formations, of Middle and Late Cambrian age, conformably overlie the Flathead sandstone, and consist of about 645 feet of glauconitic brown sandstone, green shale, and gray limestone and flat-pebble limestone conglomerate. The Bighorn dolomite, of Ordovician age, is about 400 feet thick, and overlies the undifferentiated Gros Ventre and Gallatin formations with a distinct lithologic break but no perceptible discordance. A friable white sandstone member at the base of the Bighorn dolomite is 55 to 65 feet thick; the remainder of the formation is a prominent cliff-forming unit composed of light-gray dolomite that is massive in the lower part but becomes thin-bedded in the top 40 to 60 feet. The Madison limestone overlies the Bighorn dolomite and is 665 feet thick. It consists chiefly of light-gray limestone, dolomitic limestone, and dolomite that is early Mississippian in age. Resting unconformably on the Madison is the Amsden formation of Pennsylvanian age, made up of about 250 feet of interbedded red shale, light-gray cherty dolomite, and gray limestone. The Amsden formation grades upward into the light yellowish-gray crossbedded Tensleep sandstone, about 275 feet thick, of Pennsylvanian age.

Permian rocks are represented by an unnamed sequence of red shale, siltstone, and gypsum, with subordinate limestone, 180 feet thick, which rests unconformably on the Tensleep sandstone. These rocks are overlain by the Chugwater

formation of Triassic age composed of about 800 feet of red sandstone, siltstone, and shale with a bed of gray and pink limestone 6 to 13 feet thick in the upper part. The Gypsum Spring formation of Middle Jurassic age unconformably overlies the Chugwater formation and is 145 to 185 feet thick. It consists of red shale interbedded with light-gray argillaceous limestone. The Late Jurassic Sundance formation, 280 feet thick, overlies the Gypsum Spring formation conformably in the northwestern part of the area and unconformably in the west-central and southwestern parts. The Sundance formation is marine and consists of light-gray glauconitic sandstone and green shale. It grades upward into the nonmarine Morrison formation of Jurassic age which is 185 feet thick and is composed of crossbedded gray sandstone and variegated claystone.

The Cloverly formation of Early Cretaceous age is 155 feet thick. It consists of a basal light-gray ledge-forming sandstone overlain by black and gray shale and brown siltstone. Early Cretaceous rocks overlying the Cloverly formation include the Skull Creek shale, 175 feet thick, composed of black shale with subordinate brown siltstone; the light-gray Newcastle sandstone, 40 feet thick; and the Mowry shale, 525 feet thick, composed of a lower soft bentonitic black shale member and an upper resistant siliceous shale member.

Late Cretaceous rocks include in ascending order: (1) the Frontier formation, 500 feet thick, composed of interbedded light-gray sandstone and dark-gray shale with a few beds of bentonite and conglomerate; (2) the Cody shale, 3,570 feet thick, consisting of dark-gray calcareous and noncalcareous shale, light-gray sandstone, and thin beds of bentonite; (3) the Parkman sandstone, 720 feet thick, consisting mostly of yellowish-gray sandstone with subordinate amounts of gray, greenish-gray, and brown shale; (4) the Bearpaw shale, 200 feet thick, consisting of greenish-gray shale; and (5) the Lance formation, 1,960 feet thick, composed of light-gray sandstone and gray shale.

The Fort Union formation of Paleocene age conformably overlies the Lance formation and is about 3,900 feet thick a few miles south of Buffalo. It consists of thin-bedded light-gray sandstone, gray and brown shale, and conglomerate. Where exposed in the west-central part of the Buffalo-Lake De Smet area, the Fort Union formation is divided into two members by an angular unconformity beneath which as much as 2,600 feet of strata in the middle and lower parts of the formation may locally have been removed by erosion.

The Wasatch formation of Eocene age unconformably overlies the Fort Union formation. Near the Bighorn Mountains, the Wasatch formation may be divided into (1) the Kingsbury conglomerate member, which is as much as 800 feet thick and includes beds of conglomerate made up of pebbles and cobbles of limestone and dolomite, and (2) the Moncrief member, which is as much as 1,400 feet thick and includes beds of conglomerate made up of cobbles and boulders of Precambrian crystalline rocks. The Moncrief member rests on the Kingsbury conglomerate member with an angular discordance near the mountains; eastward, both members grade laterally into a conformable, nonconglomeratic sequence of sandstone, shale, and coal that makes up the Wasatch formation east of Buffalo and Lake De Smet.

Deposits of gravel and clay of possible Oligocene age, tentatively assigned to the White River formation, cover small areas on the upper slopes of the Bighorn Mountains along the western border of the Buffalo-Lake De Smet area.

The Bighorn Mountains are the eroded remnant of a great anticlinal uplift along the flanks of which the exposed sedimentary rocks are bent upward in steep monoclinal folds. These upturned rocks on the east side of the mountains form the west limb of the Powder River Basin, a broad syncline with its steep flank on the west and its deepest part within 10 to 15 miles of the mountain front. Mesozoic and Paleozoic rocks adjacent to the mountains at some places stand vertically or are overturned. The intense folding in this belt is accompanied by thrusting to the east along northward-trending high-angle reverse faults, that bring the Madison limestone over the Kingsbury conglomerate member or Moncrief member of the Wasatch formation for distances of several miles. The conglomeratic members of the Wasatch formation overlap the deformed older formations near the mountains and are themselves folded, although much less severely. Within 3 to 5 miles east of the mountains the Wasatch formation becomes nearly flat lying and is relatively undisturbed by faulting.

Commercially important deposits of coal occur in the Wasatch formation. The coal varies in rank within narrow limits between lignite and subbituminous C. A coal bed that locally may be as much as 220 feet thick, including thin partings of shale, underlies an area of about 2½ square miles near the north end of Lake De Smet. Other beds ranging in thickness from a few inches to 35 feet crop out in the central and eastern parts of the Buffalo-Lake De Smet area. Some coal has been mined, but the tonnages of coal removed have been small. The estimated total of all classes of coal reserves amounts to about 6,400 million short tons.

Two test wells, neither of which was successful, have been drilled for oil and gas in the Buffalo-Lake De Smet area. Both wells were started in the Wasatch formation; one bottomed in the Morrison formation at a total depth of 13,205 feet, and the other bottomed in the Tensleep sandstone at a total depth of 11,041 feet. Gentle folds that occur in the Wasatch formation at several places in the central and eastern parts of the area have not been tested by drilling. One of these, near Ucross, has a surface closure of about 100 feet. Because of angular unconformities in the Tertiary sequence and thinning of the Tertiary rocks eastward, structures favoring the accumulation of oil and gas in the older rocks might be completely hidden or only vaguely reflected by gently dipping Tertiary beds.

Sand and gravel suitable for concrete aggregate and road metal are readily available in terrace deposits near the mountains and along the main streams, and large amounts of clinker suitable for road metal are available east of the mountains.

INTRODUCTION

PURPOSE OF REPORT

The information contained in this report was gathered during a geologic investigation of about 640 square miles in Johnson and Sheridan Counties, Wyo., as part of the program of the Department of the Interior for the development of the Missouri River basin. The area studied includes much coal-bearing land, and particular attention was given to tracing and measuring the thicknesses of coal beds in order to determine the coal reserves and to locate areas most favorable for mining. A study was also made of the structure and stratigraphic relationships of the outcropping rocks in the area in order to provide information that might aid in the search for oil and gas. Some information was gathered on the occurrence of other minerals, including sand and gravel, clinker, bentonite, gypsum, and gold.

PREVIOUS WORK

The general geology of the Buffalo-Lake De Smet area has been known for many years. Important early work was done by Darton (1906a, b, and c) whose investigations of the Bighorn Mountains included much of the Buffalo-Lake De Smet area. Gale and Wegemann (1910) gathered much information on the coal deposits. Demorest (1941) described faulting and folding along the east flank of the Bighorn Mountains, and Sharp (1948) discussed the stratigraphy and structural relations of Tertiary conglomerates that crop out near Buffalo and Lake De Smet. The work of other writers who have described more limited aspects of the geology of the area are cited at appropriate places in the text and listed at the end of this report.

FIELDWORK

The fieldwork on which this report is based was done during the summers of 1949 and 1950. The writer was assisted by R. H. Dott, Jr. in 1949, and by C. R. Lewis, C. A. Sandberg, and A. A. Meyerhoff in 1950. Much of the detailed mapping of coal beds was done by these men.

Aerial photographs at scales of 1:24,000, 1:31,600, or 1:36,000 were used in mapping most of the mountainous western part of the area. Topographic maps prepared for the U. S. Bureau of Reclamation at a scale of 1:24,000 with a 20-foot contour interval were used in mapping most of the coal-bearing lands in the eastern part.

All exposed coal beds more than 2 feet thick were mapped. Where coal was naturally exposed, or could be exposed by digging, sections of individual coal beds were measured about every half mile along the outcrop.

Four core holes were drilled near the north end of Lake De Smet in November and December of 1950 as part of the investigation. The drilling was done to provide information on coal deposits discovered near the lake in holes previously drilled by the U. S. Bureau of Reclamation.

ACKNOWLEDGMENTS

The writer is indebted to his field assistants, Messrs. Dott, Lewis, Meyerhoff, and Sandberg for their conscientious cooperation in the field, and to Mr. Sandberg for help in preparing this report during the winter of 1950–51.

J. M. Schopf and J. R. Gill supplied petrographic descriptions of coal recovered from the four core holes drilled by the Geological Survey near Lake De Smet and from one core hole subsequently drilled by the U. S. Bureau of Reclamation in the same area.

R. K. Hose collaborated in measuring several of the stratigraphic sections of the Mesozoic rocks.

Geologists and engineers of the Yellowstone District office, U. S. Bureau of Reclamation, furnished topographic maps of the area and the logs of their shallow borings drilled in the vicinity of Lake De Smet. Through their cooperation, a truck-mounted core drill was made available for use by the Geological Survey during November and December, 1950. D. H. Jepson and W. J. Witherspoon, Jr., geologists, U. S. Bureau of Reclamation, were especially helpful in supplying maps and records compiled during their study of the Lake De Smet reservoir site.

The writer also thanks Mr. J. E. Rice of Sheridan, Wyo., and Mr. Carl Hepp of Kearney, Wyo., for records of holes drilled near Lake De Smet, and thanks other residents of the district who furnished well logs and information on coal mines and helped in many other ways.

GEOGRAPHY

LOCATION

The Buffalo-Lake De Smet area includes parts of Johnson and Sheridan Counties in north-central Wyoming. It lies on the east flank of the Bighorn Mountains and the western margin of the Powder River Basin, and includes most of the northern and central parts of the Buffalo coal field. The area is bounded on the north by the Sheridan coal field, on the east by the Barber coal field, on the south by the southern edge of T. 50 N., Rs. 80 to 83 W., and on the west by Precambrian igneous and metamorphic rocks that make up the core of the Bighorn range. Figure 1 shows the location of the Buffalo-Lake De Smet area in relation to nearby areas described in reports of the Geological Survey.

TOPOGRAPHY AND DRAINAGE

The Buffalo-Lake De Smet area (pl. 1) includes parts of two well-defined physiographic regions, the eastern slope of the Bighorn Mountains and the western part of the Great Plains. Within the two regions are a variety of contrasting topographic forms.

The eastern flank of the Bighorn Mountains comprises an area of rugged mountain uplands, bordered on the east by a steep pine-covered slope that descends abruptly two to three thousand feet to the adjacent foothills and plains.

Smoothly rounded hills and broad flat-topped benches and terraces characterize the land surface in a belt 3 to 5 miles wide at the base of the mountain slope. Several high spurs, such as Moncrief, North, and Bald Ridges, extend eastward 3 to 4 miles beyond the mountain

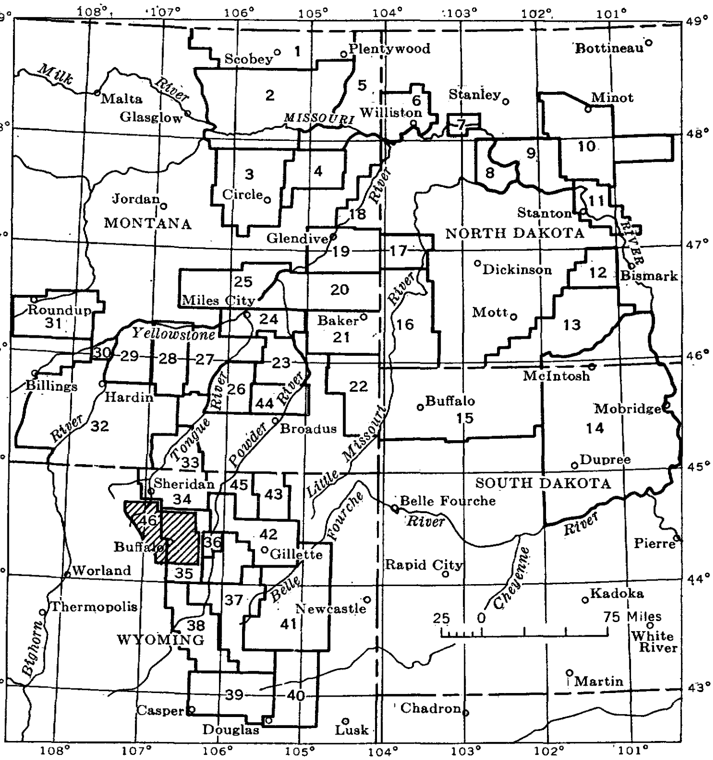


FIGURE 1.—Index map showing Buffalo-Lake De Smet area (cross-lined) and its relation to other coal fields in northeastern Wyoming and nearby States (see table below).

TABLE 1.—*Coal fields whose locations are shown by figure 1*

Index map locality	Field or area	U. S. Geol. Survey Bulletin	Author	Date of publication
1	Scobey	751-E	Collier, A. J	1925
2	Fort Peck	381-A	Smith, C. D	1910
3	McCone County	905	Collier, A. J., and Knechtel, M. M	1939
4	Richey-Lambert	847-C	Parker, F. S	1936
5	Culbertson	471-D	Beekly, A. L	1912
6	Williston	531-E	Herald, F. A	1913
7	Nesson Anticline	691-G	Collier, A. J	1919
8	Fort Berthold	726-D	Bauer, C. M., and Herald, F. A	1922
9	Fort Berthold	381-A	Smith, C. D	1910
		471-C	Pishel, M. A	1912
10	Minot	906-B	Andrews, D. A	1939
11	Washburn	381-A	Smith, C. D	1910
12	New Salem	726-A	Hancock, E. T	1922
13	Cannonball River	541-G	Lloyd, E. R	1914
14	Standing Rock and Cheyenne Reservations.	575	Calvert, W. R., Beekly, A. L., Barnett, V. H., and Pishel, M. A.	1914
15	Northwestern South Dakota	627	Winchester, D. E., Hares, C. J., Lloyd, E. R., and Parks, E. M.	1916
16	Marmarth	775	Hares, C. J	1928
17	Sentinel Butte	341-A	Leonard, A. G., and Smith, C. D	1909
18	Sidney	471-D	Stebinger, Eugene	1912
19	Glendive	471-D	Hance, J. H	1912
20	Terry	471-D	Herald, F. A	1912
21	Baker	471-D	Bowen, C. F	1912
22	Ekalaka	751-F	Bauer, C. M	1925
23	Mizpah	906-C	Parker, F. S., and Andrews, D. A	1939
24	Miles City	341-A	Collier, A. J, and Smith, C. D	1909

TABLE 1.—*Coal fields whose locations are shown by figure 1*—Continued

Index map locality	Field or area	U. S. Geol. Survey Bulletin	Author	Date of publication
25	Little Sheep Mountain	531-F	Rogers, G. S	1913
26	Ashland	831-B	Bass, N. W	1932
27	Rosebud	847-B	Pierce, W. G	1936
28	Forsyth	812-A	Dobbin, C. E	1930
29	Tullock Creek	749	Rogers, G. S., and Lee, Wallace	1923
30	Custer	541-H	Rogers, G. S	1914
31	Bull Mountain	647	Woolsey, L. H., Richards, R. W., and Lupton, C. T.	1917
32	Big Horn County	856	Thom, W. T., Jr., Hall, G. M., Wegemann, C. H., and Moulton, G. F.	1935
33	Northward extension of Sheridan	806-B	Baker, A. A	1929
34	Sheridan	341-B	Taff, J. A	1909
35	Buffalo	381-B	Gale, H. S., and Wegemann, C. H	1910
36	Barber	531-I	Wegemann, C. H	1913
37	Pumpkin Butes	806-A	Wegemann, C. H., Howell, R. W., and Dobbin, C. E.	1929
38	Sussex	471-F	Wegemann, C. H	1912
39	Glenrock	341-B	Shaw, E. W	1909
40	Lost Spring	471-F	Winchester, D. E	1912
41	Gillette	796-A	Dobbin, C. E., and Barnett, V. H.[1]	1928
42	Powder River	381-B	Stone, R. W., and Lupton, C. T	1910
43	Little Powder River	471-F	Davis, J. A	1912
44	Coalwood	973-B	Bryson, R. P	1952
45	Spotted Horse	1050	Olive, W. W	1957
46	Buffalo-Lake De Smet	1078	Mapel, W. J	1959

[1] With a chapter by W. T. Thom on the Minturn district and the northwestern part of the Gillette field.

front and stand several hundred feet above the general level of the adjacent country. Mowry Basin, a prominent topographic feature at the foot of the mountains in the west-central part of the area, is bounded on the west by mountain slopes and on the east by an arcuate line of high ridges that swings eastward from the mountain front.

The hills and terraces of the foothills belt merge gradually eastward into the plains of the Powder River Basin. In this area, the land surface is broken by many steep-sided, even-topped ridges that locally are intricately dissected by erosion. (See pl. 2.)

The total relief is about 4,400 feet; the altitudes range from about 4,100 to 8,500 feet.

The main streams head in the mountains and flow generally northeastward. Their valleys are narrow gorges in the mountains, but become broad and open east of the mountain front. The larger perennial streams include Clear Creek and its tributaries, Piney and Rock Creeks in the southern and central parts of the area, and Little Goose Creek in the northern part. Except for Little Goose Creek, which flows into the Tongue River, the streams form part of the Powder River drainage system.

Many of the smaller streams east of the mountains flow in parallel channels that trend about N. 35° W.; thus, the topography of the plains has a marked northwestward-trending grain.

Lake De Smet occupies a natural undrained basin on the divide between Piney Creek and one of its tributaries, Boxelder Creek. The

Lake is roughly oval in outline, about 3½ miles long and 1½ miles wide with its long dimension trending northwestward. It is fed by Shell Creek which flows eastward from the mountains. The lake has been used for water storage since 1923 when canals were dug connecting it with Piney Creek. Water is diverted from Piney Creek into the lake during periods of large flow and later is returned to Piney Creek when needed downstream for irrigation. The level may thus be raised about 10 feet, giving the lake a potential storage capacity of about 32,000 acre-feet and a depth, when full, of about 60 feet.

CLIMATE AND VEGETATION

The climate and vegetation of the Buffalo-Lake De Smet area is similar to that in many other parts of the northern Great Plains. The climate is cool-temperate and semiarid. The maximum temperature recorded at Buffalo is 104°F and the minimum −38°F. Climatic records are not available for the mountainous region along the western edge of the area, but the mean temperature in the mountains is much lower than on the plains, and frost may be expected in every month of the year.

The vegetation of the dry land east of the mountains consists mostly of sagebrush, various kinds of grasses, and prickly pear. A few willows and cottonwoods grow along the stream bottoms. Thickets of plum, chokecherry, serviceberry, and other bushes are found on hillsides on the lower slopes of the mountains in the northwestern part of the area, and various kinds of pine, spruce, and cedar grow abundantly on the higher mountain slopes and on the mountain uplands.

SETTLEMENT AND ACCESSIBILITY

Buffalo, the county seat of Johnson County, is the largest town in the area; its population was about 2,700 in 1950. The village of Story in the northwestern part of the area has a post office and several stores; it is primarily a summer resort. Other small settlements include Banner, Ucross, and Kearney.

The nearest railroad shipping points are on the Chicago, Burlington, and Quincy Railroad at Clearmont and at Sheridan about 23 miles northeast and about 25 miles north, respectively, of Buffalo. The Wyoming Railroad, which formerly connected Buffalo and Clearmont, was abandoned in 1944. The road bed of the North and South Railroad, which was to connect Casper, Buffalo, and Sheridan, Wyo., and Miles City, Mont., was partly built in 1923 but was abandoned before rails were laid.

U. S. Highway 87 leads northward through Buffalo, Kearney, and Banner. U. S. Highway 16 enters Buffalo from the west after crossing the Bighorn Mountains and follows the valley of Clear Creek to Ucross where it is joined by U. S. Highway 14, the main route from Sheridan eastward. Most of the area may be reached over these highways or over secondary roads or trails that branch from them.

STRATIGRAPHY

Sedimentary rocks exposed in the Buffalo-Lake De Smet area have an aggregate thickness of about 17,500 feet and range in age from Cambrian to Recent. These rocks rest on Precambrian igneous and metamorphic rocks which form the core of the Bighorn Mountains. The sedimentary sequence may be divided into 23 formations, exclusive of surficial deposits of Quaternary age. The lithology and thickness of these formations are summarized on plate 3, and their distribution is shown on plate 1.

The Madison limestone of early Mississippian age and older formations crop out in a narrow nearly continuous belt along the east flank of the mountains except where offset by faults. Formations lying between the Madison limestone and the Kingsbury conglomerate member of the Wasatch formation crop out north of Moncrief Ridge, at Mowry Basin, and south of Bald Ridge, but at most other places along the mountain front these strata are concealed beneath fault blocks composed of older rocks or beneath the Kingsbury conglomerate member or Moncrief member of the Wasatch formation. The Wasatch formation of Eocene age overlaps older rocks near the mountains and extends eastward as the surface formation over most of the central and eastern parts of the mapped area. Locally, unconsolidated deposits of pediment and terrace gravel, alluvium, colluvium, and landslide material cover the older formations near the mountains and along the main stream valleys.

All the formations from the Flathead sandstone of Middle Cambrian age to the Fort Union formation of Paleocene age are essentially concordant in dip; however, several unconformities occur in this sequence, some of them representing long periods of erosion or nondeposition. The major structural features of the area were formed after deposition of the lower part of the Fort Union formation as indicated by angular unconformities and coarse conglomerates in the Fort Union and Wasatch formations.

PRECAMBRIAN ROCKS

Igneous and metamorphic rocks, principally red and gray granite and gneiss, crop out in the high mountainous region along the western edge of the mapped area. The granites are cut by dikes of aplite, diabase, olivine gabbro, hornblende diorite, and peridotite, and fragments of all these rock types are common in surficial gravels deposited by streams heading in the mountains. The Precambrian rocks were not studied and rocks units comprising them were not mapped during the present investigation. A general description of their distribution and petrology has been given by Darton (1906a, p. 15–23).

CAMBRIAN SYSTEM

MIDDLE CAMBRIAN SERIES

FLATHEAD SANDSTONE

The Flathead sandstone is the oldest sedimentary formation in the Buffalo-Lake De Smet area. Together with the overlying undifferentiated Gros Ventre and Gallatin formations it crops out in a narrow belt marked by valleys and saddles between Precambrian granite and metamorphic rocks to the west and high ridges of resistant Bighorn dolomite to the east. See facing page.

The Flathead is 344 feet thick at Johnson Creek where it consists mainly of yellowish-gray fine- to coarse-grained crossbedded sandstone with some interbedded green micaceous siltstone and shale. The relative amounts of shale and sandstone vary in short distances. About 4 miles north of Johnson Creek, in sec. 1, T. 51 N., R. 84 W., the formation is about half sandstone and half shale. Most of the sandstone is porous and friable, although locally some beds consist of resistant quartzite. The basal part of the formation at most places is a 10- to 40-foot thick dark reddish-brown coarse-grained sandstone which contains a few scattered pebbles and thin lenses of pebbly conglomerate composed of rock fragments derived from the underlying Precambrian rocks. Most of the pebbles are less than 2 inches in maximum dimension. The conglomeratic beds rest unconformably on a surface of low relief cut on Precambrian rocks.

Several specimens of *Elrathia* sp. were found near the middle of Flathead sandstone at South Piney Creek near the C. sec. 23, T. 53 N., R. 83 W. According to A. R. Palmer, who identified the fossils, trilobites of this genus are characteristic of the late Middle Cambrian in the Rocky Mountain region.

MIDDLE CAMBRIAN AND UPPER CAMBRIAN SERIES, UNDIFFERENTIATED

GROS VENTRE AND GALLATIN FORMATIONS, UNDIFFERENTIATED

The undifferentiated Gros Ventre and Gallatin formations crop out along the western side of the Buffalo-Lake De Smet area on moderate to steep slopes above the Flathead sandstone. The formations have a combined thickness of about 645 feet at Johnson Creek in the west-central part of the area.

In general, the undifferentiated Gros Ventre and Gallatin formations may be divided into a lower unit 120 to 150 feet thick consisting

Section of the Flathead sandstone north of Johnson Creek in the NW¼ sec. 29, T. 51 N., R. 83 W.

Gallatin and Gros Ventre formations, undifferentiated.

Flathead sandstone:

	Ft
1. Sandstone, very light gray, coarse-grained, fairly well sorted, friable, crossbedded, in beds as much as 10 ft thick	95
2. Sandstone, very light yellowish gray, coarse- to medium-grained, crossbedded, in beds 2 to 5 ft thick with a few thin beds of green micaceous siltstone near top	32
3. Concealed	18
4. Shale, green	2
5. Sandstone, yellowish-gray, coarse- to fine-grained, poorly sorted; in beds ½ to 2 ft thick	5
6. Concealed	12
7. Shale and siltstone, interbedded; shale is green, micaceous; siltstone is yellowish gray, thin bedded	8
8. Sandstone, light-gray to light yellowish-gray, coarse- to medium-grained, crossbedded; in alternating thin and thick beds, with a few thin beds of green micaceous sandy shale in upper part	132
9. Siltstone, pale yellowish-green, sandy	3
10. Concealed	19
11. Sandstone, dark reddish-brown, coarse- to medium-grained, poorly sorted, crossbedded; contains some interbedded dark-green micaceous shale; a few pebbles of Precambrian crystalline rocks as much as 2 in. in diameter in bottom 2 ft	18
Total measured thickness	344

Unconformity.

Precambrian igneous and metamorphic rocks.

mostly of brown to light-tan sandstone, a middle unit 400 to 450 feet thick consisting mostly of green micaceous shale with lesser amounts of thin-bedded limestone and flat-pebble limestone conglomerate, and an upper cliff-forming unit 60 to 90 feet thick consisting mostly of slabby limestone with many layers of flat-pebble limestone conglomerate.

The basal sandstones of the undifferentiated Gros Ventre and Gallatin formations are less resistant than sandstones in the Flathead and on covered slopes the contact between the two formations is marked by a break in slope with the steeper slopes formed on the Flathead. At Johnson Creek these basal sandstones are thin-bedded, calcareous, and glauconitic, and rest with a sharp contact on thick-bedded noncalcareous nonglauconitic sandstone at the top of the Flathead.

The shale which makes up the middle unit commonly is silty and ripple-marked; it contains fucoids and worm borings. Thin beds of finely crystalline light-gray limestone that grade laterally into beds of flat-pebble limestone conglomerate occur throughout the shale sequence, becoming more numerous near the top, and thin beds of green and brown sandstone occur locally in the lower part. The unit is nonresistant and its outcrop nearly everywhere is marked by many small landslides.

The limestone in the upper cliff-forming unit of the formations is thin-bedded, finely crystalline, light gray and grayish red, and glauconitic. Partings of pink, green, and red shale and shaly limestone occur between the beds of limestone and the unit grades downward into the less resistant shale and limestone unit by increase in the number and thickness of these partings.

Section of the Gros Ventre and Gallatin formations, undifferentiated, north of Johnson Creek in the SW¼ sec. 20, T. 51 N., R. 83 W.

Sandstone member of the Bighorn dolomite.	
Unconformity (?)	
Gallatin and Gros Ventre formations, undifferentiated:	Ft
1. Limestone, pink, shaly and silty, very thin bedded	6
2. Limestone, and flat-pebble limestone conglomerate, gray, light-gray, and grayish-red, thin-bedded; contains disseminated grains of glauconite and partings of green, pink, and red shale and shaly limestone; forms cliff	83
3. Concealed by talus and slump; appears to be mainly soft green micaceous shale with thin beds of gray limestone and flat lime-pebble conglomerate; blocks of limestone talus evidently from beds 50 to 75 ft above base of unit contain *Arapahoia aspinosa* Lochman, *A. convexa* Lochman, *A. neihartensis* Lochman, *Cedaria nixonia* Lochman, *Dicellomus occidentalis* Bell (extremely abundant), *Tricrepicephalus* sp., and *Uncaspis*? sp	439
4. Sandstone, green, red, and brown, medium- to fine-grained, calcareous, thin-bedded; some layers composed mostly of glauconite and others of oolitic hematite; contains *Bolaspidella wellsvillensis* Lochman and Denson and *Armonia lata* Howell and Duncan	16
5. Shale, green, micaceous; sandstone, light-gray and light green-gray, calcareous, glauconitic; and limestone, light-gray, thin-bedded	18
6. Sandstone, light-tan and brown, calcareous, glauconitic, fine- to coarse-grained; in alternating thin and medium beds that locally are crossbedded	85
Total measured thickness	647
Flathead sandstone.	

A. R. Palmer, who identified the fossils listed in the foregoing stratigraphic section, regards the collections from units 3 and 4 as indicating Late Cambrian (Dresbach) age. Fossils collected at other localities were identified as follows:

1. From limestones exposed in a road cut on U. S. Highway 16 in the SE¼ sec. 4, T. 50 N., R. 83 W., about 120 feet below the top of the undifferentiated Gros Ventre and Gallatin formations. Fossils identified by A. R. Palmer:

Late Cambrian, early Trempeleau age.

Dikelocephalus sp.

Illaenurus cf. *I. calvini* Walter.

Corbinia sp.
Koldinoidia? sp.

2. From green shales exposed at the same locality and stratigraphic position as the collection above. Fossils identified by A. R. Palmer and Josiah Bridge:

Late Cambrian.

Dendrograptus hallianus (Prout)? (13–15 thecae in 10 mm).
edwardsi Ruedemann? (8–11 thecae in 10 mm).
species undescribed (20–24 thecae in 10 mm).

3. From a bed of limestone 30 feet below the top of the undifferentiated Gros Ventre and Gallatin formations in the SE¼ sec 33, T. 54 N., R. 84 W. Fossils identified by G. A. Cooper:

Late Cambrian or Early Ordovician.

Silicified "beekite" specimens of an orthid brachiopod, probably of the genus *Apheoorthis*.

ORDOVICIAN SYSTEM

BIGHORN DOLOMITE

The Bighorn dolomite was named by Darton (1904, p. 395) from exposures along the east side of the Bighorn Mountains. Its thickness in the Buffalo-Lake De Smet area ranges from 370 to 395 feet. The formation includes a sandstone member at the base, a massive cliff-forming dolomite member in the middle, and a thin-bedded dolomite and dolomitic limestone member at the top.

The basal sandstone member is 65 feet thick at South Piney Creek, 55 feet thick at the South Fork of Rock Creek, and 57 feet thick at Clear Creek. Its contact with the underlying limestone of the undifferentiated Gros Ventre and Gallatin formations is sharp and even. The member consists of nonresistant crossbedded friable white sandstone composed of fine- to very fine-grained well-sorted quartz grains. The sandstone contains in its lower part a few thin partings of pale-green, brown, and pink shale, and in its upper part thin lenses of coarse rounded and pitted quartz grains. Commonly the upper 10 to 20 feet is mottled and streaked shades of red and purple. Indeterminate fragments of fish bones are concentrated in lenses in the upper 5 to 10 feet. At the top of the member is 2 to 3 feet of yellowish-gray calcareous sandstone or sandstone breccia which rests on the underlying beds with a sharp, uneven contact.

Overlying the lower sandstone member of the Bighorn is about 230 feet of massively bedded tan to light-gray saccharoidal dolomite which generally forms a high westward-facing cliff. This rock characteristically weathers to a rough pitted surface. The basal 1 to 2 feet of the massive dolomite member commonly is sandy and grades downward into a bed of yellowish-gray calcareous sandstone at the top of the underlying sandstone member.

The upper thin-bedded member of the Bighorn dolomite consists of 75 to 110 feet of light-gray to white thin- to medium-bedded dense to finely crystalline dolomite and dolomitic limestone. Some of the beds weather with irregularly pitted or hackly surfaces, and locally the rock is brecciated. The upper member commonly erodes to gentle slopes that are covered by talus from the overlying Madison limestone.

Section of the Bighorn dolomite on the South Fork of Rock Creek in the SW¼, sec. 25, T. 52 N., R. 84 W.

Madison limestone.
Unconformity (?)
Bighorn dolomite:

Thin-bedded limestone and dolomitic limestone member:	Ft
1. Limestone, light-gray, thin-bedded, poorly exposed; middle 5 ft weathers to reddish clay and contains well-preserved brachiopods, corals, and bryozoa	16
2. Limestone, light yellowish-gray, dense	3
3. Limestone, dolomitic, light-gray, dense to finely crystalline, medium-bedded; basal 6-in. bed of shaly limestone forms deep reentrant	26
4. Limestone, dolomitic, light-gray; weathers to rough pitted surface stained red	20
5. Concealed	46
Massive dolomite member:	
6. Dolomite, yellowish-gray, saccharoidal, massive; weathers to ragged pitted surface; forms cliff	185
7. Limestone, dolomitic, light-gray, finely crystalline; contains small irregularly shaped flesh-colored masses of dolomite; weathers to a rough pitted surface; forms cliff; bottom 1 ft is sandy	44
Basal sandstone member:	
8. Sandstone, yellow, fine- to medium-grained, calcareous firmly cemented; contains *Receptaculites;* forms reentrant	3
9. Sandstone, mottled white, red, and purple, fine-grained, friable, nonresistant; contains a few lenses of rounded and pitted medium and coarse grains of quartz	5
10. Concealed	15
11. Sandstone, white, fine- to very fine-grained, well-sorted, porous and friable; nonresistant; contains a few partings of brown shale	30
12. Concealed	2
Total measured thickness	395

Unconformity (?)
Gallatin and Gros Ventre formations, undifferentiated.

Section of the Bighorn dolomite east of Clear Creek in the E½ sec. 10, T. 50 N., R. 83 W.

Madison limestone.
Unconformity(?)
Bighorn dolomite:

Thin-bedded limestone and dolomitic limestone member:	Ft
1. Concealed; red soil in upper third of interval	24
2. Limestone, white to yellowish-gray, brecciated, irregularly bedded	12

Section of the Bighorn dolomite east of Clear Creek in the E½ sec. 10, T. 50 N., R. 83 W.—Continued

Bighorn dolomite—Continued	
Thin-bedded limestone and dolomitic limestone member—Continued	Ft
3. Concealed	8
4. Limestone, dolomitic, white, thin- to medium-bedded, earthy	30
Massive dolomite member:	
5. Dolomite, yellowish-gray, saccharoidal; weathers to ragged pitted surface; bottom 1 to 2 ft sandy; forms cliff	235
Basal sandstone member:	
6. Sandstone, yellow, fine- to medium-grained, firmly cemented, cavernous; forms reentrant	3
7. Sandstone, mottled white and red, fine-grained; contains coarse rounded and pitted grains of quartz and abundant fish fragments concentrated in thin lenses	9
8. Concealed	13
9. Sandstone, white, mottled red and pink, quartzitic, very fine grained, well-sorted, thin- to medium-bedded, friable	32
Total measured thickness	366
Unconformity(?)	
Gallatin and Gros Ventre formations, undifferentiated.	

Darton (1906b, p. 4) correlated the basal sandstone member of the Bighorn dolomite with the Harding sandstone of Colorado on the basis of fish remains collected in the south-central part of the Bighorn Mountains near the south fork of the Red Fork of the Powder River. The age of the Harding sandstone, according to Kirk (1930, p. 465), is Middle Ordovician, probably late Black River or early Trenton. In discussing the stratigraphic equivalence of the basal sandstone of the Bighorn dolomite with the Harding sandstone, Kirk (p. 460–461) states:

> There are in the Bighorn and Bridger ranges two Ordovician sandstones that may be confused * * * The lower is the true Harding equivalent and usually carries fish fragments in fair abundance. The overlying sandstone, the basal sandstone of the Bighorn, also carries an occasional fish fragment. In this upper sandstone the bones as seen were small rolled pieces that may well have been derived from the underlying horizon. Extensive collecting in this sandstone in the Wind River and Teton ranges to the west did not yield a single piece of bone. The two sandstones differ lithologically and may readily be distinguished. The upper sandstone usually carries a characteristic and sometimes abundant invertebrate fauna consisting of cephalopods, gastropods, and *Receptaculites.*

The "basal sandstone of the Bighorn" referred to by Kirk above is represented by the 2- to 3-foot bed of yellowish-gray sandstone found at the top of the sandstone sequence in the two sections described above. Specimens of *Receptaculites oweni* Hall, *Maclurites manitobensis* Whiteaves, and *Endoceras landerense* Foerste were collected by J. M. Berdan and H. M. Duncan in 1951 from this unit and from sandy dolomite beds at the base of the massive dolomite member of the Bighorn dolomite a few inches above this unit, at the North Fork of Crazy Woman Creek in sec. 25, T. 49 N., R. 83 W., 5 miles south of the Buffalo-Lake De Smet area. According to Josiah Bridge, who identified the fossils, this assemblage "is commonly considered to be of Middle Ordovician (Trenton) age." Amsden and Miller (1942, p. 301–306) noted the occurrence of conodonts in the sandstone member of the Bighorn dolomite south of Buffalo at both Crazy Woman and Billy Creeks. They conclude that the conodont fauna of the greater part of the sandstone sequence is closely related to that of the Harding sandstone, but that the conodont fauna of the uppermost 3-foot sandstone bed differs from that below and resembles more closely the fauna found in the lower part of the Whitewood limestone in the Black Hills. Amsden and Miller (p. 306) assign a Middle Ordovician age to both the upper and lower sandstones, but suggest that the upper bed may well be referable to the Late Ordovician.

The massive dolomite member of the Bighorn dolomite contains the coral assemblage commonly found in rocks considered Upper Ordovician in western United States. *Streptelasma* sp., *Calapoecia* sp., *Halysites* (*Catenipora*) cf. *H. rubra*, *Palaeofavosites* sp., and *Palaeophyllum* sp. were collected during the present investigation at various places from the upper part of the member, and similar forms have been reported from the member at other places in the Bighorn Mountains.

The fauna of the upper thin-bedded member of the Bighorn is more abundant and varied than the fauna from the lower part of the formation and is of Late Ordovician age. About 5 feet of limy shale which weathers to a reddish clay and yields large numbers of well-preserved brachiopods, corals, and bryozoa crops out about 10 feet below the top of the member on the South Fork of Rock Creek near creek level (Darton, 1906a, p. 28). The following fossils were identified from a collection made at this locality in 1951 by Jean M. Berdan and others (USGS loc. 1362–CO):

Corals: (identified by Helen Duncan)
- *Bighornia anticonvexa* (Okulitch)
  - *parva* Duncan
  - aff. *B. patella* (Wilson)
- *Streptelasma trilobatum* Whiteaves
  - aff. *S. latusculum* (Billings)
- *Favosites* (*Palaeofavosites*) cf. *F. prolificus* Billings

Bryozoa: (identified by R. S. Boardman and Helen Duncan)
- *Arthroclema angulare* Ulrich
- *Batostoma manitobense* Ulrich
- *Bythopora?* sp.
- *Dicranopora emacerata* (Nicholson)
  - *fragilis* (Billings)

Goniotrypa cf. *G. bilateralis* Ulrich
Hallopora sp.
Helopora? sp.
Nematopora? sp.
Pachydictya sp.
Proboscina frondosa (Nicholson)
Rhombotrypa cf. *R. quadrata* (Rominger)
Sceptropora facula Ulrich
Trematopora aff. *T. cumingsi* Troedsson

Brachiopods: (identified by Josiah Bridge)
Diceromyonia subrotundata Wang
tersa (Sardeson)
Dinorthis (*Plaesiomys*) cf. *D. proavita* (Winchell and Schuchert)
Lepidocyclus perlamellosus (Whitfield)
rectangularis Wang
Megamyonia sp.
Öpikina cf. *Ö. limbrata* Wang
Rhynchotrema iowense Wang
Strophomena? perconcava Wang

Ostracodes: (identified by Jean M. Berdan)
Ceratopsis sp.
Drepanella? sp.
Krausella sp.
"*Primitia*" cf. "*P.*" *lativia* Ulrich
Schmidtella sp.
Tetradella sp.

Echinoderm fragments
Trilobite fragments
Fish fragments

This fauna is closely related to the assemblages in the Stony Mountain formation of Manitoba and the Maquoketa shale of Iowa.

CARBONIFEROUS SYSTEMS

MISSISSIPPIAN SYSTEM

MADISON LIMESTONE

The rocks included in the Madison limestone consist of about 670 feet of limestone, dolomitic limestone, and dolomite which overlie the Bighorn dolomite and underlie the Amsden formation. The Madison, together with the underlying Bighorn dolomite forms a high steeply sloping hogback that flanks the Bighorn Mountains on the east. The lower part of the Madison generally is exposed near the crest of this hogback, and the middle and upper parts crop out at successively lower elevations on steep eastward-facing dip slopes.

At the South Fork of Rock Creek, and elsewhere to the south, the Madison may be divided into a lower dolomite and limestone unit, a middle limestone unit, and an upper limestone and limestone breccia unit. All are cliff- or ledge-forming units. The lower unit consists of about 190 feet of light yellowish-gray and light-gray limy dolomite and dolomitic limestone in alternating thin, medium, and thick beds. Chert nodules occur sparsely in the lower part. At the South Fork of Rock Creek, this unit includes at its base about 18 feet of pale greenish-gray dense to earthy thin-bedded dolomite, the lower 5 feet of which contains thin lenses of sandstone composed of well-rounded and frosted medium to coarse grains of quartz. Although no fossils were found in these basal dolomites, they are lithologically distinct from the overlying beds and are similar to beds in the Bighorn River Canyon at the northern end of the Bighorn Mountains which were classified as Devonian by Richards and Rogers (1951).

The middle unit of the Madison, which is about 340 feet thick at the South Fork of Rock Creek, is more thinly bedded than the units above and below. It forms a series of ledges and steep slopes on canyon walls. The unit consists of light-gray dense to finely crystalline limestone and dolomitic limestone which locally contains chert nodules and laminae. At the South Fork of Rock Creek, a zone of pink and green limestone forms a prominent band 35 feet thick in the lower part of the sequence.

The upper unit of the Madison is a massive cliff-forming limestone about 130 feet thick. Its lower part contains solution cavities several feet across filled with a breccia of limestone, red shale, and siltstone. Its upper part is a light-gray to light bluish-gray dense to finely crystalline limestone which contains stringers and nodules of gray chert.

Section of the Madison limestone along the South Fork of Rock Creek, in the SW¼ sec. 25 T. 52 N., R. 84 W.

Amsden formation.
Unconformity
Madison limestone:

	Ft
1. Limestone, white to light-gray, finely crystalline, medium-bedded; contains nodules and thin lenses of gray chert; forms ledge	27
2. Limestone, white, dense, earthy, thin-bedded; forms reentrant	4
3. Limestone, white to light-gray, finely crystalline; thin- to medium-bedded in upper part becoming thick-bedded in lower part; contains irregularly shaped lenses of gray and light-brown chert; basal 30 ft contains large solution cavities filled with breccia of red-stained limestone and red shale; forms cliff	101
4. Limestone, white to very light gray, finely crystalline to dense, medium- to thick-bedded; contains some gray chert nodules in upper part; forms ledges	120
5. Concealed	18
6. Dolomite, white, dense to earthy, thin-bedded, blocky; contains a few nodules of gray chert in upper part	26
7. Limestone, light-gray, dolomitic, finely crystalline, thin-bedded; contains a few thin beds of coarsely crystalline light brownish-gray limestone in upper part; forms ledges	125

Section of the Madison limestone along the South Fork of Rock Creek, in the SW¼ sec. 25 T. 52 N., R. 84 W.—Continued

	Ft
Madison limestone—Continued	
8. Limestone, mottled purple and green, fine to coarsely crystalline; forms reentrant	12
9. Limestone, purple with green mottlings; in part oolitic; contains productids, spirifers, and crinoid stem [discs]; forms ledge	4
10. Limestone, dolomitic; light-gray with thin purple laminae, dense to finely crystalline, thin-bedded; forms ledge	15
11. Limestone, light-gray, dense to finely crystalline, thin- to medium-bedded; forms ledge	21
12. Dolomite and dolomitic limestone, light gray to light yellowish-brown, dense to finely crystalline; thin- to thick-bedded; some beds saccharoidal; contains small calcite-filled vugs; a few nodules of gray chert near base; forms cliff	175
13. Dolomite, light-gray and light greenish-gray, dense; contains lenses of medium to coarse frosted quartz grains in bottom 5 ft; forms ledges	18
Total measured thickness	666
Unconformity(?)	
Bighorn dolomite.	

Fragments of poorly preserved corals, brachiopods, bryozoans, and crinoids are abundant in the Madison, particularly in the middle and upper parts. Fossil collections, listed by Thom and others (1935, p. 34–35), indicate an early Mississippian (Kinderhook and Osage) age for most of the formation in the northern part of the Bighorn Mountains. Fragments of corals and other fossils were collected in 1951 by Helen Duncan and others from the upper 5 feet of the Madison at the South Fork of Rock Creek. Miss Duncan makes the following statement regarding the identification and age of these fossils (written communication, 1951):

The collection consists mainly of silicified coral fragments weathered out of the rock, but several pieces of chert containing the same kinds of corals and indication of a few other fossils were also picked up. The corals are largely fragmentary and are interpreted to be segments broken from compound coralla of *Diphyphyllum*. Two species of this genus appear to be present. Other corals identified as *Caninia* sp. indet. and *Syringopora* sp. indet. The other fossils are preserved as impressions in the chert slabs, which show indications of the bryozoan *Fenestella*, several indeterminate brachiopods including *Composita* and strophomenoids (examined by J. E. Smedley), and the ostracode *Paraparchites* (identified by I. G. Sohn). This assemblage as a whole is not particularly diagnostic; it could occur in either the lower Mississippian or in the upper Mississippian of the West. The corals remind me of the types I identified in a collection made by W. G. Pierce in 1946 from the Madison(?) in the Rairden quadrangle on the west side of the Bighorn Mountains. This faunule and its probable age significance was discussed in the [Wyoming Geological Association] guide book for the Field Conference in the Bighorn Basin, 1947 (p. 37). Mr. [James Steele] Williams and I thought that there was a good possibility that the rocks from which [W. G. Pierce's] collection was obtained were actually of Brazer (late Mississippian) age but felt that there was no real objection to including them in the Madison as mapped on the west side of the range. It would not be astonishing to find that rocks of possible late Mississippian age are included in the unit mapped as Madison on the east side of the Big Horns.

Lithologic correlations with the stratigraphic section described by Richards and Rogers (1951) at the northern end of the Bighorn Mountains suggest that the basal 18 feet of sandy dolomite included in the Madison limestone at the South Fork of Rock Creek may be Devonian in age.

PENNSYLVANIAN SYSTEM

AMSDEN FORMATION

The name Amsden was given by Darton (1904, p. 396) to a heterogeneous sequence 250 to 300 feet thick composed predominantly of light-colored cherty dolomite, red sandstone, and red shale which overlies the Madison limestone and underlies the Tensleep sandstone at Amsden Creek about 18 miles north of the Buffalo-Lake De Smet area. The Amsden formation generally forms dip slopes on the high eastward-facing ridge held up by the resistant Madison limestone.

The most complete exposures of the Amsden formation in the Buffalo-Lake De Smet area are along the South Fork of Rock Creek in sec. 25, T. 52 N., R. 84 W. The basal part of the formation at this locality consists of about 10 feet of red- and yellow-banded crossbedded conglomeratic sandstone. The coarser fragments in the sandstone include angular to rounded pebbles of light- and dark-gray chert as much as one-half inch in longest dimension and small reworked silicified fragments of the corals *Diphphyllum* and *Syringopora*, which, according to Miss Duncan, are not distinguishable from corals that occur at the top of the Madison at the same locality (see page 19). The sandstone rests on the Madison limestone with a sharp, slightly undulating contact.

Above the basal sandstone is a sequence about 150 feet thick consisting of interbedded light-colored dolomite, red shale, and in the lower part, some beds of light-gray finely crystalline limestone. The limestone is similar in color and texture to limestone which forms the upper beds of the Madison. The dolomite is dense, light-gray to white and weathers to a rough hackly surface. It contains abundant red, gray, and brown chert in nodules and stringers. Above this sequence is about 20 feet of resistant fine- to medium-grained very calcareous white and pink sandstone or sandy limestone capped by 50 to 70 feet of nonresistant red shale with some thin beds of red and violet dolomite and siltstone. A few beds of friable crossbedded white to light yellowish-gray sandstone are interbedded with red shale in the top 10 feet of the formation.

Section of the Amsden formation on the north side of the South Fork of Rock Creek in the SW¼ sec. 25, T. 52 N., R. 84 W.

Tensleep sandstone.

Amsden formation:

		Ft
1.	Siltstone, pale red, calcareous	2
2.	Sandstone, light-gray to white, fine-grained, medium-bedded, crossbedded	2
3.	Covered	7
4.	Sandstone, light-gray to white, fine-grained, medium-bedded, crossbedded	7
5.	Limestone, white, dense, contains thin lenses of red chert	1
6.	Mostly concealed; appears to be mainly red shale	49
7.	Dolomite, gray with a slight purplish tint, dense, medium- to thin-bedded; contains lenticular bed of brecciated cherty dolomite in lower part	8
8.	Covered; probably red shale	6
9.	Sandstone, white, fine-grained, very calcareous, crossbedded; forms ledge	4
10.	Dolomite, purple, shaly, fissile; forms reentrant	3
11.	Chert and limestone breccia; chert red and gray; limestone white and coarsely crystalline	1
12.	Dolomite, white, dense, thin-bedded; contains lenses of red and gray chert; forms ledge	2
13.	Dolomite and shaly dolomite, purple, thin- to very thin-bedded	4
14.	Concealed	7
15.	Dolomite, gray to white, blocky; contains nodules of gray chert	3
16.	Sandstone, white, stained pink, fine- to medium-grained, medium-bedded, very calcareous; 1-ft bed of sandy red shale at top	10
17.	Concealed, probably red shale	5
18.	Dolomite, pale-purple and gray, dense, blocky	2
19.	Shale, red and purple	2
20.	Dolomite, white to gray, dense, irregularly bedded; contains vugs filled with coarsely crystalline calcite	8
21.	Shale, purple, dolomitic, silty	1
22.	Dolomite, white to gray, dense, irregularly bedded; weathers to rough hackly surface; contains irregularly shaped masses of gray and white chert	16
23.	Dolomite, white, earthy	1
24.	Concealed, probably red shale	7
25.	Dolomite, white to grayish-yellow, dense, medium-bedded; contains thick lenses of red and gray chert; thin beds of red shale at intervals of 5 to 10 ft; forms ledges	52
26.	Concealed, probably red shale	7
27.	Limestone, light-gray, finely crystalline; forms ledge	2
28.	Shale, red, and red shaly limestone; contains *Linoproductus* cf. *L. ovatus* (Hall) and brachial valves of orthotetoids	2
29.	Limestone, light-gray, finely crystalline, thin- to medium-bedded; interbedded red shaly limestone near middle; cavities and fractures filled with coarsely crystalline calcite; top 1 ft sandy; forms ledges	17

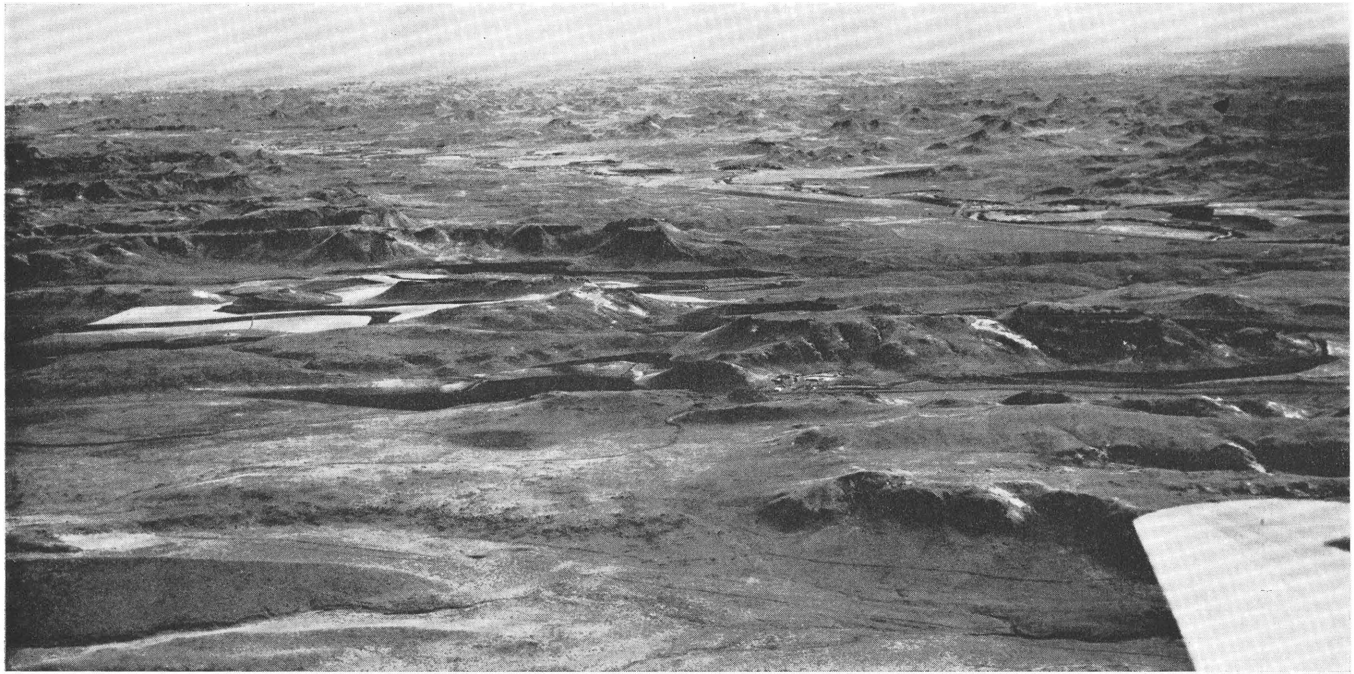
Section of the Amsden formation on the north side of the South Fork of Rock Creek in the SW¼ sec. 25, T. 52 N., R. 84 W.—Continued

Amsden formation—Continued	
30. Sandstone, red with yellowish-tan bands, medium-grained, calcareous; contains angular fragments of limestone and chert as much as ¼ in. in largest dimension and a few small fragments of silicified reworked corals	10
Total measured thickness	248
Unconformity	
Madison limestone.	

Some geologists have believed the Amsden formation on the east slope of the Bighorn Mountains includes rocks of both Mississippian and Pennsylvanian age, others that it includes only rocks of Pennsylvanian age. The assignment of the lower part of the formation to the Mississippian has been based partly on the occurrence of a coral (identified by G. H. Girty as *Menophyllum excavatum* Girty) found by Darton (1906c, p. 5) in the lower part of the formation at Soldiers Creek, about 10 miles north of the Buffalo-Lake De Smet area. Evidence from other parts of Wyoming, however, suggests that all of the Amsden formation in the Bighorn Mountains may be Pennsylvanian in age. Burk (1954) concludes from a tabulation of the ranges of fossils reported from the Amsden formation in west-central Wyoming that the break between the Mississippian and Pennsylvanian systems is an unconformity at the base of the Darwin sandstone, a widespread sandstone bed commonly found at the base of the Amsden in central and northern Wyoming. According to Burk (1954, figs. 2–5), no fossils of exclusively Mississippian age occur above the Darwin sandstone, and the predominance of forms reported are exclusively Pennsylvanian. The basal sandstone of the Amsden formation in the Buffalo-Lake De Smet area resembles the Darwin sandstone in lithology and stratigraphic position and probably can be correlated with it.

During the present investigation, *Linoproductus* cf. *L. ovatus* (Hall), another undetermined productoid, and brachial valves of orthotetoids were collected from a bed of shaly limestone 17 feet above the basal sandstone of the Amsden formation at the South Fork of Rock Creek (unit 28 of the above section). These fossils were identified by James Steele Williams who believed the assemblage too scant for precise age determination.

Pennsylvanian fossils identified by Girty are reported by Darton (1906a, p. 34) from the upper cherty beds of the Amsden at the North Fork of Crazy Woman Creek, 8 miles south of the mapped area. Darton's collection was reexamined by C. C. Branson (1939, p. 1201) who confirmed the Pennsylvanian age of the assemblage. No fossils



AERIAL VIEW EASTWARD ACROSS CLEAR CREEK

View shows topography characteristic of central and eastern parts of area. Steep-sided, flat-topped buttes and divides are capped by clinker of Walters coal bed. Photograph by the U. S. Bureau of Reclamation.

were found in the upper part of the Amsden during the present investigation.

TENSLEEP SANDSTONE

The Tensleep sandstone was named by Darton (1904, p. 397) from exposures in the lower canyon of Tensleep Creek on the west side of the Bighorn Mountains. Resistant ledges and steep dip-slopes are formed by the Tensleep where it is exposed along the east flank of the Bighorn Mountains south of Bald Ridge, at Mowry Basin, and north of Moncrief Ridge. The formation also crops out along the eastern edge of the Piney Creek fault block west of Story and near the headwaters of J. A. Creek.

The Tensleep is a thick-bedded, light yellowish-gray to white sandstone about 275 feet thick, composed chiefly of well-sorted fine to medium grains of quartz. Crossbedding on a large scale is a conspicuous feature of the formation. A few thin beds of pink or light-yellow dolomite which contain nodules and stringers of chert are interbedded with the sandstone at many places. At Mowry Basin, the base of the formation is a lenticular bed of sandstone and dolomite breccia 5 to 20 feet thick which is stained red and weathers to a rough cavernous surface. This unit rests with an uneven contact on the Amsden formation.

Section of the Tensleep sandstone north of the North Fork of Sayles Creek in the SW¼ sec. 6, T. 52 N., R. 83 W.

Gypsum and red shale sequence.
Unconformity.
Tensleep sandstone:

	Ft
1. Sandstone, white to light-yellow, fine- to medium-grained, friable, massive, crossbedded, jointed and fractured; forms cliff	44
2. Sandstone, dolomitic, pink and yellow, thin-bedded	6
3. Sandstone, white to light-yellow, fine- to medium-grained, friable, crossbedded	6
4. Sandstone, dolomitic, purple, medium-grained, thin-bedded, firmly cemented; contains nodules and stringers of red chert; basal 1 ft contains many small pits and cavities; forms weak ledge	6
5. Dolomite, purple, finely crystalline, thin- to medium-bedded; contains red and gray chert in top 1 ft	9
6. Sandstone, dolomitic, pink, fine- to medium-bedded, hard, slabby; contains a few thin beds of red dolomite and a few small cavities lined with calcite	11
7. Sandstone, white, fine- to medium-grained, friable, in alternating thick and medium beds becoming thinner bedded at top, crossbedded forms cliff	76
8. Dolomite, pink and red, silty and sandy, thin-bedded; contains dense, red dolomite concretions as much as 6 in. in diameter	6
9. Sandstone, yellow, dolomitic, fine-grained, firmly cemented, very thin bedded	3

Section of the Tensleep sandstone north of the North Fork of Sayles Creek in the SW¼ sec. 6, T. 52 N., R. 83 W.—Continued

	Ft
Tensleep sandstone—Continued	
10. Sandstone, green, silty, soft, very thin bedded; contains 4-in. bed of very coarsely crystalline and vuggy dolomite at top	1
11. Sandstone, white to light yellowish-gray, fine- to medium-grained, calcareous, friable, massive, crossbedded; forms cliff	53
12. Sandstone, white, locally stained pink, and interbedded yellow dolomite which locally contains lenses of gray chert	7
13. Sandstone, white, fine- to medium-grained, friable, massive, crossbedded; forms smoothly rounded ledges	21
14. Dolomite, yellow, hard and blocky, thin-bedded; some interbedded pink silty and sandy dolomite and dolomitic shale near the base; forms reentrant	2
15. Sandstone, white, fine-grained, calcareous, friable, crossbedded	5
16. Sandstone, yellow, medium-grained, firmly cemented, thin-bedded, slabby; contains some beds of silty flesh-colored dolomite	7
17. Sandstone and dolomite; in thin to medium contorted and brecciated beds; sandstone white, fine- to medium-grained, friable; dolomite purple; some lenses and irregularly shaped masses of purple shale and red calcareous mudstone; forms ledge	17
Total measured thickness	280
Amsden formation.	

No fossils were collected from the Tensleep sandstone during the present investigation, but marine fossils of Pennsylvanian (Des Moines) age, including fusulinids, brachiopods, pelecypods, and bryozoa, have been reported from chert and dolomite layers in the middle and upper parts of the formation at several places along the east side of the Bighorn Mountains (Darton, 1906a, p. 34; Branson, 1939, p. 1216).

PERMIAN SYSTEM

A sequence of interbedded gypsum, red shale and siltstone, and thin beds of light-gray limestone which overlies the Tensleep sandstone and underlies the Chugwater formation was included by Darton (1906a, p. 36–42) in the basal part of the Triassic Chugwater formation, although he recognized that the sequence was in part, at least, of Permian age. These strata form a narrow outcrop band along the east flank of the Bighorn Mountains at the base of steep dip slopes held up by the Tensleep sandstone.

The gypsum and red shale sequence is about 180 feet thick in the Buffalo-Lake De Smet area; it rests on the Tensleep sandstone with a sharp lithologic and topographic break. The basal 80 to 90 feet of the formation consists predominantly of red nodular shale and red siltstone. A persistent bed of pale-gray to light pinkish- or purplish-gray limestone which contains distinct wavy pink laminae occurs 20 to 25 feet above the base of the formation. This limestone bed, which is 2 to 4 feet thick, occurs on the east side of the Bighorn Mountains as far south as the Red Fork of Powder River near the southern end of the range and as far north as Lodge Grass Creek in Montana, a distance of more than 100 miles (Darton 1906a, p. 38, 40). A second bed of limestone 40 to 50 feet above the first is pale gray and argillaceous; it contains numerous disseminated black specks. This bed locally is brecciated; it weathers to a rough surface pitted with many cavities that have a semirectangular outline. The upper part of the gypsum and red shale sequence consists predominantly of gypsum with some interbedded red shale. The upper gypsiferous sequence is about 80 feet thick at the South Fork of Rock Creek where it is capped by a ledge-forming 5-foot bed of brecciated limestone which is similar to the bed of limestone near the middle part of the formation.

Section of the gypsum and red shale sequence near the South Fork of Rock Creek in the S½ sec. 25, T. 52 N., R. 84 W.

Chugwater formation.	
Gypsum and red shale sequence:	Ft
1. Limestone, pale-gray, argillaceous, brecciated; contains numerous disseminated black specks and weathers to a rough pitted surface; forms ledge	5
2. Shale, red, gypsiferous	7
3. Gypsum, white; contains a few thin partings of red shale	24
4. Shale, red, gypsiferous	3
5. Gypsum, white, granular	1
6. Shale, red, gypsiferous	5
7. Gypsum, white, granular; has shale partings 6 in. thick 5 ft above base and 3 ft below top	40
8. Siltstone, red, very poorly cemented; a few thin stringers of gypsum in upper part; poorly exposed	19
9. Limestone, pale-gray, argillaceous, thin-bedded; grades laterally and upward into limestone breccia similar to unit 1; forms ledge	5
10. Siltstone and silty shale, red with a few green streaks	36
11. Limestone breccia, red and gray, lenticular; weathers to a rough pitted surface	3
12. Siltstone, red, poorly cemented	3
13. Limestone, slightly dolomitic, light-gray and pale-red, very thin and wavy-bedded, slabby; forms ledge	4
14. Shale, red, silty; massive bed of dark-red calcareous siltstone 3 ft thick 17 ft above base	25
Total measured thickness	180
Unconformity.	
Tensleep sandstone.	

Few fossils have been reported from the gypsum and red shale sequence or its equivalents along the east side of the Bighorn Mountains. Darton (1906a, p. 42) collected a few poorly preserved mollusks from the lower part of his Chugwater formation at Rapid Creek about 3 miles north of the Buffalo-Lake De Smet area. These were identified by Girty and Schuchert as *Astartella*, possibly *A. gurleyi*, and a compressed gastropod, perhaps of the genus *Bulimorpha*. A Permian fauna is known from the basal part of the sequence near Mayoworth (Love, oral communication, 1949) about 30 miles south of the Buffalo-Lake De Smet area. The gypsum and red shale sequence on the east side of the Bighorn Mountains is lithologically similar to the red-bed facies of the Phosphoria formation in central Wyoming. Darton (1906a, p. 42) suggested that the slabby, laminated limestone near the base of the sequence (unit 13 of the above section) is an extension of the Minnekahta limestone of the Black Hills and the underlying beds of red shale and siltstone are the extension of the Opeche shale.

TRIASSIC SYSTEM

CHUGWATER FORMATION

The Chugwater formation consists chiefly of dark-red siltstone, sandstone, and shale. These rocks form a conspicuous band of red outcrops adjacent to the east flank of the Bighorn Mountains in the southwestern, west-central, and northwestern parts of the Buffalo-Lake De Smet area. The Chugwater is 810 feet thick near the North Fork of Sayles Creek in the west-central part of the area.

Three members can be recognized in the Chugwater formation in the Buffalo-Lake De Smet area. The oldest is similar in thickness, lithology, and stratigraphic position to the unit which in central Wyoming has been called the Red Peak member of the Chugwater formation (Love, 1945a). It consists of about 700 feet of moderate reddish-brown shale, siltstone, and fine- to medium-grained poorly sorted sandstone. The individual beds are lenticular. Most of the sandstone is crossbedded and some is ripple marked. The base of the member rests on the Permian gypsum and red shale sequence with a sharp change from gypsiferous beds below the contact to nongypsiferous beds above, but with no apparent unconformity.

The middle member of the Chugwater formation is tentatively correlated on the basis of its lithology and stratigraphic position with the Alcova limestone member of the Chugwater formation in central Wyoming. It consists of slabby thin-bedded light-gray or slightly pinkish slightly dolomitic limestone characterized by undulating or slightly contorted dark-gray and pink laminae. The unit is 6 feet thick at Little Goose Creek, 12 to 13 feet thick at Mowry Basin, and 13 feet thick south of Bald Ridge. The Alcova limestone member(?) generally forms a conspicuous jagged ledge or ridge that stands several feet above the adjacent strata (see pl. 4). The contact between the

Alcova limestone member (?) and the underlying sandstone of the Chugwater formation is sharp and slightly undulating.

The upper member of the Chugwater formation is a crossbedded fine- to medium-grained friable sandstone which is about 70 feet thick in the west-central and southwestern parts of the area, and about 25 feet thick near Little Goose Creek in the northwestern part. A few coarse rounded and frosted grains of quartz are scattered throughout the upper member, and locally at its base are a few fragments of limestone evidently derived from the underlying Alcova(?). The upper member is similar in lithology to the unit in the Red Fork of the Powder River area which Carlson (1949) called the Crow Mountain sandstone member of the Chugwater formation, after Love's usage (1939, p. 44) for rocks in central Wyoming.

Section of the Chugwater formation near the North Fork of Sayles Creek in the SE¼ sec. 6, T. 51 N., R. 83 W.

Gypsum Spring formation.	
Unconformity (?)	
Chugwater formation:	
Upper sandstone member:	Ft
1. Sandstone, salmon-red, medium-grained, crossbedded, fairly well sorted, a few rounded and frosted quartz grains larger than average scattered throughout the unit, bottom 1 ft contains a few angular fragments of limestone as much as ¼ in. in longest dimension	71
Alcova limestone member(?):	
2. Limestone, white with a slight purplish tint, dense, thin-bedded, slabby; contains slightly contorted dark-gray laminae; forms conspicuous ledge	13
Lower member:	
3. Sandstone, moderate reddish-brown in lower part grading upward through shades of pink and purple to white; fine to medium-grained, crossbedded	30
4. Sandstone with much interbedded siltstone and shale, moderate reddish-brown, fine- to medium-grained, poorly sorted, thin- to medium-bedded, crossbedded	200
5. Shale, siltstone, and sandstone, interbedded, moderate reddish-brown; sandstones thin- to medium-bedded; some beds ripple marked	426
6. Mostly concealed; appears to be mainly red shale and siltstone. Base of unit at base of slope formed on beds of gypsum and limestone on the top of underlying gypsum and red shale sequence	70
Total measured thickness	810
Gypsum and red shale sequence.	

The assignment of the Chugwater formation to the Triassic system on the east side of the Bighorn Mountains is based on its similarity in lithology and stratigraphic position to Triassic rocks of central and western Wyoming. The Red Peak member of the Chugwater

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formation in central Wyoming overlies the Lower Triassic Dinwoody formation and underlies the Alcova limestone member of the Chugwater formation. Concerning the age of the Alcova, Love (1948, p. 99) states:

> The [Alcova] limestone has been called Lower Triassic, Middle Triassic, and Upper Triassic by various geologists. The faunas are not definitive, but regional relationships in the Jackson Hole and Hoback Canyon areas of western Wyoming suggest that the Alcova limestone is somewhat younger than at least the major part of the Lower Triassic Thaynes limestone.

The Crow Mountain sandstone member of the Chugwater formation is overlain by fossil-bearing beds of the Popo Agie member in central Wyoming. According to Branson and Mehl (1929, p. 18), the Popo Agie member is Middle Triassic in age.

JURASSIC SYSTEM

MIDDLE JURASSIC SERIES

GYPSUM SPRING FORMATION

The rocks here described as belonging to the Gypsum Spring formation were originally included by Darton (1906a, p. 36–42) in the upper part of the Chugwater formation. Love (1939, p. 45) defined the Gypsum Spring as a member of the Chugwater formation in the northern part of the Wind River Basin, but later (1945b) he gave it formational rank and assigned it a Middle Jurassic age. Imlay (1945, p. 1020; 1947, p. 236–244) has recognized the Gypsum Spring formation in the Bighorn Basin and in the Black Hills region, and Imlay and others (1948) have shown that rocks of the same age and lithology as the type Gypsum Spring formation are present along the northeastern flank of the Bighorn Mountains in southern Montana.

The Gypsum Spring formation is 145 to 185 feet thick in the Buffalo-Lake De Smet area. It consists of red shale and claystone and thin-bedded light-colored limestone. These strata overlie the Triassic Chugwater formation and underlie the late Jurassic Sundance formation. The Gypsum Spring formation crops out in a narrow band east of the mountain front at Mowry Basin, south of Bald Ridge, and north of Moncrief Ridge. Limestone beds in the middle and upper parts of the formation form ledges and low sharp ridges which stand out as prominent white bands in contrast to the red colors of the intervening and underlying strata.

The correlation of beds in the Gypsum Spring and upper part of the Chugwater formations along the east side of the Bighorn Mountains, from the Montana-Wyoming boundary to a point near Buffalo, is shown by plate 5.

The basal 40 to 60 feet of the Gypsum Spring formation consists mainly of dark-red claystone and shale. These beds contain in the lower part a few stringers and pods of gypsum, and thin lenticular beds of brown gypsiferous limestone breccia. They rest on the underlying sandstone of the Chugwater formation with a sharp lithologic break. Elsewhere along the east flank of the Bighorn Mountains, thick beds of gypsum occur locally at or near the base of the Gypsum Spring formation, and the beds of limestone breccia found in outcrops of the formation in the Buffalo-Lake De Smet area may be the residue of impure gypsum leached by ground water.

Overlying the basal red shale and claystone of the Gypsum Spring formation is a sequence 80 to 90 feet thick consisting of red shale with beds of limestone at the base, near the middle, and at the top. The limestone is thin bedded, light colored, dense, and argillaceous. Individual beds of limestone are remarkably persistent for many miles. A persistent bed of porous light-gray to tan limestone near the base of this sequence contains abundant molds of small gastropods that are too poorly preserved for reliable generic and age determination but which, according to R. W. Imlay, resemble gastropods that occur in the upper part of the Gypsum Spring formation near Lander, Wyo. Beds of limestone near the middle of the sequence commonly are pink or very light green, and at many places contain abundant but poorly preserved pelecypods referred questionably by Imlay to *Grammatodon* and *Isocyprina*. The uppermost bed in the sequence is a prominent ledge-forming bed of very light gray argillaceous limestone that contains laminae of gray chert. This bed marks the top of the Gypsum Spring formation at Mowry Basin and south of Bald Ridge.

Near Little Goose Creek, in the northwestern part of the Buffalo-Lake De Smet area, a sequence of nonfossiliferous dark-red and pale-green shale or claystone about 60 feet thick occurs at the top of the Gypsum Spring formation above the shale and limestone sequence just described. In this area, the contact between the Gypsum Spring formation and overlying Sundance formation apparently is gradational, and it is placed at the stratigraphic change upward from predominantly red nonfossiliferous shale to predominantly green fossiliferous shale or gray sandstone.

Section of the Gypsum Spring formation north of Little Goose Creek in the N½ sec. 36, T. 54 N., R. 85 W.

Sundance formation.	
Gypsum Spring formation:	Ft
1. Claystone, moderate reddish-brown and pale-green, slightly calcareous, nonresistant	59
2. Limestone, very light gray, dense, thin-bedded; contains irregularly shaped lenses of gray chert	1½
3. Siltstone, greenish-gray, nonresistant	1

Section of the Gypsum Spring formation north of Little Goose Creek in the N½ sec. 36, T. 54 N., R. 85 W.—Continued

	Ft
Gypsum Spring formation—Continued	
4. Limestone, very light gray, thin-bedded; top 6 in. cherty; 1 foot from base a 1.8-in. bed of porous white dolomite contains mollusk fragments; forms ledge	8
5. Siltstone and claystone, moderate reddish-brown with a few pale-green beds; top 6 ft alternating pale grayish green and pale red; contains a few thin stringers of gypsum and limestone breccia; irregular lenticular masses of translucent to opaque quartz crystals imbedded in a limy quartzitic matrix 1 and 6 ft below top	29
6. Limestone, banded pale red and light gray, very argillaceous; upper 3 ft are mottled green	11
7. Limestone, light-tan to light-gray, thin- to wavy-bedded; contains a few laminae of gray chert and a few poorly preserved pelecypods (*Isocyprina?* sp)	2
8. Claystone, moderate reddish-brown and yellowish-green, nonresistant	3
9. Limestone, light-tan weathering white; dense, thin- to medium-bedded; forms ledge	2½
10. Claystone and shale, dark reddish-brown with ochre and pale-green streaks; bed of pale-gray argillaceous dolomitic limestone 6 to 8 in. thick about 18 ft from base of unit	18
11. Limestone, light-gray, dense, thin- and wavy-bedded; weathered surface pitted by molds of small gastropods; forms ledge	3
12. Claystone and shale, moderate reddish-brown, pale-green, and pale-red, calcareous in part, nonresistant	3
13. Limestone, very light gray, argillaceous, thin-bedded; contains several partings as much as 2 in. thick of pale-green claystone; forms ledge	3
14. Claystone, white, calcareous; some interbedded purple mudstone	5
15. Claystone, moderate reddish-brown; a few stringers of pale-green claystone and laminae of gypsum; the top 2 ft pale green and slightly calcareous	32
16. Covered	24
Total measured thickness	205
Unconformity(?)	
Chugwater formation.	

Section of the Gypsum Spring formation on the north side of the North Fork of Sayles Creek in the S½ sec. 6, T. 51 N., R. 83 W.

	Ft
Sundance formation.	
Unconformity.	
Gypsum Spring formation:	
1. Limestone, very light gray, argillaceous, thin- to medium-bedded; contains laminae of gray chert in top 2 ft and bottom 3 ft; forms prominent ledge	9
2. Shale, grayish-red, dolomitic, hard, blocky; top 1 ft greenish gray	4

Section of the Gypsum Spring formation on the north side of the North Fork of Sayles Creek in the S½ sec. 6, T. 51 N., R. 83 W.—Continued

	Ft
Gypsum Spring formation—Continued	
3. Shale, moderate reddish-brown; nonresistant; contains a few stringers of gypsum	25
4. Limestone, greenish-gray, argillaceous, thin-beeded; weathered surface rough and pitted	5
5. Shale, pink and green, dolomitic, brittle	7
6. Limestone, light-gray, dolomitic, dense, thin-bedded; forms ledge	1
7. Shale, moderate reddish-brown, nonresistant	3
8. Dolomite, pale greenish-gray, argillaceous, thin-bedded	1
9. Shale, moderate reddish-brown; top 2 ft pale green; contains a few beds of green shale	17
10. Limestone, gray, dense; porous with many voids formed by molds of small gastropods; forms a weak ledge	2
11. Limestone, light-brown, dense, thin-bedded; contains a few thin partings of red argillaceous dolomite	2½
12. Shale, moderate reddish-brown and grayish-red, nonresistant	6½
13. Limestone, light-gray, medium- to thin-bedded; upper and lower thirds are dense to finely crystalline, middle third earthy; about 6 in. of bright-green shale 1 ft from base; forms ledge	4½
14. Shale, green	2½
15. Claystone, very light gray, calcareous, blocky	1
16. Claystone, moderate reddish-brown	29
17. Claystone and siltstone, moderate reddish-brown; lenticular bed of gypsiferous limestone breccia 2 ft thick at base	32
Total measured thickness	152

Unconformity(?)
Chugwater formation.

Section of the Gypsum Spring formation along a tributary of Bull Creek in the center of sec. 26, T. 50 N., R. 83 W.

Sundance formation.
Unconformity.

	Ft
Gypsum Spring formation:	
1. Limestone, light-gray, dense, thin-bedded; contains a few irregularly shaped masses of quartzite which are studded with quartz crystals; forms ledge	4
2. Claystone, grayish-red, slightly calcareous	3
3. Quartzite, very light pinkish-gray encrusted with translucent to opaque quartz crystals; lenticular	½
4. Claystone, moderate reddish-brown	28
5. Dolomite, white, very argillaceous, porous, thin-bedded	5
6. Claystone, pale-red, very calcareous	6½
7. Limestone, light brownish-gray, dense, thin-bedded; bedding surfaces locally stained green	1
8. Claystone, pale-green and pale-red, very calcareous	3½
9. Shale, light-gray; weathers white; calcareous, brittle	2

Section of the Gypsum Spring formation along a tributary of Bull Creek in the center of sec. 26, T. 50 N., R. 83 W.—Continued

Gypsum Spring formation—Continued	Ft
10. Claystone, top 2½ ft pale-green and dark-red, lower 5 ft dark reddish-brown; noncalcareous to slightly calcareous; nonresistant	7½
11. Claystone, moderate reddish-brown, very calcareous; a few beds mottled pale-green; silty in upper part	10
12. Limestone, light-gray, thin-bedded; weathered surface pitted by molds of small gastropods; forms weak ledge	1
13. Shale and limestone; shale moderate reddish-brown, very calcareous; limestone pale green, argillaceous	3
14. Limestone, very light gray, dolomitic, argillaceous, thin-bedded; forms ledge	3
15. Claystone, moderate reddish-brown and dark reddish-brown, slightly calcareous; top 1 ft pale green and calcareous; nonresistant	29
16. Covered; appears to be mostly red claystone; lenticular beds of porous brown limestone breccia crop out in upper 5 ft	37
Total measured thickness	144

Unconformity(?)
Chugwater formation.

The poorly preserved gastropods and pelecypods already mentioned were the only fossils found in the Gypsum Spring formation in the Buffalo-Lake De Smet area. Imlay and others (1948) cite evidence that the age of the equivalent Piper formation in south-central Montana is Middle Jurassic (Bajocian and Bathonian).

UPPER JURASSIC SERIES

SUNDANCE FORMATION

The Sundance formation was named by Darton (1899, p. 387) from exposures near Sundance in northeastern Wyoming. In the Buffalo-Lake De Smet area, the formation consists of about 280 feet of grayish-green shale and sandy shale interbedded with light yellowish-gray to white sandstone and some gray fossiliferous limestone. The outcrop band is narrow and the formation characteristically forms grass-covered slopes and saddles.

At most places in the mapped area, the basal 30 to 40 feet of the Sundance formation consists of friable light-gray sandstone with lesser amounts of interbedded green shale. A few scattered highly polished pebbles of gray chert occur locally in the bottom 1 to 2 feet. The basal sandstone is capped by a persistent ledge-forming bed of gray fossiliferous oolitic limestone 3 to 5 feet thick. Overlying the oolitic limestone is about 220 feet of grayish-green shale and sandy shale, the upper part of which contains a few beds of gray limestone and much interbedded light-gray to white glauconitic sandstone.

Abundant *Gryphaea* weather out from beds in the lower part of the sequence, and belemnites are abundant in the upper part. The top of the Sundance formation is a bed 2 to 4 feet thick of yellow-weathering ripple-marked sandstone that can be traced for at least several miles along the east side of the Bighorn Mountains.

In the west-central and southwestern parts of the area, the Sundance formation rests unconformably on the underlying Gypsum Spring formation with a sharp lithologic break. At Little Goose Creek in the northwestern part of the area, the basal unit of the Sundance is a fine-grained pale-green sandstone 5 feet thick which overlies an alternating sequence of red and green shale in the upper part of the Gypsum Spring formation and is, in turn, overlain by about 8 feet of red and green siltstone and shale. The marine Sundance formation grades upward into the nonmarine Morrison formation through a transition zone generally less than 5 feet thick.

Section of the Sundance formation at Mowry Basin in the SE¼ sec. 31, T. 52 N., R. 83 W.

Morrison formation.	
Sundance formation:	Ft
1. Sandstone, grayish-yellow, fine-grained, calcareous, crossbedded, ripple-marked, slabby; forms ledge	4
2. Interbedded green shale and white sandstone; thin-bedded; a few scattered grains of glauconite; form reentrant	6
3. Sandstone, light-gray to white, fine- to medium-grained, glauconitic, calcareous; crossbedded; highly fossiliferous (abundant *Ostrea*); grades laterally into sandy limestone; locally contains a few thin partings of soft shaly sandstone; forms conspicuous ledge	10
4. Interbedded sandstone and shale becoming more shaly toward bottom of unit; sandstone very light gray, fine grained, glauconitic, friable, thin bedded; shale green	22
5. Limestone, gray, fossiliferous	½
6. Interbedded sandstone and shale; sandstone very light gray, fine grained, glauconitic, thin bedded; shale green	23
7. Limestone, dark gray, finely crystalline	2½
8. Shale, green; contains thin beds and laminae of fine-grained very light gray sandstone	33
9. Mostly concealed. Appears to be mainly grayish-green shale	143
10. Limestone, gray, oolitic; contains a few poorly preserved mollusks; forms ledge	3
11. Sandstone, very light gray, fine-grained; contains some interbedded green shale; has a few polished pebbles of gray chert in basal 1 ft	37
Total measured thickness	284
Unconformity.	
Gypsum Spring formation.	

Imlay (1945, p. 1020; 1947, p. 244–266), Love (1954b), and Imlay and others (1948) have discussed the age and regional correlation of the Sundance formation in Wyoming, Montana, and adjacent States. These writers believe the formation to be Late Upper Jurassic (Callovian and Oxfordian) in age. In central Wyoming, the Sundance is divided by some geologists into a sparsely glauconitic or nonglauconitic lower Sundance of Callovian age, and an abundantly glauconitic upper Sundance of Oxfordian age (Neely, 1937, p. 732, 758–59; Love, 1945b). These two units correspond with the Rierdon formation and overlying Swift formation of south-central Montana (Imlay and others, 1948). The horizon corresponding to the boundary between the upper and lower Sundance of central Wyoming and the Swift and Rierdon formations of south-central Montana is marked at many places along the east flank of the Bighorn Mountains by thick ledge-forming beds of sandstone at the top of the lower unit. In the Buffalo-Lake De Smet area, however, the contact apparently lies in a thick interval of grayish-green poorly exposed shale (unit 9 of the preceding section) where no lithologic criteria for subdivision of the formation were found.

MORRISON FORMATION

The name Morrison formation has been used throughout the Rocky Mountain region for a widespread sequence of nonmarine varicolored shale and claystone and drab sandstone generally considered to be of Late Jurassic age. These beds crop out along the east side of the Bighorn Mountains above the Sundance formation and below the Cloverly formation. The Morrison is nonresistant and poorly exposed at most places in the Buffalo-Lake De Smet area.

The Morrison formation is about 180 feet thick at Mowry Basin where it consists of light-gray, green, red, and purplish-gray claystone and shale, and lenticular beds of light-gray fine-grained friable sandstone. Commonly the beds of sandstone contain pebbles and lenticular partings of clay. Most of the sandstone is crossbedded, and some is ripple marked. Fragments of bone and a few highly polished chert pebbles weather out locally from sandstone and shale in the lower 20 to 40 feet of the formation.

Except for a few indeterminate fragments of bone, no fossils were found in the Morrison formation in the Buffalo-Lake De Smet area; however, C. C. Branson (1935) and T. C. Yen (1952) have described fresh-water invertebrates of Jurassic age from the Morrison near Mayoworth, 30 miles south of Buffalo.

Section of the Morrison formation near Mowry Creek in the NE¼ sec. 31, T. 52 N., R. 83 W.

Cloverly formation.	
Unconformity (?)	
Morrison formation:	Ft
1. Claystone, violet, green, and light-gray, calcareous	85
2. Sandstone, grayish-white weathering yellowish gray, very fine to medium-grained, crossbedded, calcareous; forms ledge	13
3. Conglomerate consisting of pebbles of shale and sandstone as much as 1 in. in longest dimension, and a few fragments of coal in matrix of medium-grained sandstone; lenticular; pinches out within a few feet	1
4. Claystone, red, green, and gray, calcareous	64
5. Sandstone, grayish-white, silty to fine-grained, calcareous, lenticular; contains a few fragments of bone; forms weak ledge	13
6. Shale, gray and red, calcareous	3
Total measured thickness	179
Sundance formation.	

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

CLOVERLY FORMATION

The Cloverly formation was named by Darton (1904, p. 398) from exposures near the now abandoned Cloverly post office on the west side of the Bighorn Mountains. On the east side of the range, Darton (1906b, p. 7) included in the Cloverly a persistent basal sandstone member about 30 feet thick, and an upper "reddish or ash-colored" claystone member 20 to 40 feet thick. Overlying the upper claystone member is a sequence of thin-bedded light-gray to brown siltstone and sandstone and dark-gray shale which contains distinctive globular dahllite concretions, and which are commonly known as the rusty beds (Washburne, 1908, p. 350). Darton included the rusty beds in the basal part of his Colorado formation. Later, Hewett and Lupton (1917, p. 19) subdivided Darton's Colorado formation, placing the rusty beds in the basal part of the Thermopolis shale. The usage of Hewett and Lupton has been followed by most subsequent writers in describing these rocks in southern Montana.

Love (1945c) and others working in the southern part of the Bighorn Basin and in central Wyoming maintain that a horizon corresponding to the upper limit of the rusty beds is a more logical top of the Cloverly formation, both for surface and subsurface geologic correlation, than is the top of the underlying claystone sequence. Love (1945c) notes that the rusty beds are more persistent than the claystone and basal sandstone units of the Cloverly, that they contain nonmarine Lower Cretaceous fossils identical with those in the underlying claystone, and that at some places beds of sandstone in the rusty beds sequence intertongue with the underlying claystone unit. Accordingly, the upper boundary of the Cloverly formation in central Wyoming has been raised stratigraphically to include the rusty beds. In this report, the upper boundary of the Cloverly was chosen to conform with the usage of Love.

The Cloverly formation is about 155 feet thick in the Buffalo-Lake De Smet area. It crops out in a narrow band along the east side of the Bighorn Mountains north of Moncrief Ridge, at Mowry Basin, and south of Bald Ridge. Resistant beds at the top and base of the formation locally form low ridges or ledges; the middle part forms grass-covered slopes and saddles.

The base of the Cloverly formation in the Buffalo-Lake De Smet area is a massive light-gray to white crossbedded sandstone about 30 feet thick. The sandstone is composed mainly of subrounded grains of clear quartz, but locally it contains scattered grains of pink and brown chert. It is coarse grained in its lower part and becomes finer grained in its upper part. The sandstone rests with a sharp contact on the underlying variegated beds of the Morrison formation; it passes upward through a thin interval of light-gray and purple to black locally carbonaceous shale into a sequence of dark-gray shale interbedded with thin beds of brown siltstone which constitutes the remainder of the formation. Numerous globular concretions of dahllite as much as 2 inches in diameter weather out from the upper part of this sequence. A persistent ledge-forming bed of brown calcareous siltstone tops the formation. The combination of a ledge-forming bed of siltstone above a bed which yields abundant dahllite concretions provides a recognizable horizon for mapping and correlation in the Buffalo-Lake De Smet area and in adjacent areas to the south.

The following section of the Cloverly formation which was measured by R. K. Hose in 1951 at Muddy Creek, 8 miles south of the Buffalo-Lake De Smet area, is representative of the lithology of the formation in the area.

Section of the Cloverly formation north of Muddy Creek in the NW ¼ sec. 36 and SE ¼ sec. 25, T. 49 N., R. 83 W.

	Ft
Skull Creek shale (lowest part):	
1. Shale, black, bentonitic; poorly exposed	19
Cloverly formation:	
2. Siltstone, brownish-gray, calcareous, thin-bedded, slabby; forms ledge	5½
3. Shale and siltstone, dark-gray and light-gray weathering drab tan to brown; interbedded in beds 4 to 6 in. thick; contains abundant globular concretions of dahllite	23

Section of the Cloverly formation north of Muddy Creek in the NW¼ sec. 36 and SE¼ sec. 25, T. 49 N., R. 83 W.—Continued

	Ft
Cloverly formation—Continued	
4. Shale, dark-gray; top 8 ft clay shale and remainder silty shale; 6-in. zones containing iron-stained siltstone concretions 12 to 15 ft above base	32
5. Clay shale, grayish-olive in upper half, dark-gray in lower half; unit capped by 2-in. bed of ferruginous pebbly sandstone	12
6. Shale, gray to black weathering drab brown, noncalcareous; 2-ft zones of thin-bedded brown calcareous siltstone at top and near middle of unit; a few beds of siltstone 4 to 6 in. thick in upper part of unit	31
7. Sandstone, brown to black; conglomeratic with a few pebbles as much as ½ in. long	½
8. Shale, olive-gray weathering ochre; plastic	6½
9. Shale, brownish-black, silty, carbonaceous	2
10. Shale, light yellowish-gray, silty	5
11. Sandstone, light yellowish-gray, medium-grained, well-sorted; lenticular	2
12. Clay shale, brownish-black, carbonaceous	9
13. Mostly concealed; appears to be light-gray fine-grained sandstone	17
14. Sandstone, very light gray, fine-grained, calcareous, well-sorted, thin-bedded, crossbedded	8
15. Sandstone, light yellowish-gray; weathers light yellowish brown to white; composed mostly of medium to coarse rounded grains of quartz, fairly well sorted, crossbedded. This and overlying unit form conspicuous and persistent ridge that supports a growth of cedars and scrubby pines	3
Total measured thickness of Cloverly formation	156½
Unconformity(?)	
Morrison formation.	

SKULL CREEK SHALE

The Skull Creek shale was named by A. J. Collier (1922, p. 79) from exposures along Skull Creek southeast of Osage in northeastern Wyoming. In that part of Wyoming and adjacent parts of South Dakota the formation includes from 175 to 275 feet of black fissile shale with a few ironstone concretions and some thin sandy beds at its base (Rubey, 1930, p. 5). According to Collier (1922, p. 79) and many other geologists, the formation is equivalent to most if not all the lower black shale member of the Thermopolis shale (fig. 2).

The Skull Creek shale is about 175 feet thick in the Buffalo-Lake De Smet area. The formation is nonresistant and at most places is poorly exposed. The lower half is made up of black shale interbedded and interlaminated with light-gray or brown siltstone similar to that in the upper part of the underlying Cloverly formation. Capping

	Buffalo-Lake De Smet area		Nearby areas		
Series	This report	Darton, 1906b	South-central Montana, Knappen and Moulton, 1930	East side Bighorn Mts., Mont., Richards, 1955	Central Wyo., Love, 1945; Thompson, et al, 1949
Upper Cretaceous (part)	Frontier formation	Colorado	Frontier formation	Frontier formation	Frontier formation
Lower Cretaceous	Mowry shale: Siliceous shale member	Mowry member	Mowry shale	Mowry shale	Mowry shale
	Mowry shale: Black shale member		Thermopolis	Thermopolis	
	Newcastle sandstone		Muddy sand of drillers	Unit containing sandstone dikes	Muddy sandstone
	Skull Creek shale	formation	shale	shale	Thermopolis shale
			Rusty beds	Birdhead ss. member	
	(Dahllite concretions)	(Dahllite concretions)	(Dahllite concretions)	(Dahllite concretions)	Rusty beds; (Dahllite concretions)
	Cloverly formation	Cloverly formation	Greybull sandstone member; Cloverly formation	Cloverly and Morrison formations undifferentiated	Cloverly and Morrison formations, undifferentiated
Upper Jurassic (part)	Morrison formation	Morrison formation	Morrison formation		

Lines are dashed where correlation with the Buffalo-Lake De Smet area is approximate.

Figure 2.—Terminology and correlation of Lower Cretaceous rocks in the Buffalo-Lake De Smet and nearby areas.

the silty sequence is a bed of brown siltstone about 2 feet thick which at most places forms a ridge or ledge. The upper half of the formation is black flaky shale. The contact between the Skull Creek shale and the underlying Cloverly formation is gradational; in the Buffalo-Lake De Smet area it is at the top of a conspicuous ledge-forming bed of brown siltstone underlain by beds that contain numerous dahllite concretions.

The ledge-forming bed of brown siltstone near the middle of the Skull Creek shale in the vicinity of Buffalo may correlate with the Birdhead sandstone member of the Thermopolis shale (Thom and others, 1935, p. 47) near the northern end of the Bighorn Mountains, as the two units are at about the same stratigraphic position.

Section of the Skull Creek shale in the SW¼ sec. 25, T. 49 N., R. 83 W.

Newcastle sandstone.	
Skull Creek shale:	Ft
1. Shale, grayish-back, flaky; some interlaminated light-gray siltstone in basal 10 to 15 ft	85
2. Siltstone, tan to light-gray, calcareous, thin-bedded; contains a few plant fragments; forms ledge	2½
3. Shale and siltstone, interbedded and interlaminated; becomes more silty toward top; shale grayish black; siltstone brown	19
4. Siltstone, brown, calcareous, thin-bedded; contains a few large steel-gray calcareous siltstone concretions; forms ledge	2
5. Shale and siltstone, interbedded and interlaminated; shale grayish black; siltstone brown	47
6. Shale, gray to black, bentonitic; a zone of ferruginous siltstone concretions near middle of unit; poorly exposed	19
Total measured thickness	174½
Cloverly formation.	

Few fossils have been reported from the Skull Creek shale, and none was collected during the present investigation. Cobban (1951, p. 2176) lists a Lower Cretaceous (Albian) marine fauna collected in central Montana from black shales equivalent to the Skull Creek, and he notes (p. 2175) that the Lower Cretaceous pelecypod *Inoceramus bellvuensis* Reeside has been found in the Skull Creek shale in the Black Hills region.

NEWCASTLE SANDSTONE

The Newcastle sandstone was named by E. T. Hancock (1920, p. 40) from exposures near Newcastle in northeastern Wyoming where it underlies a wide area that extends into parts of adjacent States. Its correlative, the Muddy sandstone member of the Thermopolis shale, is widespread in northern and central Wyoming.

The Newcastle sandstone is from 40 to 50 feet thick in the Buffalo-Lake De Smet area where it consists predominantly of light-gray to white friable fine-grained sandstone with some thin partings of black shale, especially near the top and base of the formation. Where the Newcastle is well exposed, its light color contrasts strongly with the black shales of the underlying Skull Creek and overlying Mowry. Near Kelly Creek in sec. 36, T. 50 N., R. 83 W., the Newcastle sandstone forms a prominent bare ridge, but elsewhere the formation is less resistant and at many places it is concealed by slope wash from the overlying Mowry shale.

The contact between the Newcastle sandstone and the underlying Skull Creek shale is placed at the base of rocks consisting mainly of sandstone. Below this horizon thin lenses and partings of sandstone commonly occur in the upper part of the Skull Creek shale through a stratigraphic interval of about 5 feet.

Both marine and nonmarine fossils have been reported from the Newcastle sandstone. Equivalent rocks in central Montana are Early Cretaceous in age (Cobban, 1951, p. 2179).

Section of the Newcastle sandstone at Mowry Basin in the center of the SE¼ sec. 31, T. 52 N., R. 83 W.

	Ft
Mowry shale (lower part):	
1. Covered. Soil changes from black at top of interval to light gray at base	9
Newcastle sandstone:	
2. Sandstone, gray, fine- to medium-grained, friable; weathers gray and brown	8
3. Sandstone, light-gray to white, fine-grained, thin-bedded, cross-bedded; forms thin slabs and plates; 2-in. parting of black shale near top	7
4. Sandstone, light-gray to white, fine-grained, thin-bedded, cross-bedded; contains several thin partings of black shale; upper 8 ft is slightly bentonitic	21
5. Sandstone and shale, interlaminated; becomes more shaly toward base	3
6. Bentonite, gray	1
Total measured thickness of Newcastle sandstone	40
Skull Creek shale.	

MOWRY SHALE

The Mowry shale was named by Darton (1904, p. 400; 1906a, p. 53) from exposures in Mowry Basin on the east side of the Bighorn Mountains. As described by Darton, the Mowry beds were the middle unit of his Colorado formation and consisted of a sequence of hard light-gray shale and thin-bedded sandstone that weathers light gray and forms ridges. These shale beds are separated from the Newcastle sandstone by 150 to 200 feet of soft black shale which, when occurring on the western side of the Bighorn Mountains, has in the past been mapped as part of the Thermopolis shale. Thompson, Love, and Tourtelot (1949) advocated that the Mowry shale in central Wyoming be defined to include not only the hard light-gray shale but also the underlying black shale. Two of their reasons for doing so are as follows:

(1) The contact between the upper shale member [of the Thermopolis shale] and the Mowry shale [as previously defined by Darton] is gradational, commonly poorly exposed, and is based primarily on the degree of silicification, which is locally quite variable; in some places * * * hard siliceous shales rest directly on the Muddy sandstone; (2) the contact between the upper shale member and the Mowry shale cannot be picked satisfactorily in the subsurface, either in samples or on electric logs.

The Mowry shale as used in this report, which follows the usage advocated by Thompson, Love, and Tourtelot, includes the strata lying between the Muddy sandstone member (Newcastle sandstone of this report) of the Thermopolis shale and the Frontier formation. As thus used the Mowry shale is also equivalent to rocks in the Black Hills which Rubey (1930, p. 4) included in the Mowry shale.

The Mowry shale is about 525 feet thick in the Buffalo-Lake De Smet area. The formation includes a lower, nonresistant black shale member about 200 feet thick and an upper resistant light-gray siliceous shale member about 325 feet thick. These members have been mapped separately.

Black-weathering clay shale constitutes the bulk of the lower black shale member. Some of the shale is bentonitic and thin beds of gray bentonite occur at several horizons in the member. The contact with the underlying Newcastle sandstone is gradational through about 10 feet of alternating thin layers of black shale and fine-grained white sandstone. The black shale member characteristically forms slopes covered with patchy vegetation and a black gumbo soil.

The upper shale member of the Mowry is one of the most distinctive rock units in the Buffalo-Lake De Smet area. It is composed mostly of hard, brittle, siliceous shale that weathers silvery gray. The member forms a low but conspicuous bare ridge covered with chips of the weathered rock. Fish scales are common in the upper part of the member, and many thin beds of bentonite are present. The member also includes a few beds of well-cemented light-gray very fine grained sandstone. Most of the sandstone beds are thin, but at Mowry Basin a bed of gray sandstone near the top of the member is about 14 feet thick and forms a jutting ledge. The contact between the light-gray siliceous shale and the underlying black shale is gradational through an interval of 10 to 20 feet in which shales of the two lithologies alternate.

Section of the Mowry shale about ½ mile north of the North Fork of Sayles Creek, secs. 5 and 6, T. 51 N., R. 83 W.

	Ft
Frontier formation.	
Mowry shale:	
Siliceous shale member:	
1. Shale, dark-gray to black; weathers dark gray; brittle; 6-in. bed of hard silty sandstone near middle of unit	27
2. Sandstone, silty to very fine grained, thin-bedded; forms ledge	14
3. Bentonite, pale-yellow	2
4. Shale, gray; weathers light gray; siliceous, brittle; contains numerous fish scales	10
5. Siltstone, light-gray, hard; forms ledge	2
6. Shale, dark-gray; weathers light gray; contains a few beds of light-gray siltstone	58
7. Bentonite, pale-green to light-gray	2
8. Shale, gray; weathers light gray; siliceous, brittle; contains numerous fish scales and several thin beds of bentonite less than 1 ft thick	110
9. Bentonite, light-gray	2
10. Shale, gray; weathers light gray; brittle; locally slightly silty	25
11. Bentonite, light-gray	2½
12. Shale, gray; weathers light gray; brittle; contains several thin beds of bentonite less than 1½ ft thick	46
13. Bentonite, light-gray	2½
14. Shale, gray; weathers light gray; brittle; contains fish scales; thin beds of bentonite about 1 ft thick near middle of unit	22
Black shale member:	
15. Mostly concealed; appears to be mainly soft black shale containing ironstone concretions that weather purplish black	41
16. Bentonite, light yellowish-gray	4
17. Shale, grayish-black, soft, poorly exposed	50
18. Bentonite, light-gray	2
19. Shale, grayish-black, poorly exposed; contains a few ironstone concretions	29
20. Bentonite, light-gray	2
21. Shale, grayish-black, soft, bentonitic	52
22. Bentonite, grayish-yellow	2
23. Shale, grayish-black; slightly sandy in lower part	20
Total measured thickness	527
Newcastle sandstone.	

Abundant fish scales and bones and a few impressions of ammonites and other marine mollusks have been reported from the Mowry shale from various parts of the northern Great Plains, but well-preserved diagnostic fossils are rare. R. K. Hose in 1951 collected impressions of *Inoceramus* sp., *Metengonoceras* sp., and *Neogastroplites wyomingensis* (Reeside and Weymouth) from the upper part of the siliceous shale member at Muddy Creek, 8 miles south of the Buffalo-Lake De Smet area. These fossils were identified by W. A. Cobban who believes them to be Early Cretaceous in age.

UPPER CRETACEOUS SERIES

FRONTIER FORMATION

The Frontier formation was named by Knight (1902, p. 721) for a coal-bearing sequence of marine and nonmarine rocks, mainly sandstone and shale, exposed near Kemmerer in southwestern Wyoming. The name was introduced into the Powder River Basin by Hares (1916, p. 238) and since has been widely used to include beds of sandstone and shale that crop out along the east flank of the Bighorn Mountains above the siliceous Mowry shale and below the Cody shale.

Near Buffalo, the Frontier formation is about 500 feet thick and is made up of interbedded and interlaminated dark-gray shale and light-gray sandstone. The formation is entirely marine. It is nonresistant and makes grass-covered slopes east of the conspicuous ridge formed by the underlying siliceous Mowry shale. Most of the sandstone in the Frontier formation is fine grained and is in beds less than 3 inches thick; however, a zone 30 to 40 feet thick at the top of the formation contains medium- to coarse-grained conglomeratic sandstone in beds a few inches to 10 feet or more thick. The beds of conglomerate contain rounded pebbles of black chert as much as 2 inches in maximum dimension; they commonly form low, rounded ledges or ridges that stand a few feet above the adjacent slopes and flats. A few thin beds of bentonite, generally less than 1 foot thick, crop out in the middle and lower parts of the formation. Sandstone and shale in the lower part of the Frontier grade downward into hard siliceous shale of the Mowry through a stratigraphic interval of about 20 feet. The contact between the two formations is placed arbitrarily at the base of a bed of bentonite 4 to 6 feet thick which occurs at about the change from dark-weathering nonresistant shale above to light-gray resistant shale below.

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Section of the Frontier formation north of Dry Muddy Creek in the N½ sec. 1, T. 48 N., R. 83 W.

	Ft
Cody shale (lower part):	
1. Bentonite, grayish-orange	1
2. Mostly concealed; about 5 ft of dark-gray silty shale exposed near middle of unit	27
Frontier formation:	
3. Sandstone and shale, interbedded and interlaminated; shale dark gray; weathers grayish brown. Sandstone light gray to white, fine to medium grained, with a few beds of slabby calcareous sandstone which are as much as 1 in. thick and contain coarse grains of black chert; 3-in. bed of sandstone at top of unit contains rounded and polished granules and pebbles of black chert as much as 1½ in. in maximum dimension	36
4. Siltstone, tan and light-gray, calcareous; contains well-formed cone-in-cone structure and some lenses 6 to 8 in. thick of friable, coarse-grained, light-gray sandstone which contain granules and pebbles of black chert as much as ¾ in. long; forms weak ledge; yields following fossils (USGS Mesozoic loc. 22809 and 23154):	
Inoceramus n. sp. aff. *I. fragilis* Hall and Meek	
Gyrodes aff. *G. conradi* Meek	
Metoicoceras n. sp.	
cf. *M. praecox* Hass	
Mantelliceras cf. *M. canitaurinum* Haas	2½
5. Sandstone, light-gray to white; weathers yellowish gray; fine-grained; in beds less than ½ in. thick separated by partings of dark-gray shale; a few thin beds of siltstone with incipient cone-in-cone structure	33
6. Shale with interlaminated sandstone; shale dark gray; sandstone light gray, fine grained, in lenticular beds as much as 1½ in. thick; beds of dark-gray septarian limestone concretions with septa of bright-yellow calcite 3 and 12 ft above base of unit; widely spaced dark-gray septarian concretions of silty limestone, which weather moderate brown, 20 feet above base of unit; contains the following fossils (USGS Mesozoic loc. 22801; bed of sandstone 43 ft above base of unit):	
Acanthoceras? n. sp.	
(USGS Mesozoic loc. 22807, concretions 12 ft above base of unit):	
Acanthoceras? n. sp	65
7. Bentonite, pale olive-green	4
8. Sandstone and shale, interbedded and interlaminated; shale dark gray; sandstone light gray, fine grained	15
9. Shale, dark-gray; a few laminae of light-gray fine-grained sandstone	6

Section of the Frontier formation north of Dry Muddy Creek in the N½ sec. 1, T. 48 N., R. 83 W.—Continued

	Ft
Frontier formation—Continued	
10. Sandstone and shale, interbedded and interlaminated; sandstone light gray, fine grained; shale dark gray; a bed of widely spaced dark-gray, brown-weathering septarian limestone concretions as much as 10 ft in diameter at top of unit; contains following fossils (USGS Mesozoic loc. 22804; concretions at top of unit): *Nuculana* sp. *Inoceramus* n. sp. aff. *I. fragilis* Hall and Meek *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 *Acanthoceras? amphibolum* Morrow (USGS Mesozoic loc. 22806, 14 ft above base of unit): *Ostrea* sp. *Acanthoceras? amphibolum* Morrow	39
11. Shale and sandstone, interbedded and interlaminated; shale dark gray; sandstone very light gray, fine to medium grained, crossbedded, mostly in beds less than 4 in. thick with a few lenticular beds as much as 8 in. thick; a bed of bentonite 6 in. thick 40 ft above base of unit	43
12. Sandstone, yellowish-gray; weathers dark yellowish orange; crossbedded, calcareous; contains scattered granules and pebbles of black chert as much as ¼ in. long in a matrix of medium-grained sand with many red and green grains; forms ledge	1
13. Shale and sandstone, interbedded and interlaminated; mostly sandstone in upper part and shale in lower part; shale dark gray; sandstone very light gray, fine to medium grained, crossbedded in beds and lenses as much as 4 in. thick; contains following fossils (USGS Mesozoic loc. 22805; 2 ft above base of unit): *Acanthoceras? amphibolum* Morrow	16
14. Sandstone, very light gray, weathers grayish orange; fine-grained, friable, noncalcareous; contains a few laminae of dark-gray shale	2
15. Silty shale and sandstone, interlaminated; shale dark gray; sandstone light gray, fine grained	15
16. Silty shale and siltstone, interlaminated, dark-gray; 6-in. lens of fine-grained light-gray sandstone in top 1 ft of unit	15
17. Sandstone and shale, interbedded and interlaminated; shale dark gray to grayish black; sandstone light gray to white, weathers light gray and light brown; very fine grained to silty; crossbedded, in lenticular beds mostly less than 1 in. thick; two or three lenticular beds of sandstone as much as 1 ft thick near top of unit	142

Section of the Frontier formation north of Dry Muddy Creek in the N½ sec. 1, T. 48 N., R. 83 W.—Continued

	Ft
Frontier formation—Continued	
18. Shale, dark-gray, weathers dark yellowish brown; slightly silty	11
19. Shale, light olive-gray, very silty; lower 2 ft bentonitic	5
20. Bentonite, light greenish-gray in lower half and light olive-gray in upper half; near base of unit a light-brown layer 3 in. thick present for at least 1 mile along outcrop	5
21. Shaly siltstone, dark yellowish-brown; contains concretions of dark-gray calcareous siltstone which are 2 to 3 ft long and about 9 in. thick; 1-ft lenticular bed of brown-weathering sandstone at base of unit	12½
22. Shale, dark-gray, silty, flaky	1
23. Shale and siltstone, light olive-gray, bentonitic; more silty in upper half of unit; contains platy concretions of calcareous manganiferous siltstone	6
24. Bentonite, pale olive-gray	1
25. Siltstone dark-gray to grayish-brown, bentonitic; becomes more bentonitic toward top of unit; a few platy concretions of dark-gray calcareous siltstone as much as 4 ft long	15
26. Shale, medium dark-gray, bentonitic	5
27. Bentonite, light olive-gray	2
28. Shale, dark-gray to grayish-black; weathers dark yellowish brown; contains minor silty partings	13
29. Bentonite, pale olive-green to gray; contains a 2 ft zone of light-gray bentonitic shale near middle of unit	6
Total measured thickness of Frontier formation	517
Mowry shale (siliceous shale member):	
30. Shale and siltstone, gray, brittle, weathers rusty brown along joint surfaces	5½
31. Shale, gray to light-gray, brittle; contains laminae and thin beds of fine-grained sandstone	27

Plate 6 is a chart adapted from Cobban and Reeside (1952, p. 1958–9) and from unpublished data compiled by W. A. Cobban (written communication, 1950) showing the fossil zones represented by the fossils that are listed in the above stratigraphic section. The Frontier formation in the Buffalo-Lake De Smet area is equivalent in age to the Belle Fourche shale and lower part of the Greenhorn formation of the Black Hills and central Montana.

CODY SHALE

The Cody shale was named by C. T. Lupton (1916, p. 171) for exposures near Cody on the northwestern side of the Bighorn Basin. The formation includes a thick sequence of marine sandstone and shale of Late Cretaceous age which in the Buffalo-Lake De Smet area overlies conglomeratic sandstone of the Frontier formation and underlies the Parkman sandstone. The Cody crops out near the east flank of the mountains in a band of steeply dipping rocks as much as 1 mile wide. The sandstone and shale that make up the Cody are nonresistant and characteristically form gentle grass-covered slopes and broad valleys.

Intense folding and faulting at some places and poor exposures at others prevent reliable measurement of the thickness of the Cody shale in the Buffalo-Lake De Smet area; however, the formation is about 3,550 feet thick near Elgin Creek, about 3 miles south of the area.

The Cody shale includes several units whose lithology and diagnostic fossil content permit correlation with the well-known Upper Cretaceous section of the Black Hills and central Montana. Seven members were recognized during the present investigation. In ascending order they are: (1) lower shale member, (2) Greenhorn calcareous member, (3) Carlile shale member, (4) Niobrara shale member, (5) sandstone and shale member, (6) Shannon sandstone member, and (7) upper shale member. Fossils collected from the Cody shale are listed in the measured section on pages 50–57, and the fossil zones represented by the collections are shown by plate 6.

Lower shale member.—The lower shale member is chiefly soft dark-gray noncalcareous fissile shale. At most places a few thin laminae of light-gray sandstone occur in its lower part. The base of the member is placed at the top of the bed of coarse conglomeratic sandstone that characterizes the top of the Frontier formation. The lower shale member is 80 feet thick at Mowry Basin and 67 feet thick near Elgin Creek in sec. 12, T. 49 N., R. 83 W. Scattered dark-gray septarian limestone concretions in the upper part of the member yield a marine fauna which according to W. A. Cobban is common to the middle part of the Greenhorn formation of the Black Hills.

Greenhorn calcareous member.—The Greenhorn calcareous member is 136 feet thick near Elgin Creek. It is divisible into a lower unit consisting of about 60 feet of dark-gray very calcareous fossiliferous shale and an upper unit about 75 feet thick consisting of about 35 feet of interbedded and interlaminated dark-gray shale and light-gray fine-grained sandstone which grades upward into 40 feet of massive fine-grained light- to dark-gray calcareous sandstone. The lower calcareous shale of the Greenhorn member weathers bluish gray in contrast to the dark-gray weathering noncalcareous shale of the underlying lower shale member. The contact between the two members is fairly sharp and where exposures are good can be determined within 1 to 2 feet.

A shale sample collected near Elgin Creek from the basal part of the Greenhorn calcareous member contained a varied assemblage of foraminifera which are listed in the measured section on page 56 (unit 37). S. K. Fox identified the fossils and reported on their age as follows:

Analysis of the eleven species from this sample indicates equivalence with the Greenhorn of various parts of the western interior. Six species are restricted to the Greenhorn in the northern Black Hills section—*Marginulina* sp., *Robulus* ,p., *Saracenaria reesidei, Gumbelina moremani,* and *Bulimina wyomingensis.* These forms are particularly characteristic of the upper Greenhorn of the northern Black Hills. Several species in this assemblage occur in the "Greenhorn" part of the Colorado shale at Mosby, Montana: *Vaginulina* n. sp., *Dentalina* sp., and *Bulimina wyomingensis. Saracenaria reesidei* and *Marginulina* sp. are restricted to the "Greenhorn" part of the Cody shale in the eastern Bighorn Basin. *Planularia* n. sp. has not been reported from other Greenhorn localities. No characteristic Hartland species reported by Morrow from Kansas appear in * * * (the sample). It would appear that the Buffalo samples are most closely related to the upper Greenhorn as it is developed in the northern Black Hills.

According to Cobban, megafossils collected from concretions in the upper sandy shales and sandstones of the member represent the zone of *Watinoceras reesidei* Warren, and are typical of the upper part of the Greenhorn formation of the northern Black Hills.

Carlile shale member.—The Carlile shale member is 156 feet thick near Elgin Creek. It contains three units of differing lithology. The lowest unit consists of 44 feet of interbedded and interlaminated light-gray fine-grained sandstone and dark-gray noncalcareous shale. This unit rests with a sharp even contact on massive sandstone of the Greenhorn calcareous member. Above the sandy beds is 20 feet of dark-gray noncalcareous shale which contains several beds of rusty or maroon-weathering ironstone concretions. Most of the concretions are oval in cross section and 6 inches or less in maximum dimension. The upper 92 feet of the Carlile is dark-gray shale which contains several beds of fossiliferous dark-gray septarian limestone concretions commonly about 1 foot in diameter which weather light-gray and contain veins of dark-orange or yellow calcite.

Fossils collected from the Carlile shale member near Elgin Creek are listed in the stratigraphic section on pages 50–57. According to W. A. Cobban, the member is equivalent in age to the middle part of the Turner sandy member and the Sage Breaks member of the Carlile shale in the northern Black Hills.

Niobrara shale member.—The Niobrara member of the Cody shale is 985 feet thick near Elgin Creek. It consists of soft dark-gray shale and contains several thin beds of bentonite. The base of the member is a unit of noncalcareous shale about 175 feet thick which is characterized by two or three prominent beds of dark yellowish-orange silty limestone concretions as much as 10 feet in diameter. These concretions are septarian with thick veins of light-yellow calcite and are abundantly fossiliferous. Because of their size, color, and lithology they are easily recognized at many places along the mountain front and thus are excellent guides for mapping. The remaining 810 feet of shale in the Niobrara is calcareous, becoming increasingly so near the top. The calcareous shale comprising the middle and upper parts of the member rests on the basal noncalcareous shale with a fairly sharp contact which at good exposures can be determined within 5 to 10 feet.

The fossiliferous concretions in the basal noncalcareous unit of the Niobrara shale member yields a fauna which according to W. A. Cobban represents the zone of *Scaphites preventricosus* Cobban and is equivalent in age to the basal part of the Niobrara shale of the Black Hills and northern Great Plains. Except for fragments of *Inoceramus* encrusted with *Ostrea congesta* Conrad, no fossils were found in the upper calcareous shale.

Sandstone and shale member.—The sandstone and shale member of the Cody shale is 1,070 feet thick near Elgin Creek. It consists of a dark-gray shale with interbedded and interlaminated layers of fine-grained light-gray sandstone, and a few beds of bentonite mostly less than 1 foot thick. Fossiliferous limestone concretions at various horizons in the middle and upper parts yield a marine invertebrate fauna similar to that found in the Eagle sandstone of the northern Great Plains. No fossils were found in the lower part of the member.

Shannon sandstone member.—The Shannon sandstone member of the Cody shale is 215 feet thick near Elgin Creek. It consists mainly of nonresistant fine-grained light-gray sandstone with many thin partings of dark-gray shale. Glauconite is scattered throughout the sandstone and locally is very abundant, giving a pale-olive color to the weathered rock. The Shannon sandstone member becomes more shaly in its lower part and grades downward through a stratigraphic interval of about 20 to 30 feet into the underlying sandstone and shale member.

Fossils found in large yellowish-brown calcareous sandstone concretions in the middle and upper parts of the Shannon sandstone member are similar to those found in the underlying sandstone and shale member and, according to W. A. Cobban, are characteristic of the Eagle sandstone in central Montana.

Upper shale member.—The upper shale member is about 925 feet thick near Elgin Creek. It consists largely of dark-gray noncalcareous shale with a few thin partings of light-gray fine-grained sandstone in the lower part. The member is gradational downward into the Shannon sandstone member. A few beds of bentonite, each less than

2 feet thick, occur at various horizons. A thin but persistent bed of fine-grained sandstone containing polished pebbles of black, green, and gray chert as much as 1 inch in longest dimension was noticed about 80 feet above the base of the member. No fossils other than a few specimens of *Inoceramus* cf. *I. barabini* Morton and *Baculites* aff. *B. haresi* Reeside were found in the member; however, it probably corresponds to the Claggett shale of south-central Montana for it is stratigraphically at the same position.

Section of the Cody Shale near Elgin Creek in the N½SW¼ sec. 12, and the N½ sec. 13, T. 49 N., R. 83 W.

	Ft
Parkman sandstone.	
Cody shale:	
Upper shale member:	
1. Clay shale, grayish-black; contains several beds of dark-gray septarian limestone concretions which yield following fossils (USGS Mesozoic loc. 22833; concretions 98 ft stratigraphically below top of unit): *Inoceramus* cf. *I. barabini* Morton; *Baculites* aff. *B. haresi* Reeside	293
2. Shale, dark-gray; interlaminated light-gray siltstone and very light gray fine-grained sandstone near base; bed 1 ft thick of grayish-green bentonite 78 ft from base; unit partly covered	515
3. Shale, dark-gray to grayish-black; has a few laminae and thin beds of light-gray fine-grained sandstone; a 3-in. bed of fine-grained sandstone with highly polished pebbles of black, green, and gray chert as much as 1 in. in diameter at top of unit; 4 or 5 beds of dark-gray silty limestone concretions as much as 1 ft long which weather dark reddish brown; contains the following fossils (USGS Mesozoic loc. 22832 and 22824; from reddish-brown weathering concretions): *Nuculana* sp.; *Geltena* cf. *G. gracilis* (Meek and Hayden); *Inoceramus barabini* Morton; *Baculites haresi* Reeside	65
4. Bentonite, pale greenish-gray	1½
5. Shale and sandstone, interbedded; shale dark gray; sandstone light gray, fine grained; 2 beds of ellipsoidal dark-gray silty limestone concretions which weather dark reddish brown	12
6. Shale, dark-gray, sandy	42
Total measured thickness of upper shale member of Cody shale	927½

Section of the Cody Shale near Elgin Creek in the N½SW¼ sec. 12, and the N½ sec. 13, T. 49 N., R. 83 W.—Continued

Cody shale—Continued

Shannon sandstone member: Ft

7. Sandstone and shale, interbedded; more sandy near base. Sandstone very light gray; weathers yellowish gray; fine to medium grained, slightly calcareous; very thin bedded; contains a few grains of glauconite. Shale dark gray, sandy; contains several beds of moderate yellowish-brown calcareous sandstone concretions which yeild the following fossils (USGS Mesozoic loc. 22803; concretions in top 10 ft of unit):
   Perissonota sp.
   Pecten (*Syncyclonema*) *halli* Gabb
   Baculites haresi Reeside
   aquilaensis Reeside
   Placenticeras planum Hyatt ---------- 76
8. Sandstone, pale-olive, very fine grained, slightly calcareous, glauconitic; has many thin partings of dark-gray shale; top 15 ft fine- to medium-grained sandstone which contains sparse glauconite; beds of widely spaced moderate yellowish-brown calcareous sandstone concretions about 25 and 75 ft above base of unit; contact with underlying unit is gradational; contains following fossils (USGS Mesozoic loc. 22823; sandstone concretions 75 ft stratigraphically above base of unit):
   Pteria linguaeformia (Evans and Shumard)
   Anomia n. sp.
   Lucina aff. *L. subundata* Hall and Meek
   Volutoderma? sp.
   Baculites haresi Reeside ---------- 139

Total measured thickness of Shannon sandstone member of Cody shale ---------- 215

Shale and sandstone member:

9. Siltstone and shale, interlaminated; siltstone very light gray; shale dark gray; several beds of ellipsoidal rusty-weathering ironstone concretions as much as 6 in. long; contains the following fossils (USGS Mesozoic loc. 23148; float about 75 ft stratigraphically below top of unit):
   Pecten (*Syncyclonema*) *hallii* Gabb
   Turritella n. sp.
   Eutrephoceras alcesense Reeside
   Baculites haresi Reeside
   Scaphites hippocrepis (DeKay)
   Placenticeras sp ---------- 125
10. Shale and siltstone, interbedded and interlaminated; shale dark gray to grayish black; siltstone light yellowish gray; crushed fossil fragments in shale in upper half of unit ---------- 57

Section of the Cody Shale near Elgin Creek in the N½SW¼ sec. 12, and the N½ sec. 13, T. 49 N., R. 83 W.—Continued

Cody shale—Continued

Shale and sandstone member—Continued	Ft
11. Clay shale, dark-gray to grayish-black; a few thin stringers of light yellowish-gray siltstone; 3 or 4 beds of ellipsoidal rusty-weathering ironstone concretions; a bed of dark yellowish-brown calcareous siltstone concretions which weather moderate-brown at top of unit	28
12. Bentonite, grayish-yellow, small moderate-yellow cone-in-cone concretions	1
13. Shale, dark-gray to grayish-black; upper half of unit contains many laminae of light-gray siltstone; bed of closely spaced dark-gray calcareous siltstone concretions as much as 2 ft long and 1 ft thick 2 ft below top; a bed of dark-gray septarian limestone concretions that weather white 5 ft below top	39
14. Bentonite, grayish-yellow	1
15. Shale, dark-gray, silty; beds of dark-gray white-weathering limestone concretions from 6 to 18 in. in diameter about 15, 25, and 35 ft above base; bed of closely spaced light-gray calcareous siltstone concretions about 6 in. thick and 2 ft long at base; contains the following fossils (USGS Mesozoic loc. 22830; concretions 35 ft stratigraphically 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 loc. 22828; concretions 25 ft above base of unit): *Scaphites hippocrepis* (DeKay); *Placenticeras meeki* Boehm; *Baculites aquilaensis* var. *separatus* Reeside. (USGS Mesozoic loc. 22829; concretions 15 ft above base of unit): *Inoceramus* sp.; *Pteria* cf. *P. linguaeformis* (Evans and Shumard); *Anomia* sp.; *Baculites haresi* Reeside; *aquilaensis* var. *obesus* Reeside	51
16. Shale, dark-gray, silty	48
17. Bentonite, yellowish-gray; scattered dark greenish-gray concretions about 12 in. in diameter	1

Section of the Cody Shale near Elgin Creek in the N½SW¼ sec. 12, and the N½ sec. 13, T. 49 N., R. 83 W.—Continued

Cody shale—Continued

Shale and sandstone member—Continued — Ft

18. Shale and sandstone, interlaminated; shale dark gray; sandstone very light gray, fine grained; dark-gray septarian limestone concretions 1 in. to 6 in. in diameter which weather yellowish gray and contain fucoidal markings on their exterior; conspicuous bed of moderate brown calcareous silstone concretions as much as 10 ft in diameter 5 ft below top; contains the following fossils (USGS Mesozoic loc. 22821; from septarian limestone concretions):
    Baculites aquilaensis Reeside
    haresi Reeside
    Scaphites hippocrepis (DeKay)
    (USGS Mesozoic loc. 22834; float from this unit):
    Fasciolaria aff. *F. cheyennensis* (Meek and Hayden) — 30
19. Shale and sandstone, interlaminated; shale dark gray; sandstone light gray, fine grained; septarian limestone concretions which weather light brown about 30 ft above base — 123
20. Bentonite, yellowish-gray, 1 ft thick; underlain by 6-in. bed of calcareous sandstone which forms weak ledge — 1½
21. Sandstone and shale, interbedded and interlaminated; shale dark gray; sandstone very light gray, fine grained; local lenses of sandstone as much as 1½ ft thick contain tabular dark-gray limestone concretions that weather light brown; contains the following fossils (USGS Mesozoic loc. 22822; from tabular limestone concretions 240 ft below top of unit):
    Nucula sp.
    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

Section of the Cody Shale near Elgin Creek in the N½SW¼ sec. 12, and the N½ sec. 13, T. 49 N., R. 83 W.—Continued

	Ft
Cody shale—Continued	
Shale and sandstone member—Continued	
21. Sandstone and shale—Continued	
Baculites aquilaensis Reeside	
aquilaensis var. *separatus* Reeside	
aquilaensis var. *obesus* Reeside	
haresi Reeside	
asper Morton?	565
Total measured thickness of shale and sandstone member of Cody shale	1,070
Niobrara shale member;	
22. Shale, grayish-black, noncalcareous, poorly exposed	40
23. Shale, dark-gray to grayish-black; weathers light gray to brown; very calcareous; partly covered	300
24. Shale, dark-gray to grayish-black, alternately calcareous and noncalcareous, poorly exposed	190
25. Shale, dark-gray, very calcareous, partly covered; a few stringers of bentonite less than 1 in. thick; contains a few poorly preserved *Inoceramus* and *Ostrea congesta*	182
26. Bentonite, very light gray	1
27. Shale, grayish-black, noncalcareous, partly covered	73
28. Shale, dark-gray, noncalcareous; a bed of medium-gray septarian limestone concretions at top of unit	40
29. Mostly concealed; appears to be mainly dark-gray shale; conspicuous bed of dark yellowish-orange septaria silty limestone concretions as much as 10 ft. in diameter at top of unit; beds of similar concretions crop out less noticeably near middle and at base of unit; contains following fossils (USGS Mesozoic loc. 23151; concretions at top of unit):	
Inoceramus aff. *I. erectus* Meek	
n. sp.	
Pholodomya payypracea Meek and Hayden	
Cardium sp.	
"*Tellina*" sp.	
Parmicorbula n. sp.	
Creonella? n. sp.	
Polinices sp.	
Gyrodes conradi Meek	
Xenophora simpsoni Stanton	
Turritella cf. *T. whitei* Stanton	
Anchura? sp.	
Baculites mariasensis Cobban	
Scaphites preventricosus Cobban	
(USGS Mesozoic loc. 23152; concretions at base of unit):	
Inoceramus n. sp	
Anchura? n. sp	159
Total measured thickness of Niobrara shale member of the Cody shale	985

Section of the Cody Shale near Elgin Creek in the N½SW¼ sec. 12, and the N½ sec. 13, T. 49 N., R. 83 W.—Continued

	Ft
Cody shale—Continued	
Carlile shale member:	
30. Mostly concealed; appears to be mainly dark-gray silty shale; several beds of dark-gray, light-gray weathering septarian concretions with veins of dark orange calcite; contains following fossils (USGS Mesozoic loc. 22816; concretions 58 ft. stratigraphically above base unit): *Inoceramus* n. sp.; *Baculites* cf. *B. besairiei* Collignon; *Prionocyclus* n. sp.; *Scaphites corvensis* Cobban. (USGS Mesozoic loc. 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)	92
31. Shale, silty, dark-gray; weathers dusky yellowish brown; noncalcareous; several beds of rusty-weathering dark-gray ironstone concretions	20
32. Shale and sandstone, interbedded and interlaminated; shale dark gray, noncalcareous; sandstone white to light gray, fine grained; in lenticular beds as much as 1 in. thick; platy dark-gray limestone concretions locally in sandstone; contact with underlying unit very sharp; yields following fossils (USGS Mesozoic loc. 22813; concretionary sandstone lens 27 feet stratigraphically above base of unit): *Inoceramus dimidius* White; *perplexus* Whitfield; *Polinices* sp.; *Scaphites whitfieldi* Cobban; *Prionocyclus wyomingensis* Meek. Shale sample from near base of unit contains the following foraminifera, identified by S. K. Fox: *Haplophragmoides carlilensis* Fox; *Globigerina cretacea* d'Orbigny	44
Total measured thickness of Carlile shale member of the Cody shale	156

Section of the Cody Shale near Elgin Creek in the N½SW¼ sec. 12, and the N½ sec. 13, T. 49 N., R. 83 W.—Continued

	Ft
Cody shale—Continued	
Greenhorn calcareous member:	
33. Sandstone, light- to dark-gray; weathers light gray; fine- to medium-grained, friable, calcareous; lower part of the unit contains many thin partings of dark-gray shale; bed of medium-gray sandy limestone concretions which weather light-gray 9 ft. above base of unit; yields following fossils (USGS Mesozoic loc 22819; concretions 9 ft. stratigraphically above base of unit): *Serpula* sp. *Inoceramus labiatus* Schlotheim *Ostrea* sp. *Cerithium* n. sp. *Mammites* sp. *Watinoceras* sp. "*Pachydiscus*" n. sp.	41
34. Shale and sandstone, interlaminated; basal 3 ft. bentonitic; shale dark gray; sandstone light gray, fine grained; slightly calcareous	20
35. Bentonite	2
36. Shale, dark-gray; weathers moderate yellowish brown; sandy, slightly calcareous	12
37. Shale, dark-gray; weathers dark bluish gray; calcareous; contains following fossils (USGS Mesozoic loc. 22811; near base of unit): *Inoceramus labiatus* Schlotheim *Borissjakoceras* sp. Shale sample contains following microfauna identified by S. K. Fox: *Robulus* sp. *Planularia* n. sp. *Saracenaria reesidei* Fox *Marginulina* n. sp. *Dentalina basiplanata* Cushman *Vaginulina* n. sp. Young *Gumbelina moremani* Cushman *Bulimina wyomingensis* Fox *Valvulineria* sp. *Globigerina cretacea* d'Orbigny	61
Total measured thickness of Greenhorn calcareous member	136

Section of the Cody Shale near Elgin Creek in the N½SW¼ sec. 12, and the N½ sec. 13, T. 49 N., R. 83 W.—Continued

	Ft
Cody shale—Continued	
Lower shale member:	
38. Shale, silty, dark-gray noncalcareous; scattered dark-gray septarian limestone concretions near top; yields following fossils (USGS Mesozoic loc. 22808; concretions in unit at Dry Muddy Creek in the NE¼ sec. 1, T. 48 N., R. 83 W.): *Pteria* n. sp. *Inoceramus* cf. *I. fragilis* Hall and Meek *Dentalium pauperculum* Meek and Hayden *Anchura?* sp. *Oligoptycha* sp. *Metoicoceras whitei* Hyatt *Dunveganoceras* sp. (USGS Mesozoic loc. 22815; concretions in unit about 2 miles south of Dry Muddy Creek SE¼NE¼SW¼ sec. 12, T. 48 N., R. 83 W.): *Pteria* sp. *Inoceramus* aff. *I. fragilis* Hall and Meek *Scaphites delicatulus* Warren *Sciponoceras gracile* (Shumard) *Allocrioceras pariense* (White) *Borissjakoceras* cf. *B. reesidei* Morrow	22
39. Mostly concealed; appears to be mainly dark-gray noncalcareous shale	45
Total measured thickness of lower shale member	67
Total measured thickness of Cody shale	3, 557
Frontier formation (upper part):	
40. Sandstone, light-gray, conglomaratic; contains abundant pebbles of black chert as much as ½ in. in longest dimension, forms ledge	4

PARKMAN SANDSTONE

The Parkman sandstone was named by Darton (1906a, p. 58) from exposures near the town of Parkman, about 40 miles northwest of Buffalo. The formation is about 720 feet thick in the Buffalo-Lake De Smet area and is made up chiefly of sandstone with some shale near the base and top. Beds of sandstone in the lower and middle parts of the formation stand out in bold outcrops and characteristically form resistant ledges and ridges; the upper part of the formation is less resistant and commonly is poorly exposed.

The basal part of the Parkman grades into the underlying Cody shale through a transitional zone as much as 150 feet thick in which thin beds of light-gray ledge-forming sandstone alternate with beds of dark-gray shale. Above the transitional zone there is about 280 feet of ridge-forming thick-bedded sandstone which contains numerous brown-weathering calcareous sandstone concretions 6 feet or more in maximum dimension. The sandstone is light gray to light yellowish gray, fine grained, and crossbedded. The remainder of the formation consists largely of interbedded light-gray sandstone and dark greenish-gray shale with some thin beds and partings of brown carbonaceous shale in the upper part. A persistent bed of white sandstone about 10 feet thick marks the top of the formation.

Marine and fresh-water invertebrates, dinosaur bones, turtle shell fragments, and fragments of petrified wood have been reported from the Parkman in nearby areas (Darton, 1906a, p. 59; Thom and others, 1935, p. 59). The upper part of the formation contains many fragments of leaves and twigs. The Parkman passes northward into the nonmarine Judith River formation of central Montana.

Section of the Parkman sandstone in the N½ sec. 13, T. 49 N., R. 83 W., about 2 miles south of the Buffalo-Lake De Smet area

	Ft
Bearpaw shale.	
Parkman sandstone:	
1. Sandstone, white, fine-grained, friable, crossbedded	8
2. Shale, pale-brown and moderate-brown, carbonaceous	25
3. Sandstone, very light gray, fine- to medium-grained, friable, medium-bedded; contains a few small moderate-brown calcareous siltstone concretions and a few laminae of moderate-brown carbonaceous shale	130
4. Shale and sandstone, interbedded; shale dark greenish gray, silty, slightly carbonaceous; sandstone very light gray, very fine grained; thin-bedded	45
5. Sandstone and shale, interbedded; sandstone very light gray, fine to very fine grained, locally calcareous and slabby, crossbedded, in beds as much as 2 ft thick; shale dark greenish gray, sandy, slightly carbonaceous	85
6. Sandstone, very light gray, weathers grayish yellow; fine- to medium-grained, calcareous, crossbedded, in alternating thin, medium, and thick beds; contains moderate-brown calcareous sandstone concretions as much as 4 ft long; lenticular bed 2 ft thick of moderate-brown carbonaceous shale 215 ft above base; unit forms ridges and knolls; yields following fossils 30 ft above base: *Pinna* sp., *Inoceramus* sp., *Ethmocardium whitei* (Dall), *Gyrodes* sp., *Baculites* sp	283
7. Sandstone and shale, interbedded; becomes less sandy toward base; sandstone very light gray, fine-grained, thin-bedded, locally calcareous and slabby, crossbedded; contains a few moderate-brown sandstone concretions; shale dark gray	145
Total measured thickness	721
Cody shale.	

BEARPAW SHALE

The Bearpaw shale was named by Stanton and Hatcher (1905, p. 13–14) for a sequence of marine shale typically developed on the south side of the Bearpaw Mountains. The formation may be traced from its type locality southward across Montana into northeastern Wyoming where, in the Buffalo-Lake De Smet area, it consists of a thin sequence of marine shale that is conformable with both the underlying Parkman sandstone and the overlying Lance formation. The Bearpaw is nonresistant and poorly exposed. It forms soil-covered slopes or flats on which, at most places, it can scarcely be distinguished from adjacent formations.

The Bearpaw is mainly dark greenish-gray shale with some thin laminae of light-gray fine-grained sandstone in the upper part. The formation is about 200 feet thick along a tributary to Elgin Creek 2 miles south of the Buffalo-Lake De Smet area where it rests on the Parkman sandstone with a fairly definite contact that can be determined within about 3 feet stratigraphically. The dark-colored shale of the Bearpaw grades upward into a sequence of interbedded light-colored sandstone and dark greenish-gray shale which constitutes the lower part of the Lance formation. The contact between the Bearpaw and Lance is placed arbitrarily at the top of a bed of grayish-yellow bentonite 1 foot thick underlain by 2 to 3 feet of fine-grained light-gray sandstone which at some places forms an inconspicuous ledge. This sandstone carries a marine fauna identified by W. A. Cobban as *Baculites* aff. *B. compressus* Say, *Acanthoscaphites nodosus* var. *brevis* (Meek), *A. nodosus* var. *quadrangularis* (Meek and Hayden), *Nucula* sp., *Nuculana* cf. *N. corsicana* Stephenson, *Pteria* (*Oxytoma*) *nebrascana* (Evans and Shumard), and *Ostrea* sp. This assemblage is common to the lower and middle parts of the Bearpaw shale in south-central Montana (pl. 6).

The Bearpaw is the youngest marine formation in the Buffalo-Lake De Smet area.

LANCE FORMATION

The Lance formation was named by Hatcher (1903, p. 369) who used the term "Lance Creek beds" for sedimentary rocks mainly continental in origin exposed near Lance Creek in Converse County, eastern Wyoming. At the type locality these beds conformably overlie the Fox Hills sandstone and underlie the Fort Union formation. The Fox Hills sandstone could not be distinguished in the Buffalo-Lake De Smet area, and the beds here classified as Lance rest directly on the Bearpaw shale.

The upturned edges of steeply dipping beds in the Lance formation are exposed in the southwestern, west-central, and northwestern parts

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of the Buffalo-Lake De Smet area in an outcrop band one-fourth to one-half mile wide trending northwestward parallel to the Bighorn Mountain front. The formation generally is poorly exposed on soil-covered slopes and flats that differ little from those formed on the overlying Fort Union formation or underlying Bearpaw shale. At some places, however, resistant beds in the Lance form low ridges and knobs.

The Lance formation is fairly well exposed along North Fork of Crazy Woman Creek, 5 miles south of the mapped area, where the formation is 1,970 feet thick. The basal 150 to 200 feet is thin- and even-bedded light-gray sandstone which becomes shaly towards the base and grades downward into the marine shale of the underlying Bearpaw. The remainder of the Lance consists of light-gray to light yellowish-gray fine- to medium-grained crossbedded sandstone in beds as much as 75 feet thick which locally form bold outcrops but which pass into thin-bedded nonresistant sandstone and shale in short distances along the strike. Lenticular stringers and partings of brown carbonaceous shale occur sparsely throughout the formation.

No fossils, other than a few fragments of bone, were found in the Lance during the present investigation. Wegemann (1912, p. 446) reported remains of *Triceratops* and *Trachodon* in the lower and middle parts of the formation in the Sussex coal field, a few miles to the south. These fossils establish the age of the beds as latest Cretaceous.

TERTIARY SYSTEM

PALEOCENE SERIES

FORT UNION FORMATION

The Fort Union formation was named by Meek and Hayden (1861, p. 433) from exposures near Fort Union, now Buford, N. Dak. In the Buffalo-Lake De Smet area, the Fort Union consists of nonmarine sandstone, shale, and conglomerate which overlies the Lance formation and underlies the Kingsbury conglomerate member of the Wasatch formation. The Fort Union formation crops out in an irregular band as much as 1 mile wide at Mowry Basin and in a narrow wedge on the west side of Kingsbury Ridge. Elsewhere, it is concealed by the unconformably overlapping Kingsbury conglomerate member of the Wasatch formation.

The Fort Union is well exposed in badlands about 6 miles south of the Buffalo-Lake De Smet area where R. K. Hose (written communication, 1949) describes its general lithologic character as follows:

The Fort Union formation is about 3,950 feet thick in the southeastern part of T. 49 N., R. 82 W. The lower 1,500 feet consists of resistant thin-bedded ferruginous sandstone, pale-olive claystone, gray siltstone, and some light-gray fine-grained sandstone. The next higher 1,500 feet of beds are much the same except for the presence of several thick carbonaceous shales. The remainder of the formation, in an area 5 to 7 miles southeast of Kingsbury Ridge, contains poorly consolidated sandstone lenses, shale, and conglomerate that resemble the lithology of the Kingsbury conglomerate member of the Eocene Wasatch formation. This conglomeratic sequence grades laterally into finer grained strata within a few miles north and south along strike.

Northward from the area described by Hose, the Kingsbury conglomerate member of the Wasatch progressively overlaps the Fort Union and older formations so that west of Kingsbury Ridge only the basal part of the Fort Union is represented in a narrow wedge of ferruginous sandstone and shale. Farther northward, at Mowry Basin, the outcrop band of the Kingsbury swings eastward from the mountains exposing the Fort Union formation for about 4 miles. Here an angular unconformity divides the Fort Union into two members. The lower member has a maximum exposed thickness of about 1,000 feet. Its thickness is variable, however, and at places the member is absent owing to erosion prior to deposition of the upper member. The lower member is similar in lithology to the lower part of the Fort Union formation a few miles to the south. The upper member, with a maximum exposed thickness of about 1,200 feet, contains in the basal 200 to 300 feet lenticular beds of conglomerate 1 to 20 feet thick. Rock fragments that make up the conglomerate are subrounded to angular pebbles and cobbles of limestone, dolomite, and chert. They are imbedded in a matrix of coarse-grained light-gray sandstone. The conglomeratic beds are interbedded with pink, green, and gray sandy shale. This sequence forms a series of low ridges near Mowry Creek in secs. 29 and 33, T. 52 N., R. 83 W., and it weathers to a series of pale-pink and white bands on grassy, gravel-strewn slopes north and south of Sayles Creek in sec. 4, T. 51 N., R. 83 W. These conglomeratic beds grade upward into a very poorly exposed sequence of sandstone and shale which constitutes the remainder of the formation.

Conglomerate beds in the upper member of the Fort Union formation at Mowry Basin are similar to those in the upper 900 feet of the Fort Union formation south of Kingsbury Ridge a few miles to the south, suggesting that the conglomeratic strata at the two places are equivalent. If this correlation is correct, as much as 2,600 feet of strata in the middle and lower parts of the formation at Mowry Basin may have been removed by erosion prior to deposition of the upper member.

The Fort Union formation is conformable on the underlying Lance formation and the contact between them is gradational. For convenience in mapping, the contact is placed at the base of a sequence of thin- to medium-bedded, friable, white to very light gray sandstone which contains resistant beds of maroon-weathering ferruginous concretionary siltstone and a few thin beds of brown and black carbonaceous shale. Massive lenticular channel sandstone beds that contain only minor amounts of brown carbonaceous shale characterize the Lance formation below this horizon.

No fossils other than fragments of plant remains were found in the Fort Union formation during the present investigation. R. W. Brown (1949) states that equivalent strata in other parts of the Powder River Basin yield the remains of plants, fresh-water mollusks, and primitive mammals of Paleocene age.

EOCENE SERIES

WASATCH FORMATION

The Wasatch formation was named by Hayden (1869, p. 161) for exposures near Evanston in southwestern Wyoming. Wegemann (1917) who recognized that the Tertiary sequence near Pumpkin Buttes included beds of both Paleocene and Eocene age later used the name for rocks in the Powder River Basin. Wegemann retained the name Fort Union formation for the beds of Paleocene age, and applied the name Wasatch formation to the overlying beds of Eocene age. He stated (p. 60) that the basal part of the Wasatch formation near Pumpkin Buttes grades northward into the Kingsbury conglomerate member, which had previously been considered part of the Fort Union formation, and that near Buffalo an angular unconformity at the base of the Kingsbury marks the contact between Eocene rocks and older formations. In the central and northern parts of the Powder River Basin where the Kingsbury is absent, Thom and Dobbin (1921) defined the base of the Wasatch formation as the top of the Roland coal bed or the equivalent horizon. The usage of Wegemann for Tertiary rocks in the southern part of the Powder River Basin and of Thom and Dobbin for Tertiary rocks in the central and northern parts has been followed by most subsequent writers.

Investigations in southwestern Wyoming, the results of which have been summarized by Nace (1936, p. 130–131) and Wood and others (1941, p. 35–36) have shown that rocks included in the Wasatch formation in the Powder River Basin may not be equivalent to any part of the Wasatch formation in southwestern Wyoming. These authors suggest that the name Wasatch be abandoned for northern Wyoming Eocene rocks as meaningless in reference to the type area of the Wasatch. Inasmuch as other names suggested have had only limited acceptance, however, the name Wasatch is retained in this report, following the usage of Wegemann.

The Wasatch formation crops out over most of the Buffalo-Lake

ALCOVA LIMESTONE MEMBER(?) OF CHUGWATER FORMATION (Ꞩa) AND ASSOCIATED ROCKS NEAR SOUTH END OF MOWRY BASIN, SEC. 7, T. 51 N., R. 83 W.

ꞨC is Chugwater formation, Jgs is Gypsum Spring formation, and Js is Sundance formation.

A. SILICIFIED TREE TRUNKS STANDING UPRIGHT IN SANDSTONE AND SHALE OF WASATCH FORMATION, NW¼ SEC. 31, T. 51 N., R. 80 W.

The tree behind the car is 18 feet long and 3 feet in diameter at its upper end.

B. PEDIMENT SURFACE AT MOWRY BASIN, N½ SEC. 25, T. 52 N., R. 84 W.

De Smet area. Near the mountains, an angular unconformity divides the formation into two lithologically distinct members. The lower of these is the Kingsbury conglomerate member, and the upper is the Moncrief member. Eastward from the mountains the two members grade laterally into a single nonconglomeratic sequence of sandstone, shale, and coal which could not be subdivided. This fine-grained sequence makes up the Wasatch formation east of Buffalo and Lake De Smet.

Kingsbury conglomerate member.—The Kingsbury conglomerate was named by Darton (1906a, p. 62) from exposures at Kingsbury Ridge in T. 49–50 N., R. 82 W. It was later considered a member of the Fort Union formation and finally a member of the Wasatch. The Kingsbury consists of lenticular beds of conglomerate as much as 20 feet thick interstratified with beds of light-gray and light greenish-gray shale and sandy shale. Subrounded pebbles, cobbles, and boulders of limestone and dolomite derived from Paleozoic and Mesozoic formations exposed in the Bighorn Mountains make up most of the larger rock fragments in the conglomerates. The largest boulders are about 4 feet in maximum dimension, but most are less than 1 foot. Pebbles of black and gray chert are common minor constituents, and a few pebbles of Precambrian crystalline rocks imbedded in coarse-grained sandstone occur locally in the upper part of the member. The conglomeratic beds of the Kingsbury are resistant to erosion and at most places hold up a line of high ridges.

The Kingsbury conglomerate member rests unconformably on the Fort Union and older formations with an angular discordance of about 45° near Sand Draw in sec. 30, T. 50 N., R. 82 W. Eastward from the mountains the angularity decreases rapidly as does the number and thickness of conglomeratic beds that make up the member. About 6 miles south of the Buffalo-Lake De Smet area and 8 miles east of the mountain front, the Kingsbury grades laterally into finer grained sediments, and the Wasatch formation overlies the Fort Union formation without observable angular discordance. Massive beds of conglomerate at the base of the Kingsbury conglomerate member overlie conglomerates in the Fort Union formation with a discordance of about 25° at Mowry Basin in the W½ sec. 33, T. 52 N., R. 83 W., whereas a mile to the northeast along Rock Creek the basal beds of the Wasatch formation, which here contain only a few stringers of conglomerate, rest on the Fort Union formation with little if any discordance in dip.

The Kingsbury grades upward into light-gray sandstone and light-brown and greenish-gray sandy shale. The top of the Kingsbury is placed at the top of the main conglomeratic mass, although thin lenticular beds of conglomerate are present locally through several hundred feet of overlying strata.

Darton (1906a, p. 61) estimated that the Kingsbury in the Buffalo-Lake De Smet region is as much as 2,500 feet thick. As mapped during the present investigation the Kingsbury is much thinner, ranging from an estimated 800 feet in the high ridge north of the North Fork of Rock Creek to less than 100 feet at Rock Creek in the NW¼ sec. 34, T. 52 N., R. 83 W. Its maximum thickness at Kingsbury Ridge probably is between 500 and 800 feet.

The Kingsbury probably is an alluvial-fan deposit formed locally in response to uplift in the central part of the Bighorn Mountains (Gale and Wegemann in 1910, p. 144).

The Kingsbury conglomerate member has yielded few fossils, and none has been found in the lower beds of the member. Its assignment to the Eocene, therefore, is based largely on its stratigraphic relation to underlying, equivalent, and overlying formations of known age. In 1948, R. W. Brown (p. 1165–1172) summarized the then existing paleontological and stratigraphic evidence regarding the age of the Kingsbury and presented additional evidence showing that its age is Eocene. A few fragile fresh-water mollusks collected in 1951 by R. K. Hose from conglomeratic beds on the east side of Kingsbury Ridge have been identified by T. C. Yen as *Pisidium* sp. undet., *Viviparus* sp. undet., *Hydrobia*? *eulimoides* Meek, *Goniobasis* cf. *G. tenera* (Hall), *Physa* cf. *P. longiuscula* Meek and Hayden, *Physa* sp. undet., *Macrocyclus* sp. undet., *Unio* sp. undet., and *Discus* cf. *D. ralstonensis* (Cockerell). Yen states that this collection contains a mixed fauna, some of the fossils being related to Paleocene species and some to early Eocene species, but that *Discus ralstonensis* (Cockerell) has been reported so far only from early Eocene beds.

Moncrief member.—The Moncrief member of the Wasatch formation consists of as much as 1,400 feet of poorly stratified conglomerate composed of boulders, cobbles, and pebbles of Precambrian igneous and metamorphic rocks interbedded with lenses of light-gray coarse-grained sandstone and greenish-gray siltstone. The deposits cap high spurs and ridges that extend eastward as much as 3 miles from the flank of the Bighorn Mountains and rise several hundred feet above the adjacent foothills and plains. The Moncrief is thickest and best exposed at Moncrief Ridge in the northwestern part of the Buffalo-Lake De Smet area and at North and Bald Ridges in the southwestern part.

The Moncrief member was named the Moncrief gravel by R. W. Sharp in 1948 from exposures at Moncrief Ridge. Previously, the deposits had been described as pre-Pleistocene or early Pleistocene glacial debris (Salisbury and Blackwelder, 1903, p. 221–223; Alden, 1932, p. 41–44), as late Tertiary or early Quaternary bench gravel (Darton, 1906a, p. 68–70), or as an early Tertiary conglomerate perhaps contemporaneous with some part of the coal-bearing phase of the Wasatch formation (Taft, 1909, p. 131; Demorest, 1938, p. 22–23). Sharp (1948) presented evidence to show that his Moncrief gravel is a near-source fanglomerate which grades eastward in the Powder River Basin into much finer grained rocks in the upper part of the coal-bearing facies of the Wasatch formation.

The larger rock fragments that make up conglomeratic beds in the Moncrief member consist mainly of granite and gneiss with lesser amounts of pegmatite, schist, hornfels, and diabase. Boulders 5 to 10 feet in maximum dimension are common in the upper beds of the deposit, and a few boulders are much larger. Sharp (p. 5–6) gives the following description of the deposit at Moncrief Ridge:

> Matrix in the gravel is predominately arkosic and usually sparse, particularly in the upper part where the boulder beds are coarsest, thickest, and most numerous. However, even here fines are not entirely lacking, for beds of arkose and fine micaceous sand outcrop in the midst of great boulder layers within 155 feet of the top of Moncrief Ridge * * *. The deposits become finer-grained downward and eastward, with an increase in the number and thickness of arkose and micaceous arkosic sandstone layers. Boulder beds become fewer and thinner and their constituents smaller in the same direction * * * and near the base cobbles and pebble beds are common.
>
> The finer materials contain crudely spherical arkosic concretions 1 to 2 feet in diameter, formed by local cementation. These are identical with concretions in the so-called "Wasatch" of this area. The micaceous sandstone contains small limonitic concretions. Cementation of the gravel is poor except locally where some arkosic layers are well cemented and weather out in large fragments or outcrop as ledges. The gravel is white to light gray and tan. Beds containing stones rich in ferromagnesian minerals are brownish, and micaceous sandy layers are colored grayish green by chloritized biotite. Bedding is nearly indistinguishable in the coarser phases of the deposit * * * and at best it is crude and irregular with many scour channels and some crossbedding in the fine layers.

A feature noted in most descriptions of the deposit is the deep weathering and disintegration of many of the boulders and cobbles. Sharp (p. 6) states that some boulders of granite as much as 5 feet in diameter are friable to the core.

Sharp (p. 1) defined the boundaries of his Moncrief gravel as follows: "The present topographic surface determines the top of the unit * * *; the lowermost and outmost gravel bed consisting primarily of pre-Cambrian rock debris * * * [determines the base]." For convenience in mapping, the Moncrief member as used in this report includes only the main conglomeratic mass; laterally equivalent strata that may contain thin beds of conglomerate but which are predominantly finer grained are disregarded.

Where the Moncrief member is closest to the mountain front, an angular unconformity separates the Moncrief from the underlying Kingsbury conglomerate member. North of Johnson Creek, in the NE¼ sec. 29, T. 51 N., R. 83 W., the Kingsbury dips about 60° E., whereas higher on the same slope the overlying Moncrief is nearly horizontal. Likewise, in the vicinity of Sand Draw, in the southwest corner of T. 50 N., R. 82 W., the Kingsbury dips from 25° to 42° E., whereas a few hundred yards to the north on Bald Ridge the Moncrief member and associated finer grained sandstone and sandy shale dip less than 3° E.

Sharp (p. 6) gives the thickness of his Moncrief gravel as at least 1,400 feet at Moncrief Ridge and 1,200 feet at Clear Creek. He suggests (p. 9) that the gravel was deposited on a surface of considerable local relief. At Bald Ridge the relief may have been 1,000 feet in less than 2 miles, inasmuch as the base of the nearly flat-lying Moncrief is at least 1,000 feet higher in the SW¼ sec. 11, T. 50 N., R. 83 W., than it is 1½ miles to the northeast in the SW¼ sec. 1 of the same township.

No fossils have been found in the conglomeratic beds of the Moncrief member, but vertebrate and plant remains have been found in finer grained beds with which the conglomerates interfinger. R. W. Brown (1948, p. 1170) recognized leaves of *Cercidiphyllum arcticum* (Heer) Brown, *Platanus* sp., *Aralia* sp., and pieces of coniferous wood from arkosic sandstone and green micaceous shale near the mouth of Clear Creek canyon, in the center of W½ sec. 6, T. 50 N., R. 82 W. He considered this collection to be of early Tertiary age. The remains of the Eocene vertebrates *Hyracotherium* (*Eohippus*) and *Coryphodon* were found by Brown (p. 1169) in the NW¼ sec. 27, T. 50 N., R. 82 W. in beds which can be traced laterally into the lower part of Bald Ridge.[1]

Coal-bearing beds.—The angularity of the discordance between the Kingsbury conglomerate member and the Moncrief member of the Wasatch formation diminishes rapidly eastward from the mountains and in a short distance both members pass laterally into a conformable sequence consisting of more than 1,000 feet of sandstone, shale, subbituminous coal, and lignite. These beds crop out in the central and eastern parts of the mapped area. The coal-bearing beds of the Wasatch formation as a whole are nonresistant and characteristically erode to rolling hills or badlands. Locally, however, coal beds that have burned underground have altered the overlying rocks to bright red clinker and this material, being resistant to erosion, caps many divides and buttes in the eastern part of the area. On bare slopes the prevailing color of the coal-bearing facies is light yellowish gray

[1] Location originally given by Brown as the NW¼ sec. 29, T. 50 N., R. 82 W., is here corrected.

with brown or gray bands marking the outcrop of coal or carbonaceous shale.

Partial section of the coal-bearing beds of the Wasatch formation east of Clear Creek in the S½ sec. 31, T. 53 N., R. 80 W.

	Ft	in	Ft	in
Clinker, red (horizon of the Walters coal bed); top of unit is summit of ridge			3	0
Shale and sandstone, interbedded; sandstone very light gray to grayish yellow, fine grained to silty, friable; shale gray; interval poorly exposed			66	0
Shale, dusky brown, carbonaceous			3	6
Concealed; probably sandstone and shale			35	0
Sandstone, very light gray, fine-grained, calcareous, crossbedded; interbedded greenish-gray siltstone near base			24	0
Concealed			15	0
Shale, light olive-yellow			12	0
Coal and carbonaceous shale (Healy bed) as follows:				
Coal		2		
Shale, brown, carbonaceous		1		
Coal	3	8		
Shale, brown, carbonaceous		2		
Coal	8	11		
Total			13	0
Sandstone and shale, interbedded; sandstone white, fine grained, friable; shale gray			31	0
Coal (Schuman bed)			2	7
Shale, light olive-gray, grading upward to dusky-brown carbonaceous shale in top 3 ft			18	6
Shale, dusky-brown carbonaceous				6
Coal (Timar bed?)			1	3
Shale, dusky-brown, carbonaceous			2	0
Sandstone and shale, interbedded; sandstone very light gray, fine grained, calcareous; shale olive gray; bed of gray, yellow-weathering sandy limestone concretions 8 ft. above base			28	0
Shale, dark-gray; contains a few shell fragments near base			12	0
Limestone, light-gray; weathers yellowish brown; composed largely of shells of fresh-water mollusks				4
Coal (Upper Cameron bed)			1	6
Shale, gray; upper 8 in. is dusky brown			19	0
Shale, dusky-brown, carbonaceous; contains a few ½-in. seams of coal			3	0
Shale, gray, slightly carbonaceous			5	6
Coal (Lower Cameron bed)			3	1
Concealed			20	0
Sandstone, light-gray, fine-grained; contains a few yellowish-gray limestone concretions			7	0
Concealed			24	0
Shale, dusky-brown, carbonaceous				6
Coal (Murray bed)			3	6
Shale, dusky-brown, carbonaceous			1	0
Sandstone, very light gray, fine-grained, friable; contains a few thin partings of gray shale			12	0

Partial section of the coal-bearing beds of the Wasatch formation east of Clear Creek in the S½ sec. 31, T. 53 N., R. 80 W.—Continued

	Ft	in
Shale, dusky-brown, carbonaceous	2	0
Coal	1	4
Shale, dusky-brown, carbonaceous		6
Shale, olive-gray, sandy near top	14	0
Coal, shaly	2	5
Shale and sandstone, interbedded; shale olive gray; sandstone very light gray, fine grained, friable, crossbedded	35	0
Shale, dusky-brown, carbonaceous; contains a few ½-in. seams of coal	3	6
Shale, olive-gray, sandy near base	8	0
Sandstone, very light gray, fine-grained, friable, crossbedded	10	0
Shale, dusky-brown, carbonaceous	2	0
Coal (upper bench of the Ucross bed)	2	8
Shale, dusky-brown, carbonaceous		6
Sandstone, light-gray to light yellowish-gray, very fine grained, friable; upper 3 to 4 ft. shaly	12	0
Coal (middle bench of the Ucross bed)	1	7
Shale, dusky-brown, carbonaceous	1	6
Sandstone, light yellowish-gray, very fine grained; contains many partings of gray shale	7	0
Shale, olive-gray; 1-in. seam of coal near top	1	6
Sandstone, very light gray, friable	5	0
Coal (lower bench of Ucross bed)		9
Shale, dusky-brown, carbonaceous	1	6
Concealed	24	0
Sandstone, gray to white, fine-grained, crossbedded, shaly near top	11	0
Shale, dusky-brown, carbonaceous	3	0
Shale, gray, silty; base of interval at creek level	3	0
Total measured thickness	521	6

Partial section of the coal-bearing beds of the Wasatch formation west of Crazy Woman Creek in the E½ sec. 24, T. 51 N., R. 80 W., and sec. 19, T. 51 N., R. 79 W.

	Ft	in	Ft	in
Clinker, red (horizon of the Walters bed); exposed at summit of butte			6	0
Sandstone and shale, interbedded; sandstone yellowish gray, friable; shale gray			33	0
Shale and siltstone, interbedded; light yellowish-gray, slightly carbonaceous			9	0
Sandstone, light-gray, fine-grained; contains closely spaced carbonaceous laminae			5	0
Shale and siltstone, interbedded; shale gray, siltstone pale yellowish gray; unit contains a few tabular calcareous siltstone concretions			20	6
Carbonaceous shale and coal as follows:				
Shale, brown carbonaceous	2	10		
Coal, shaly		10		
Shale, brown, carbonaceous		10		
Total			4	6

Partial section of the coal-bearing beds of the Wasatch formation west of Crazy Woman Creek in the E½ sec. 24, T. 51 N., R. 80 W., and sec. 19, T. 51 N., R. 79 W.—Continued

	Ft	in	Ft	in
Shale, light-gray			21	0
Sandstone, pale yellowish-gray, fine-grained; some interbedded gray shale			24	0
Shale, brown, carbonaceous, sandy; a few thin seams of coal			2	0
Sandstone, very light gray, fine-grained, crossbedded			6	0
Shale, brown, carbonaceous, sandy			3	0
Sandstone, very light gray, fine-grained, crossbedded			8	6
Section below offset ¼ mile to east:				
Coal and carbonaceous shale as follows (Healy bed):				
Shale, pale-brown, carbonaceous	1	2		
Coal	3	1½		
Shale, brown, carbonaceous		1		
Coal		10		
Shale, brown, carbonaceous		½		
Coal, contains a lenticular bed of carbonaceous siltstone as much as 10 in. thick 3 ft. above base	5	10		
Shale, brown, carbonaceous		1		
Shale, light-gray	4	11		
Shale, brown, carbonaceous		8		
Coal	3	5½		
Shale, brown, carbonaceous	2	10		
Coal	1	8½		
Shale, brown, carbonaceous		3		
Total			25	2
Shale, gray, slightly carbonaceous			2	6
Siltstone, pale-gray			3	6
Covered			9	0
Shale and siltstone, interbedded; shale brown, carbonaceous; siltstone light gray			2	6
Sandstone, light yellowish-gray, fine-grained, friable, numerous laminae of gray shale			14	0
Coal (Schuman bed)			1	0
Shale, brown, carbonaceous			13	0
Covered			9	0
Coal and carbonaceous shale as follows (Timar bed):				
Shale, brown, carbonaceous	2	0		
Coal	1	4		
Shale, brown, carbonaceous		4		
Coal, shaly		8		
Shale, brown, carbonaceous		3		
Coal		6		
Shale, brown, carbonaceous	1	0		
Coal	2	0		
Shale, brown, carbonaceous		2		
Total			8	3

Partial section of the coal-bearing beds of the Wasatch formation west of Crazy Woman Creek in the E½ sec. 24, T. 51 N., R. 80 W., and sec. 19, T. 51 N., R. 79 W.—Continued

	Ft	in	Ft	in
Section below offset ¼ mile to east:				
Covered			8	0
Shale, brown, carbonaceous			1	0
Shale, light-gray to grayish-green			2	0
Siltstone and silty shale, yellowish-gray			5	0
Shale, brown, carbonaceous				6
Shale, light-gray, slightly carbonaceous			1	6
Coal, shale, and sandstone as follows (Cameron beds):				
Shale, brown, carbonaceous		2		
Coal and silicified wood		10		
Shale, brown, carbonaceous	1	0		
Partly covered; mostly light-gray sandstone	9	0		
Coal	1	9		
Shale, brown, carbonaceous		9		
Covered	5	0		
Shale, brown, carbonaceous		9		
Coal, shaly		10		
Shale, brown, carbonaceous		8		
Total			20	9
Shale, gray			1	6
Sandstone, very light yellowish gray, fine-grained			7	6
Shale, brown, carbonaceous			4	6
Shale, yellowish-gray			6	0
Shale, brown, carbonaceous			8	0
Sandstone, very light gray, fine-grained			3	0
Shale, brown, carbonaceous			1	0
Coal			1	6
Shale, brown, carbonaceous				6
Mostly covered; in part very light yellowish gray sandstone; some brown carbonaceous shale			25	0
Sandstone, very light yellowish gray, very friable			15	0
Shale, pale-brown to brownish-gray			24	0
Sandstone, very light yellowish gray, fine-grained, crossbedded, friable			9	6
Coal and carbonaceous shale as follows:				
Coal	1	2		
Shale, brown, carbonaceous	1	6		
Coal		9		
Shale, light-gray and light-brown, carbonaceous	2	6		
Coal	1	7		
Shale, brown, carbonaceous		6		
Total			8	0
Sandstone, light yellowish-gray, friable			5	6

Partial section of the coal-bearing beds of the Wasatch formation west of Crazy Woman Creek in the E½ sec. 24, T. 51 N., R. 80 W., and sec. 19, T. 51 N., R. 79 W.—Continued

	Ft	in	Ft	in
Coal and shale as follows:				
Shale, brown, carbonaceous	3	6		
Coal		9		
Shale, light-gray	2	1½		
Coal		6		
Shale, light-gray	6	4		
Shale, brown, carbonaceous		6		
Coal		3½		
Shale, light-gray	1	0		
Total			15	0
Sandstone, light yellowish-gray, fine-grained, crossbedded, friable; a few partings of gray shale			9	0
Shale, light-gray				5
Shale, brown, carbonaceous; a few thin seams of coal			2	0
Siltstone, light-gray; a few calcareous siltstone concretions in lower part			5	0
Section below offset 500 ft east:				
Partly covered, in part light-gray sandstone and gray shale			20	0
Sandstone, yellowish-gray, fine-grained, friable			7	0
Shale, brown, carbonaceous			3	7
Coal (Ucross bed?)			2	5
Section below offset 500 ft east:				
Covered			22	6
Coal and shale as follows:	Ft	in		
Shale, brown, carbonaceous	4	0		
Coal		8		
Shale, brown, carbonaceous	1	3		
Coal		6		
Shale, brown, carbonaceous		1		
Total			6	6
Shale, light-gray			2	0
Covered			12	0
Sandstone, yellowish-gray, fine-grained to silty, crossbedded; contains a few partings of gray shale			19	0
Shale, light-gray, contains fresh-water pelecypods and gastropods			3	0
Limestone, orange, gypsiferous, contains the casts of fossil mollusks				4
Coal			1	8½
Shale, light-gray, silty			1	6
Sandstone, yellowish-gray, fine-grained, crossbedded, friable			21	6
Shale, greenish-gray, contains tabular calcareous siltstone concretions as much as 6 ft long			6	0
Covered			4	0
Sandstone, light-gray, fine-grained; exposed at creek level, Crazy Woman Creek			7	0
Total measured thickness			561	1

Sandstone makes up about 50 percent of the Wasatch formation in the eastern and central parts of the Buffalo-Lake De Smet area. Much of the sandstone is friable, medium- to fine-grained, and crossbedded. Most of the beds are lenticular and cannot be traced for any great distance. West of Buffalo and Lake De Smet, the beds of sandstone thicken, become coarser grained, and those in the upper part of the coal-bearing sequence, above the horizon of the Healy coal bed, become arkosic. Beds of shale which are interbedded with the sandstone in the eastern and central parts of the Buffalo-Lake De Smet area are dark to medium gray or brown; beds of shale and siltstone in the western part commonly are grayish green.

Most of the coal beds in the Wasatch formation crop out east of a line that passes through Buffalo and along the west shore of Lake De Smet. Coal beds that can be traced as far west as this line are thickest near the line; they thin irregularly eastward, but grade rather abruptly westward into brown carbonaceous shale or noncarbonaceous sediments.

Fragments of fossil plants and leaves are abundant in the brown and gray shales, and fresh-water mollusks occur locally in both the shale and sandstone. A ledge-forming bed of limestone, composed mainly of the fragments of fresh-water mollusks and ranging in thickness from less than 1 inch to about 1 foot, crops out near the middle of the coal-bearing sequence and underlies about 125 square miles in the northeastern part of the area. Fossils collected from this bed at various places were identified by J. B. Reeside and T. C. Yen as follows:

Mollusks collected from a bed of fossiliferous limestone that overlies the Upper Cameron coal bed

N½ sec. 2, T. 52 N., R. 81 W.; fossils identified by J. B. Reeside, Jr.:
- *Viviparus* cf. *V. raynoldsanus* (Meek and Hayden)
- *Gyraulus* sp.
- *Carinorbis* sp.
- *Sphaerium* cf. *S. formosum* (Meek and Hayden)

NE¼NW¼ sec. 20, T. 53 N., R. 80 W.; fossils identified by T. C. Yen:
- *Unio* cf. *U. priscus* Meek and Hayden
- *Sphaerium* cf. *S. formosum* Meek and Hayden
- *Pisidium* sp. undet.
- *Viviparus* sp. undet.
- *Valvata* sp. undet.
- *Hydrobia* cf. *H. recta* White
- *Pleurocera* cf. *P. warrenanum* (Meek and Hayden)
- *Palaeancylus* sp. undet.
- *Ferrissia* cf. *F. minuta* (Meek and Hayden)
- *Carinulorbis* sp. undet.

NW¼SW¼ sec. 35, T. 54 N., R. 81 W.; fossils identified by T. C. Yen:
- *Unio* sp. undet.
- *Viviparus* cf. *V. paludinaeformis* (Hall)

Fragments of silicified wood are common in the coal-bearing facies of the Wasatch formation. Silicified stumps with roots attached are numerous at the base of the thicker coal beds. A log 18 feet long and 3 feet in diameter that stands upright in a bed of shaly fine-grained sandstone in sec. 30, T. 51 N., R. 80 W., is shown by plate 7*A*. Smaller silicified stumps and logs litter the ground here and elsewhere in the eastern part of the mapped area.

A fragment from a jaw, identified by C. L. Gazin as that of the small condylarth *Hyopodus simplex*, and the incisors of several fossil rodents were found by R. K. Hose and the writer in sec. 5, T. 47 N., R. 80 W., about 12 miles south of the Buffalo-Lake De Smet area. These fossils came from beds about 90 feet above the Healy coal bed. Gazin (written communication, 1950) states that *Hyopodus simplex* "is characteristic of the lower horizons of the Gray Bull (lower Eocene)."

OLIGOCENE SERIES

WHITE RIVER FORMATION(?)

Beds of conglomerate tentatively assigned to the White River formation crop out in isolated patches on the high mountain uplands north of Clear Creek in the northwestern part of T. 50 N., R. 83 W., and also near the headwaters of Gronmund Creek in the southwestern part of the same township. A small deposit of similar rock rests on the Madison limestone and Amsden formation in secs. 27 and 34, T. 54 N., R. 85 W. The deposits consist of boulders, cobbles, and pebbles of Precambrian cystalline rocks embedded in a poorly stratified matrix of coarse-grained arkosic sandstone and brown sandy clay. At some places conglomeratic beds are interstratified with beds of crumbly light gray marl. The distribution of these deposits suggests that they are remnants of more extensive deposits that filled valleys and canyons of an old land surface.

F. W. Osterwald is reported by Love (1952, p. 5) to have found the fossil remains of *Mesohippus*, a horse characteristic of the White River formation, on the high slopes of the Bighorn Mountains about 10 miles north of the area here described. The fossil was found in beds of conglomerate and clay similar to those in the Buffalo-Lake De Smet area.

TERTIARY AND QUATERNARY SYSTEMS

TERRACE DEPOSITS

Terrace deposits of silt, sand, and gravel ranging in thickness from 10 to 30 or more feet occur along most of the main northeastward-flowing streams in the Buffalo-Lake De Smet area. Plate 8*A* shows the distribution and thickness of these deposits. The largest areas of terraces are along Clear and Rock Creeks in the vicinity of Buffalo, on the divide between Bull and Dry Creeks south of Buffalo, and on the divides near Piney and Little Piney Creeks in the vicinity of Kearney. The terrace gravels consist mostly of rounded to subrounded cobbles and pebbles of Precambrian igneous and metamorphic rocks with smaller amounts of limestone, dolomite, quartzite, and chert. Interbedded with the gravels are lenses of sand and silt. Fragments of clinker and petrified wood occur in the lower deposits. The larger rock fragments at most places are 4 inches or less in maximum dimension, although many deposits contain scattered boulders as much as 1 foot in diameter and terraces near the mountains contain a few boulders 3 feet or more in maximum dimension.

The deposits occur from 10 to 600 feet above the present streams. For convenience in distinguishing among high, intermediate, and low deposits, the terraces are grouped, according to their height above the present streams, into 4 main levels or groups of levels. Terraces adjacent to the mountains have a pronounced basinward gradient which is greatest on the lower levels. Upslope, the levels tend to merge (see plate 8*B*).

The table below shows the relative elevations of terraces in the Buffalo-Lake De Smet area and compares the nomenclature of terrace levels used in this report with that used by Alden (1932) for features along the east flank of the Bighorn Mountains.

Terrace levels		Height above present streams, in feet
Alden (1932)	This report	
Tt^1	Tt	450–600
Qt^2	Qt_3	300–350
	Qt_{3-}	230–275
Qt^3	Qt_{2+}	170–220
	Qt_2	130–160
Qal	Qu { Qt_1	10–25
	Qu { Qal	0–10

QUATERNARY SYSTEM

PEDIMENT DEPOSITS

Thin deposits of silt, sand, and gravel cover several broad pediment surfaces along the east flank of the Bighorn Mountains at the base of the steep mountain slopes. The coarser fragments making up these deposits are subangular to subrounded pebbles and cobbles of limestone, sandstone, and chert derived from formations exposed along the mountain front. At most places, the deposits are less than 6 feet thick. They rest on surfaces that merge at their mountainward end against steep dip slopes of the Tensleep sandstone (pl. 7*B*). The gradient decreases away from the mountains, and the deposits merge basinward with stream terrace deposits at the level of Qt_2.

LANDSLIDE MATERIAL

A landslide about 1 mile long and one-half mile wide in sec. 33, T. 54 N., R. 84 W., contains several huge blocks of Madison limestone and Bighorn dolomite broken from the north end of the Piney Creek fault block. The mass, lubricated by plastic shale of the Gros Ventre and Gallatin formations, has moved several hundred feet downslope over the Moncrief member of the Wasatch formation.

Another large slide is located near the southern end of the Piney Creek fault block in sec. 7, T. 52 N., R. 83 W., and sec. 12, T. 52 N. R. 84 W. The landslide is composed of a heterogeneous mass of Madison limestone, Bighorn dolomite, and rock fragments derived from the Kingsbury conglomerate member of the Wasatch.

Two oval-shaped masses in sec. 17 and in the N½ sec. 20, T. 51 N., R. 83 W., are composed of large jumbled blocks of Bighorn dolomite surrounded by limestone and shale of the undifferentiated Gros Ventre and Gallatin formations (pl. 9*A*). These materials crop out near the crest of a high ridge formed by the Kingsbury conglomerate member of the Wasatch formation. Darton (1906a, p. 92–93) described these masses as fault blocks, but such faulting as was observed nearby accounts neither for the present position of the displaced material, nor for the chaotic stratigraphic relations observed within the blocks themselves. A simpler explanation is that these masses are the remnants of a landslide largely removed by erosion so that only the most resistant constituents remain on the Kingsbury and older rocks.

A large area of coalescing landslide material covers nearly half of sec. 6, T. 52 N., R. 83 W., and parts of adjoining sections in the township to the north. The slumped material is from the Moncrief member of the Wasatch formation. There are many smaller areas of landslide material where steep slopes are underlain by the fine-grained facies of the Moncrief member of the Wasatch formation.

COLLUVIUM

Colluvium is shown on the geologic map (pl. 1) where heterogeneous aggregates of rock detritus that resulted from the transporting action of gravity are so thick that they obscure the underlying bedrock. Although the term properly includes landslide material, landslides generally could be distinguished from other types of colluvium and were mapped separately.

The largest accumulations of colluvium are near the northern and southern edges of the Piney Creek fault in the northwestern part of

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the Buffalo-Lake De Smet area where thick deposits of slope wash and talus from the granite cliffs of the fault block cover areas of a square mile or more. An accumulation of colluvium also covers an irregularly shaped area of about three-fourths square mile in sec. 17, T. 51 N., R. 83 W., and parts of adjoining sections to the north and west. This deposit includes a large proportion of granitic debris which ranges in size from sand to boulders as much as 4 feet across and which came from cliffs a short distance to the west.

ALLUVIUM

Narrow bands of Recent alluvium border most of the permanent and many of the intermittent streams in the mapped area. The deposits consist of silt and sand interspersed with lenses of gravel. Along Piney, Shell, and Clear Creeks, alluvium and gravel deposits on terraces from 10 to 15 feet above the present streams were mapped as alluvium and terrace deposits, undifferentiated.

STRUCTURE

The Lake De Smet area includes parts of two major structural features of northern Wyoming. These are the Bighorn Mountain uplift on the west and the bordering Powder River Basin on the east.

The Bighorn Mountains are the eroded remnant of a great anticlinal uplift that extends from south-central Montana southeastward across north-central Wyoming for a distance of about 140 miles. The range is structurally and topographically highest in its central part near the latitude of Buffalo and Lake De Smet.

The east flank of the range is also the west flank of the Powder River Basin, a broad synclinal depression that occupies much of northeastern Wyoming and part of southeastern Montana. The basin is asymmetrical with its deepest part near the mountain uplift. At the latitude of Buffalo and Lake De Smet, the axis of the basin is almost parallel to the trend of the mountains, and at depth it probably extends across the Buffalo-Lake De Smet area on a line, at most places 10 miles or less east of the Bighorn Mountain front, from the northeastern corner of T. 83 W., R. 53 N., through Buffalo (Pierce and others, 1951).

Mesozoic and Paleozoic rocks near the mountain front are bent sharply upward in a narrow belt parallel to the range. The intense folding in this belt is accompanied by reverse faulting which locally brings Paleozoic rocks over Tertiary formations. The Tertiary rocks overlap the deformed older formations near the mountains and are themselves folded, although much less severely. The Tertiary rocks extend into the plains of the Powder River Basin with decreasing eastward dips that become nearly horizontal east of Buffalo and Lake

De Smet. The maximum structural relief in the Buffalo-Lake De Smet area cannot be determined because an unknown thickness of rock has been stripped by erosion from the Precambrian core of the Bighorn Mountains; however, Paleozoic rocks exposed on the flanks of the range are at least 15,000 feet higher in elevation than the equivalent beds in the trough of the Powder River Basin, and the total structural relief may be much greater.

The structural relations of the area are shown by the sections, plate 10.

STRUCTURAL FEATURES OF THE MOUNTAIN FRONT

FOLDS

Folding in Mesozoic and Paleozoic rocks along the mountain front is shown on the geologic map, plate 1, by structure contours drawn at 1,000-foot intervals on the top of the Madison limestone. On the higher parts of the mountains, the rocks dip toward the basin at angles as low as 20°. The dips increase at the base of the mountains and at places Mesozoic rocks in the foothills are vertical or overturned to the west. Within 3 to 4 miles of the mountains the dips flatten to 45° or less. A southeastward-plunging anticline and accompanying syncline interrupt this simple monoclinal flexure on the higher slopes of the range north of Little Goose Creek. The two folds may be traced for about 2 miles. Their axial trend is about N. 60° W., not quite parallel to the mountain front. The Amsden formation and Madison limestone are the surface rocks exposed by the folds.

FAULTS

Faults that cut the steeply folded rocks along the mountain front are mostly high-angle reverse faults, or tear faults with almost vertical dips. The dominant direction is northeastward with trends ranging from about N. 45° E. to N. 20° E. Other faults parallel the mountain front with a trend averaging about N. 30° W. Many of the faults have curving traces and a fault with a northeast trend may pass into one with a northwest trend in a short distance.

The faulting has resulted in the displacement of large segments of the mountain front to the east. The northernmost displaced segment is referred to as the Piney Creek segment, and the southernmost is referred to as the Sayles Creek-Bald Ridge segment. Relatively unfaulted parts of the mountain front alternate with these faulted segments north of Moncrief Ridge, at Mowry Basin, and south of Bald Ridge.

Piney Creek segment.—The Piney Creek segment extends from Moncrief Ridge southward for about 9 miles to the headwaters of

Shell Creek. It is made up of Precambrian igneous and metamorphic rocks bordered on the east by a band of younger sedimentary rocks that locally includes all formations from the Flathead sandstone to the Chugwater formation. The sedimentary rocks dip eastward with about the same steepness as the equivalent rocks exposed along the adjacent unfaulted parts of the mountain front.

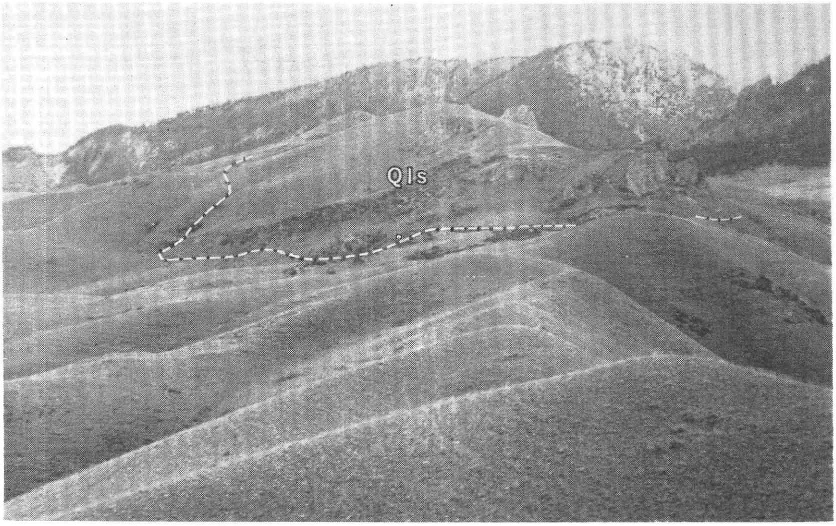
The Piney Creek segment is bounded on the north and south by northeastward-trending high-angle faults which displace outcrops of sedimentary rocks on the faulted block about 3 miles eastward. The trace of the fault at the northern end of the Piney Creek segment could not be followed with any certainty where it passes southwestward into the Precambrian core of the Bighorn Mountains, although Demorest (1941, p. 173) suggests that this fault extends across the range as a major structural feature. The fault at the southern end of the Piney Creek segment branches in sec. 18, T. 52 N., R. 83 W., and a second high-angle fault with a more southerly trend may be followed for some distance in Precambrian rocks.

The faults at both the northern and southern ends of the Piney Creek segment are connected by a northwestward-trending high-angle fault that bounds the segment on its eastern or basinward side. At many places, this fault brings the Madison limestone against the Moncrief member of the Wasatch formation. Talus everywhere conceals the fault surface, but its dip at various places may be determined from the configuration of the fault trace as it is mapped across valleys and ridges. North of South Piney Creek the fault surface is nearly vertical; between South Piney and J. A. Creek it dips at a high angle towards the plains; and south of J. A. Creek it is again nearly vertical. At depth the fault surface may curve westward beneath the faulted block.

Faults of as much as 50 feet displacement cut the Bighorn dolomite at several places within the Piney Creek segment, but none of these faults could be followed for more than a few tens of feet in the adjacent rocks.

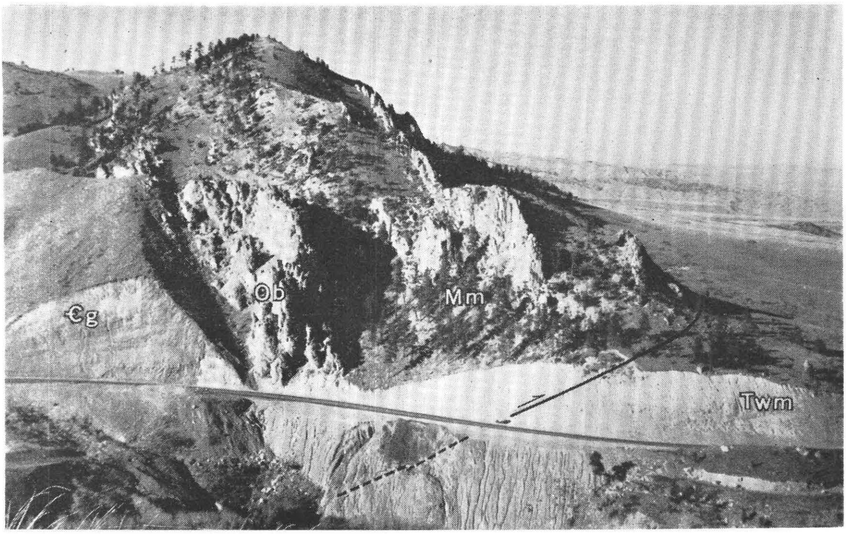
Sayles Creek-Bald Ridge segment.—The Sayles Creek-Bald Ridge segment includes an area of rather complexly faulted Paleozoic and Precambrian rocks that extends along the mountain front from the North Fork of Sayles Creek southward for about 7 miles to Bald Ridge. As with the Piney Creek segment to the north, Paleozoic and Precambrian rocks in Sayles Creek-Bald Ridge segment are displaced eastward relative to the equivalent rocks exposed to the north and south.

At the northern end of the Sayles Creek-Bald Ridge segment, a large block of Precambrian granite is bounded on the north, east, and south by an arcuate fault that brings the granite against all formations



A. LANDSLIDE IN SEC. 17, T. 51 N., R. 83 W.

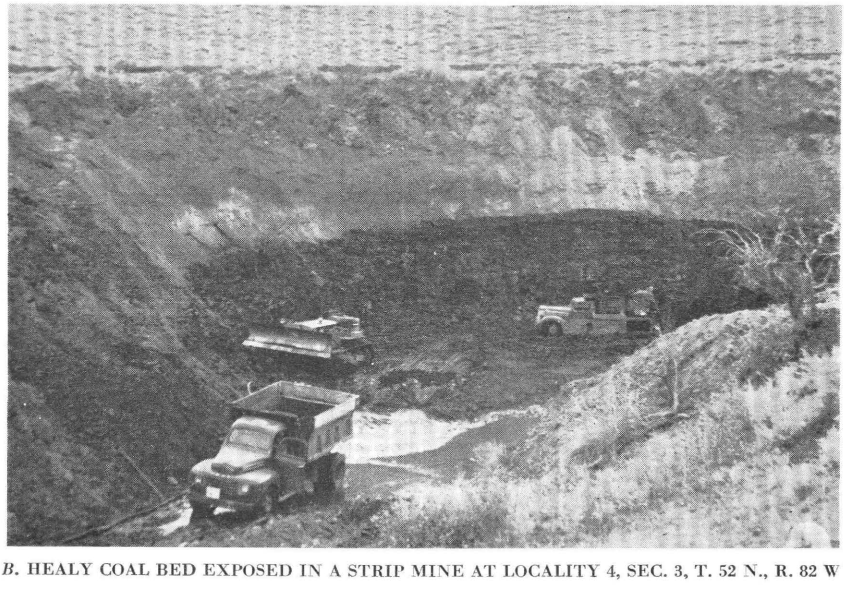
Huge blocks projecting from the near end of landslide mass (Qls) are Bighorn dolomite. Dotted line indicates approximate base of slide.



B. THRUST FAULT EXPOSED IN ROAD CUT ON U. S. HIGHWAY 16, SE½ SEC. 4, T. 50 N., R. 83 W.

Line shows position of fault trace. Vertically dipping beds of Gros Ventre and Gallatin formations, undifferentiated (Cg), Bighorn dolomite (Ob), and Madison limestone (Mm) are thrust eastward over Moncrief member of Wasatch formation (Twm).

A. UPPER CAMERON COAL BED AND OVERLYING FOSSILIFEROUS LIMESTONE AT LOCALITY 138, SEC. 25, R. 53 N., R. 80 W.



B. HEALY COAL BED EXPOSED IN A STRIP MINE AT LOCALITY 4, SEC. 3, T. 52 N., R. 82 W in turn from the Flathead sandstone to the Tensleep sandstone. North of the main fault, a branching fault with a trend of about N. 45° W. and an unknown displacement cuts out part or all of the Flathead sandstone for a distance of about 1½ miles.

A northward-trending high-angle reverse fault brings Paleozoic and Mesozoic rocks on the west against the Kingsbury conglomerate member and Moncrief member of the Wasatch formation on the east for a distance of about 2 miles between the South Fork of Sayles Creek and Johnson Creek. The trace of this fault was lost beneath colluvium in sec. 17, T. 51 N., R. 83 W. In the adjoining sections to the north, however, the Cody shale is thinned more than 1,000 feet suggesting that the fault may continue northward with diminishing displacement as one or more bedding-plane faults in the Cody shale. Traced southward, this fault cuts across outcrops of the Madison limestone and older rocks along the mountain front. At Johnson Creek the outcrop of the Bighorn dolomite is offset as much as 1,000 feet to the north on the west side of the fault, but the displacement diminishes southward and the fault appears to die out as it reaches the base of the Flathead sandstone.

A fault trending about N. 20° W., upthrown on the west, extends from Johnson Creek southward for about 3½ miles to Clear Creek. This fault brings the Amsden formation, the Madison limestone, or the Bighorn dolomite on the west side against the Moncrief or Kingsbury conglomerate members of the Wasatch formation on the east. The fault surface dips about 25° to the west in a road cut along U. S. Highway 16 where vertically dipping beds of the Madison limestone are thrust over nearly horizontal beds of the Moncrief member of the Wasatch formation (pl. 9*B*).

South of Clear Creek a block of Paleozoic and Precambrian rocks at the south end of the Sayles Creek-Bald Ridge segment is offset several hundred feet to the east along a high-angle fault that curves around the northern, eastern, and southern sides of the displaced block. Along part of this fault, the Amsden formation or the Madison limestone is in contact with the Moncrief member of the Wasatch formation.

Lines drawn between outcrops of unfaulted Paleozoic formations at Mowry Basin and the same formations south of Bald Ridge very nearly coincide with outcrops of these rocks on the intervening fault blocks of the Sayles Creek-Bald Ridge segment, indicating that the eastern component of displacement along reverse faults between Sayles Creek and Bald Ridge is probably less than one-quarter mile at most places.

Faults at Mowry Basin.—Paleozoic and Mesozoic rocks exposed at Mowry Basin are cut by high-angle faults at several places. The largest of these faults, with a maximum apparent horizontal displacement of about 1,000 feet, trends about N. 45° E., almost normal to the strike of the beds, for about 1 mile in secs. 23, 24, and 26, T. 52 N., R. 84 W. The fault trace turns abruptly northward in the SW¼ sec. 24 and the fault dies out in the lower member of the Mowry shale.

A northward-trending reverse fault at least 1 mile long in secs. 29 and 32, T. 52 N., R. 83 W., cuts the Parkman sandstone and Bearpaw shale displacing their outcrops about 800 feet northeastward on the west side of the fault. The fault trace could not be followed northeastward in the Lance formation nor southward in the Cody shale.

Near the center of sec. 25, T. 52 N., R. 84 W., the Sundance formation on the west is in contact with the Mowry shale on the east along a reverse fault about three-quarters of a mile long which trends northwestward parallel to the strike of the beds.

STRUCTURAL FEATURES OF THE PLAINS

FOLDS

Beds of coal in the Wasatch formation were used as key horizons in drawing the structure contour map for the central and eastern parts of the Buffalo-Lake De Smet area (pl. 1). Persistent coal beds are absent in a belt about 6 miles wide adjacent to the mountains, however, and as no other reliable key horizons could be found in the Wasatch formation, contour lines are omitted in this area. The dip of the Wasatch formation in this belt is to the east. The observed dips, less than 5° north of Shell Creek, become somewhat steeper between Shell Creek and French Creek near the high ridges underlain by the Kingsbury conglomerate member. The strata south of French Creek are more nearly horizontal with dips mostly less than 2° east, although locally the Kingsbury conglomerate member of the Wasatch formation dips 20° or more to the east, with beds nearest the mountains having the steepest dips.

Gentle undulating folds in the Wasatch formation east of Buffalo and Lake De Smet are shown on plate 1 by contour lines drawn at intervals of 50 feet on the base of the Healy coal bed. The strata have a low regional dip to the east or northeast. The maximum structural relief in this area is about 200 feet with the structurally highest points near a line trending about N. 30° W. through Buffalo and Lake De Smet and the structurally lowest points along the northern boundary of T. 53 N., Rs. 80 and 81 W.

A series of gentle folds that trend about N. 30° W. lies in the central part of the area, and another group of low anticlines and synclines that trend about N. 60° E. crosses the southeastern part at right angles to the first group. A structural high in the south-central part of

T. 53 N., R. 80 W. has a closure of about 100 feet. The maximum surface closure on the remaining folds is less than 50 feet.

FAULTS

The nearly flat-lying Wasatch formation east of the mountains is relatively undisturbed by faulting. A northeastward-trending normal fault was observed in the south-central part of T. 50 N., R. 80 W. This fault extends for about 1 mile, and has a maximum displacement of about 50 feet, downdropped on the north.

The correlation of coal beds found in holes drilled near the north end of Lake De Smet suggests that a high-angle fault underlies terrace gravels at the northern end of the lake and extends an unknown distance northwestward beneath terrace gravels and alluvium of Piney Creek. Strata west of the fault appear to be dropped from 30 to 150 feet relative to those on the east.

PERIODS OF DEFORMATION

All the strata of the Buffalo-Lake De Smet area, from those of Middle Cambrian age up to and including those of Cretaceous age, are essentially concordant in dip. Unconformities are present within this sequence and some of them represent considerable intervals of erosion or nondeposition, but pre-Tertiary folding, if any, was very gentle. Demorest (1941, p. 174) reported that "basal Chugwater conglomerates found at various places along the eastern front of the mountains contain pebbles derived from Cambrian rocks." This led him to believe that an ancestral range was uplifted and deeply eroded in late Paleozoic or early Mesozoic time probably at the site of the present mountains. No such conglomerates were found during the present investigation.

The earliest clear record of the rise of the Bighorn Mountains is in the local but sharp discordance in dip between the lower and upper members of the Fort Union formation at Mowry Basin. Fragments of Paleozoic rocks in conglomerates that lie above this unconformity indicate deep erosion of nearby areas to the west. The age of this conglomerate is not positively known, but presumably it is late Paleocene. At least three subsequent episodes of deformation are indicated by the structural relations of rocks younger than the Fort Union formation. These episodes have been summarized by Sharp (1948, p. 14) as (1) an uplift which produced the Kingsbury conglomerate member of the Wasatch formation, (2) a second uplift which deformed the Kingsbury and produced the gravel of the Moncrief member of the Wasatch, and (3) a period of thrust faulting toward the east during which Paleozoic rocks were thrust over the Moncrief. Presumably these movements were completed during Eocene time.

Since then the rocks exposed on the east flank of the mountains and west edge of the Powder River Basin probably have maintained their present relative positions.

MINERAL DEPOSITS

COAL

DISTRIBUTION AND CORRELATION

Commercially important deposits of coal occur in the Wasatch formation in the central and eastern parts of the Buffalo-Lake De Smet area. Nine main coal beds and several local beds were mapped and their thicknesses measured at about 1,000 localities (pl. 1). The coal-bearing strata are almost flat lying and their outcrops follow closely the contours of the land surface. The youngest bed crops out on high points along the divide between Piney and Boxelder Creeks east of Lake De Smet, and on the high divide north of Piney Creek in the north-central part of the mapped area; the oldest bed is near the level of Clear Creek in the northeastern corner of the area.

Plate 11 shows the stratigraphic relationships of the coal beds in various parts of the area and the variations from place to place of the intervals between beds. Average stratigraphic intervals between the principal coal beds and the range in thickness of the beds is given below.

Generalized section of the principal coal beds in the Buffalo-Lake De Smet area, Wyoming

[Intervals given are from the base of the lower bed to the base of the next higher bed]

Bed	*Thickness (in feet)*
Monument Peak (10 to 20 ft)	
Interval	150–175
Walters (20 to 35 ft)	
Interval	165
Healy (5 to 25 ft thick at outcrop; bed tentatively correlated with Healy reported as much as 220 ft thick in drill holes)	
Interval	25
Schuman (1 to 9 ft)	
Interval	35
Timar (1 to 4 ft)	
Interval	35
Cameron beds (1 to 5 ft; commonly two or more beds present in stratigraphic interval of 10 to 35 ft)	
Interval	60
Dry Creek (1 to 8 ft)	
Interval	35
Murray (1 to 7 ft)	
Interval	90–110
Ucross (1 to 15 ft)	

Stone and Lupton (1910, p. 127) correlate the Healy bed with the lower Ulm bed of the Sheridan coal field to the north. None of the other coal beds in the Buffalo-Lake De Smet area can be positively correlated with coal beds described elsewhere in the Powder River Basin; however, on the basis of stratigraphic intervals between coal beds (Taft, 1909, for the Sheridan coal field; Wegemann, 1913, for the Barber coal field; Olive, 1957, for the Spotted Horse coal field), it seems evident that the lowest coal exposed in the Buffalo-Lake De Smet area is about 400 feet stratigraphically above the Fort Union-Wasatch contact in the Spotted Horse coal field to the northeast, and about 700 feet above the Fort Union-Wasatch contact in the Sheridan coal field to the north.

A general description of the principal coal beds in the Buffalo-Lake De Smet area follows.

Monument Peak bed.—The Monument Peak bed crops out on the sides of high peaks in the north-central part of the area, principally in the southeastern part of T. 53 N., R. 82 W., near the top of Monument Peak, from which it is named, and on the highest parts of the divide north of Piney Creek in the same township. It may be represented also by beds of clinker on the divide between Boxelder and Clear Creeks in T. 52 N., R. 81 W. The Monument Peak bed contains 19 feet 6 inches of coal, exclusive of several thin partings of shale, in the SW¼ sec. 26, T. 53 N., R. 82 W (loc. 22). It is reported by Gale and Wegemann (1910, pl. 9) to contain about 16 feet of coal near an abandoned mine about one-half mile to the southwest.

Walters bed.—The Walters bed, named by Gale and Wegemann (1910, p. 153), has burned extensively in the Buffalo-Lake De Smet area and is represented at most places by thick clinker which caps high, even-topped divides and buttes. Where unburned, the Walters bed is from 20 to 35 feet thick and includes many thin partings of shale. Unburned areas are small and coal in the Walters bed constitutes an unimportant part of the total coal reserves.

Healy bed.—The Healy bed, named by Gale and Wegemann (1910, p. 153), is widespread in the Buffalo-Lake De Smet area; it contains almost half of the total estimated reserves of coal. Like the Walters bed, the Healy bed is extensively burned. Its outcrop commonly is marked by a band of clinker near the base of steep-sided ridges and divides. The Healy bed at most places is more than 10 feet thick, and at many places is more than 15 feet thick. At locality 44 in T. 51 N., R. 80 W., the bed is 29 feet thick including 1 shale parting 6 feet 7 inches thick and 3 minor partings 1 to 7 inches thick. It contains at least 29 feet 6 inches of coal without partings in the Kreselok mine in sec. 2, T. 53 N., R. 82 W. Partings in the Healy bed increase in thickness at the expense of the coal in the extreme east-central and southeastern parts of the Buffalo-Lake De Smet area. Locally in T. 50 N., R. 80 W., the bed is represented by a zone 10 to 20 feet thick of carbonaceous shale which contains no coal.

Cores and logs from test holes drilled near Lake De Smet indicate that the Healy coal bed thickens westward near the lake. Graphic logs of these holes are shown on plates 12 and 13. Core hole GS–2A, drilled on the eastern side of the lake in sec. 8, T. 52 N., R. 82 W., penetrated 53 feet of coal, including thin partings of shale, in the Healy bed. Hole A–1, drilled in sec. 31 of the township to the north, penetrated 46 feet of coal and thin partings of shale. Near the south end of Lake De Smet the Healy bed is 27 feet thick in seismograph shothole 65, drilled in the SE¼ sec. 23, T. 52 N., R. 82 W., but the bed increases in thickness to 112 feet, including shale partings, in hole 305 one mile to the west. Within a few hundred feet west of hole 305, coal in the thick Healy bed grades rapidly into sandstone and shale so that only thin stringers of coal occur in the sequence equivalent to the Healy bed on the low hills south and west of Lake De Smet.

Healy(?) coal bed.—A thick coal bed found in core holes drilled northwest of Lake De Smet is correlated tentatively with the Healy bed and is referred to as the Healy(?) bed. It underlies an area at least 1 mile wide and 2½ miles long in the northeastern part of T. 52 N., R. 83 W., and adjoining parts of the townships to the north and east. The coal bed may average more than 100 feet thick under this area. It is bounded on the east by the fault that passes under the north end of the lake; the extent of the coal to the north and west is unknown, and data from drill hole D are inconclusive in establishing the southwestern margin of the thick coal. The fence diagram, plate 14, shows the thickness and extent of the Healy and Healy(?) coal beds in the area explored by drilling.

The correlation of this bed with the Healy coal bed is based on two lines of evidence. First, the Healy bed thickens westward at an average rate of 85 feet per mile between drill holes 65 and 305 so a thick accumulation of Healy coal west of the fault at the north end of Lake De Smet is in keeping with the known trends of thickness changes in the Healy bed. Second, the stratigraphic interval between the base of the thick coal bed and the base of a prominent zone of coal and carbonaceous shale considered to be the Walters bed is fairly close to the interval between the Healy bed and overlying Walters bed where they are exposed east of Lake De Smet. The interval is 265 feet in hole GS–6, compared to 225 feet in outcrops along the east shore of the lake.

Five core holes, GS–1, 7, 200, GS–3, and A–6, located between U. S. Highway 87 and Lake De Smet, penetrated 56 to 134 feet of coal, including thin partings of shale, in the Healy(?) bed. Clinker or terrace gravel overlies the coal at all five locations; thus an additional unknown thickness of coal at the top of the bed has been destroyed by burning or erosion. The total thickness of the Healy(?) bed is 115 feet in hole GS–6 (NW¼ sec. 1, T. 52 N., R. 83 W.) where both the top and bottom of the bed were drilled.

The logs of four holes which J. E. Rice drilled west of U. S. Highway 87 near Shell Creek in 1950 are shown graphically on plate 12. Hole C penetrated 223 feet of coal, and hole F, 162 feet of coal. The remaining two holes, D and E, penetrated coal, but probably neither reached the base of the Healy(?) coal bed. As no cores were taken from these holes, and the logs were made by observation of the cuttings and of drilling characteristics, partings of shale, if present, may not have been noticed.

The base of the burned coal bed mapped along the west shore of Lake De Smet as the Healy(?) bed appears to be stratigraphically much higher than the base of the thick coal found in drill holes C, 200, and D. No thick coal beds crop out south of hole D, however, where the strata dip gently eastward, and a considerable thickness of rock at the horizon of the Healy(?) can be examined at the surface. It is believed that within a mile of hole D the lower part of the Healy(?) bed interfingers laterally with shale and sandstone containing only thin stringers of coal, and that the bed of clinker that crops out along the west shore of the lake south of hole D was produced by a tongue of coal equivalent only to the upper part of the thick Healy(?) bed.

A water well drilled in 1944 on the Carl Hepp property about 3 miles northwest of Lake De Smet penetrated 224 feet of coal and brown shale beneath 43 feet of overburden. The altitude of the base of this coaly sequence corresponds closely to that of the thick coal found in holes to the south.

Schuman bed.—The Schuman bed is named from the cattle camp operated by the Schuman ranch in the S½ sec. 15, T. 52 N., R. 80 W. It is an important coal bed in the northeastern part of the Buffalo-Lake De Smet area; it underlies much of the divide between Clear and Dry Creeks and a part of the divide between Clear and Boxelder Creeks. At these divides the bed commonly ranges in thickness from 3 to 4 feet, reaching a maximum observed thickness of 9 feet 1 inch, including a 5-inch parting of shale near the base, at locality 33 in T. 52 N., R. 80 W. The Schuman bed thins southwestward and westward and grades into a bed of carbonaceous shale which at only a few places contains more than 1 foot of coal.

Timar bed.—The Timar bed crops out about 50 to 60 feet below the Healy bed along both sides of Dry Creek in the central and southeastern parts of T. 51 N., R. 80 W., and on the sides of the divide between Dry and Crazy Woman Creeks in T. 50 N., R. 80 W. It is named for its occurrence in the southeastern part of T. 51 N., R. 80 W., about 4 miles east of the Timar ranch. The Timar bed commonly ranges in thickness from 2 to 4 feet, but at some localities it is thicker, and in the northeastern part of T. 50 N., R. 80 W., it contains as much as 8 feet of coal in two benches separated by 3 to 4½ feet of shale.

Cameron beds.—The Cameron coal beds crop out in a zone 90 to 130 feet stratigraphically below the Healy bed in the valleys of Piney, Boxelder, and Clear Creeks, and beds of coal at about the same stratigraphic position crop out in the southeastern part of the area along the valleys of Dry and Crazy Woman Creeks. The uppermost coal bed in the zone is referred to as the Upper Cameron bed. It crops out in the northern and central parts of the mapped area and may be identified at most places by a ledge-forming bed of fossiliferous limestone as much as 1 foot thick that rests on, or a few inches above, the coal (pl. 15*A*). The Upper Cameron bed is 4 feet or more thick at several places along Piney and Boxelder Creeks in T. 53 N., Rs. 81 and 82 W., reaching a maximum observed thickness of 7 feet 5 inches (not including a shale parting 1 foot 2 inches thick) at locality 16 in T. 53 N., R. 82 W. The bed contains 5 feet 5 inches of clean coal near the mouth of Cameron Gulch in the same township (locality 7, sec. 12). The Cameron beds are named from this exposure. Seismograph shotholes 62 and 64 in the valley of Boxelder Creek northeast of the Jack Moore Reservoir reportedly found from 9 to 12 feet of coal at about the horizon of the Upper Cameron bed. The bed thins southeastward; where it crops out in the eastern part of the Buffalo-Lake De Smet area, it generally contains less than 3 feet of coal.

One or more lenticular beds of coal occur from 3 to 35 feet below the Upper Cameron bed in many parts of the area. These beds are collectively called the Lower Cameron bed, although the coal probably occurs as discontinuous lenses at several stratigraphic levels. The Lower Cameron bed is thickest northeast of Buffalo in the valley of Clear Creek where it has been mined at several places. It is 13 feet 9 inches thick, including minor partings of shale, in the Clear Creek Coal Company mine in the SE¼ sec. 20, T. 51 N., R. 81 W. and is reported to have about the same thickness in seismograph shot holes drilled in secs. 18 and 19 of the same township. The Lower Cameron bed probably was worked at the now abandoned Munkre and Mitchell mines in the southeastern part of T. 51 N., R. 82 W., where, according to Gale and Wegemann (1910, pl. 10), it is as much as 19 feet thick, including partings of shale and bone. Elsewhere in the mapped area, the Lower Cameron bed generally is less than 3½ feet thick.

Dry Creek bed.—The Dry Creek bed was named by Gale and Wegemann (1910, p. 153) from exposures along the banks of Dry

Creek in the southwestern part of T. 51 N., R. 80 W. At locality 121 in sec. 32 it crops out 165 feet below the Healy bed; it is 9 feet thick there and includes two 1-inch shale partings. A coal bed at this stratigraphic position in the southeastern corner of T. 50 N., R. 80 W. contains as much as 3½ feet of coal. Elsewhere, the Dry Creek bed apparently is represented by a bed of carbonaceous shale which only locally contains more than 2 feet of coal.

Murray bed.—The Murray bed is named from its occurrence at the mouth of Murray Draw in T. 52 N., R. 81 W. (locality 88). The bed is 180 to 200 feet below the Healy bed and is exposed along Clear and Piney Creeks, in the north-central part of the mapped area, and along Double Cross Draw in the northeastern part. Shale partings in the Murray bed increase in thickness near the head of Double Cross Draw drainage area, and the coal appears to grade into carbonaceous shale southward in the valleys of Dry Creek and its tributaries.

The thickness of coal in the Murray bed generally varies from 4 to 6 feet. The coal occurs locally in two benches separated by 1 to 6 feet of shale. The bed is thickest near its point of disappearance below the stream level of Clear Creek in sec. 24, T. 52 N., R. 81 W., where at locality 76 it contains 5 feet 7 inches of coal in an upper bench and 2 feet 5 inches of coal in a lower bench, the two benches being separated by 2 feet 5 inches of shale. Nearby, at the mouth of Murray Draw, the bed contains 7 feet 2 inches of coal in a single bench which has been mined to a small extent.

Ucross bed.—The Ucross bed lies about 80 to 110 feet stratigraphically below the Murray bed and about 270 to 300 feet below the Healy bed. It crops out near Ucross in the valleys of Clear Creek and Double Cross Draw in the northeastern corner of the area, and at or near the level of Crazy Woman and Dry Creeks in the southeastern part. The bed has also been found in holes drilled for water in the valleys of Boxelder and Dry Creeks in the north-central part of the area.

The Ucross bed consists of a zone of carbonaceous shale as much as 40 feet thick in which beds of coal may occur in discontinuous lenses at several horizons rather than in a continuous stratum. The coal is thickest along Clear Creek in sec. 30, T. 53 N., R. 80 W. (loc. 177), where 13 feet 7 inches of coal occurs in a zone of coal and carbonaceous shale 37½ feet thick. About 3 miles to the south, in the SW¼ sec. 13, T. 52 N., R. 81 W. (loc. 48) near the point where the Ucross bed passes under the level of Clear Creek, the bed contains 12 feet 7 inches of coal not including 8 inches of partings. The Ucross bed is reported to contain between 22 and 23 feet of coal in wells drilled for water in the valley of Boxelder Creek in secs. 20 and 21, T. 53 N., R. 81 W.

Local beds.—In addition to the widespread beds of coal described above, several other beds or lenses of coal may be traced for only short distances. These local beds are described in the section on coal in the various townships, pages 97–119; they include a bed about 40 feet above the Healy bed in the southeastern part of T. 53 N., R. 82 W., which contains as much as 8 feet 3 inches of coal at locality 18; a bed 50 to 60 feet below the Healy bed in the northern part of T. 53 N., R. 81 W., which contains about 5½ feet of coal at locality 38; a bed about 150 feet below the Healy bed in the northwestern part of T. 53 N., R. 80 W., which contains about 5 feet of coal at locality 50; and a bed 50 feet below the Murray bed in the northwestern part of T. 53 N., R. 81 W., which contains nearly 5 feet of coal at localities 52 and 60.

PHYSICAL AND CHEMICAL CHARACTER

The coal in the Buffalo-Lake De Smet area varies in rank within narrow limits between lignite and subbituminous C, as defined by the American Society of Testing Materials (1938). The coal is hard and massive where freshly mined or where kept wet by ground water, but it disintegrates rapidly when exposed to weathering. Where fresh or only slightly weathered, the coal is black and lustrous and does not show pronounced woody texture. Coal in the Monument Peak bed in T. 53 N., R. 82 W. has a brown streak and weathers to a brownish-black powder.

Cores of coal from holes GS–1, GS–2A, GS–3, and GS–6, drilled by the Geological Survey, and from hole A–6, drilled by the U. S. Bureau of Reclamation, were studied by J. M. Schopf and J. R. Gill at the Geological Survey coal geology laboratory, Columbus, Ohio. Detailed logs of the cores from these holes are given on pages 119–133. Schopf and Gill describe the physical characteristics of the coal as follows (Mapel, Schopf, and Gill, 1953, p. 17–18):

> The coal from the cores obtained in the Lake De Smet area is dull black when moist, somewhat brownish when dry, with only slight differentiation of constituents according to luster. The coal is close to the borderline between subbituminous coal and lignite and not sufficiently metamorphosed for vitrain to assume its characteristic brilliance and conchoidal fracture. The coal contains about 30 percent moisture; it checks and breaks down readily on exposure to air. Checking is usually deeper in attrital layers but more closely spaced in woody bands. Surface textures on fresh fractures distinguish fairly well between constituents.
>
> Most of the partings are black carbonaceous shale that does not contrast strongly in appearance with the moist coal. Woody lenses are almost as abundant in many of the partings as they are in the coal. In these woody lenses a carbonaceous matrix rich in detrital mineral matter is present instead of a normal matrix of attrital plant debris. More easily recognized shale partings are gray. None of the dark shale is very tough but some of it is platy. Slickensides are common along sloping contacts between shale and woody lenses.
>
> A few layers of light-colored siltstone include some woody fragments similar to the woody inclusions in the shale. The contrast in compaction between siltstone and its coaly inclusions is more prominent than in the shale and, when present, the coaly pieces in siltstone show extreme contortion.

The sandstone at the bottom of some holes is barely cemented and much more friable than the siltstone interbedded with the coal. A few bands of white clay that disintegrate in water also were observed.

The bone and claystone logged in hole 7 by geologists of the Bureau of Reclamation presumably are similar to the partings described above rather than to the much denser, tough carbonaceous shale and siltstone identified as bone in the coal fields of the central and eastern United States.

None of the partings in the coal cores from the Lake De Smet area show any distinctive characteristics that would identify individual partings from hole to hole within the area. All indications suggest that local tonguing relationships exist between the partings and the coal. This is consistent with the general expectation for a local coal deposit of such unusual thickness where lithologic units within the deposit are likely to be highly lenticular.

Schopf and Gill (idem, p. 18) make the following comments regarding the coal ingredients:

Woody material in bands makes up about 34 to 39 percent of the coal studied in cores from the Lake De Smet area. Most of the woody bands appear lenticular; some are as much as 7 inches thick but the average thickness is less than 3½ inches. Annual rings are discernible in some of the woody material. These occurrences suggest that medium-sized trees grew in the swamp that was transformed later into this coal deposit.

Much of the attrital coal, in which woody fragments are dispersed, probably was derived from material supplied by the larger plants. Microscope studies, which can be mentioned only incidentally now, are required for accurate description of the microscopic fragments. The attrital matrix is mostly translucent, only a small amount consisting of opaque organic matter. Both megascopic and microscopic resinous bodies are common; direct evidence of fungal decay can be seen by microscopic examination.

Fusain occurs at some levels in the deposit but is not an important constituent. A band three-quarters of an inch thick occurred in hole GS–6 at a depth of 238 feet and a band half an inch thick in hole GS–1 at 117 feet 11½ inches depth. Most of the fusain occurs as partings less than 2 millimeters thick, and probably represents less than 1 percent of the deposit.

Blebs of yellow resins are fairly common in the attrital coal and in shaly partings. Some blebs are more than half an inch in diameter and have a distinctly resinous luster and appearance. Probably the resin was derived from coniferous plants but it usually is not directly associated with woody remains. Occurrences of resin blebs are noted in descriptions of coal cores but no resinous concentrations appear prominent enough to be of interest for commercial separation.

Analyses of standard face samples of coal mined in the Buffalo-Lake De Smet area and the average analyses of coal samples from drill holes near Lake De Smet are given in tables 2 and 3.

BURNING OF THE COAL BEDS

Coal beds at many places in the Buffalo-Lake De Smet area are burned along their outcrops or under shallow cover, and the resulting heat has baked and fused the overlying rocks into masses of hard, stony clinker. The Healy and overlying coal beds are extensively burned and at places the resulting clinker is more than 150 feet thick. The clinker generally is various shades of red, but locally it is also

TABLE 2.—*Analyses of standard face samples of coal mined in the Buffalo-Lake De Smet area, Johnson and Sheridan Counties, Wyo.*

[Analyses by personnel of U. S. Bureau of Mines, Pittsburgh, Pa.]

Laboratory sample	Location	Rank designation [1]	Sample condition [2]	Air-dry loss	Proximate				Ultimate					Heat value (Btu)
					Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	
D-25128	Clear Creek Coal Co. mine, SE¼ sec. 20, T. 51 N., R. 81 W.; lower Cameron bed.	Lignite (53-81)	A	17.6	31.1	28.7	31.4	8 8	1.4	6.6	43.3	0.8	39.1	7,350
			B	---------	16.4	34 9	38 0	10 7	1.7	5.6	52 5	1.0	28.5	8,920
			C	---------	---------	41.7	45.5	12.8	2.1	4.5	62.8	1.2	16.6	10,670
			D	---------	---------	47.8	52.2	---------	2.4	5.2	72 0	1.4	19.0	12,240
D-50515	Krezelok mine, SW¼ sec. 1, T. 53 N., R. 82 W.; Healy bed.	Subbituminous (54-84).	A	12.1	30.7	29.8	34.4	5.1	.4	6.7	46 2	1.0	40.6	7,900
			B	---------	21.2	33.9	39.1	5.8	.4	6.1	52 6	1.2	33.9	8,990
			C	---------	---------	43.0	49.7	7.3	.5	4.7	66.7	1.5	19.3	11,400
			D	---------	---------	46.4	53.6	---------	.5	5.1	71.9	1.6	20.9	12,300
6469	Mitchell mine, NW¼ sec. 26, T. 51 N., R. 82 W.; lower Cameron bed—upper bench.[3]	Subbituminous (47-84).	A	20.5	26.8	32 8	27.9	12.5	.6	6.0	42 7	.6	37.5	7,340
			B	---------	7.9	41.3	35.1	15.7	.8	4.8	53.7	.8	24 3	9,240
			C	---------	---------	44.8	38.2	17.0	.9	4.2	58 3	.8	18 8	10,030
			D	---------	---------	54 0	46 0	---------	1.1	5.0	70.3	1.0	22 6	12,090
6470	Mitchell mine, NW¼ sec. 26, T. 51 N., R. 82 W.; lower Cameron bed—lower bench.[3]	Lignite (53-83)	A	22.9	29.0	29.1	34.6	7.2	.4	6.5	44 6	.5	40.7	7,630
			B	---------	8.0	37.7	45.0	9.4	.5	5.2	57.9	.7	26.4	9,890
			C	---------	---------	41.0	48 8	10.2	.6	4.7	62.9	.7	21.0	10,750
			D	---------	---------	45.6	54.4	---------	.6	5.2	70.0	.8	23.4	11,970
6410	Munkre mine, SE¼ sec. 36, T. 51 N., R. 82 W.; lower Cameron bed—middle bench.[3]	Subbituminous (54-85).	A	19.9	28 0	29.7	32.8	9.5	.7	6.4	43.8	.6	39.0	7,580
			B	---------	10.1	37.1	41.0	11.8	.9	5.2	54.7	.8	26.5	9,460
			C	---------	---------	41.3	45.5	13.2	1.0	4.6	60.9	.8	19.6	10,530
			D	---------	---------	47.5	52.5	---------	1.2	5.3	70.1	1.0	22.5	12,120

[1] Numbers in the parenthesis are calculated on the mineral-matter-free basis. The first number represents fixed carbon on the dry basis reported to the nearest whole percent; the second number represents the heat value on the moist basis expressed as hundreds of Btu.

[2] A, as received; B, air-dried; C, moisture free; D, moisture and ash free.

[3] Analyses reported by Gale, H. S., and Wegemann, C. H., (1910, p. 150).

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TABLE 3.—*Weighted average analyses of coal found in drill holes near Lake De Smet, Johnson County, Wyo.*

[Form of analysis: A, as received; B, mineral-matter free; C, mineral and moisture free; D, moist mineral-matter free]

Core-hole designation (pl. 12)	Total coal thickness (inches)	Percent									Btu		
		Mineral (1.08 ash plus 0.55 S)	Ash	Sulfur	Moisture		Volatile matter		Fixed carbon		C	D	A
			A	A	B	A	C	A	C	A			
GS-1	545.7	7.0	5.1	0.6	31.3	29.1	45.8	29.0	54.2	34.5	12,440	8,550	7,970
GS-2A	489.8	6.9	6.1	.5	32.8	30.5	47.4	30.3	52.6	33.0	12,540	8,410	7,845
GS-3	446.7	8.6	7.7	.6	27.9	28.3	45.3	29.4	54.7	34.6	12,470	8,690	7,890
GS-6	817.5	10.3	9.2	.6	32.7	29.3	45.8	28.6	54.2	32.8	12,470	8,380	7,515
7	1,219.0	11.0	9.7	1.0	26.1	23.6	45.0	31.9	53.0	34.8	12,570	9,240	8,270
Total or average values	3,518.7	9.3	8.1	.7	29.6	27.0	46.4	30.1	53.6	34.0	12,510	8,750	7,940

black, yellow, or purple. It resists erosion and thus forms conspicuous protective caps on many high buttes and ridges. The thickness of clinker formed depends on such factors as the thickness of the bed that has burned, the quality of the coal, and the thickness, porosity, and lithology of the cover. Rogers (1917) has described the processes of burning and the physical and chemical changes that occur in the altered rock.

Shallow undrained depressions characterize broad clinker-covered surfaces in some parts of the Buffalo-Lake De Smet area. The depressions apparently were formed by the slumping of clinkered sediments into the space vacated by the burned coal bed. The anomalous position of Lake De Smet on the divide between Piney and Boxelder Creeks, and the abundance of clinker in the vicinity of the lake suggest that the lake basin was formed in such a manner by burning of the thick Healy and Healy(?) coal beds. Similarly, another undrained depression nearly 1 mile long and 40 feet deep in the broad valley that extends southeastward from the south end of the lake may have resulted from burning of the Healy bed.

MINING

PAST AND PRESENT OPERATIONS

Coal has been mined intermittently in the Buffalo-Lake De Smet area for more than 50 years. Some of the coal was used in locomotives on the now defunct Wyoming Railroad, but for the most part mining has been limited to the domestic needs of local ranchers.

The only active mine in the area in 1951 was the Clear Creek Coal Co. mine in the SW¼ sec. 20, T. 51 N., R. 81 W. The mine consists of an incline driven to a depth of about 50 feet, and a drift which extends horizontally from the end of the incline for about 1,500 feet in the Lower Cameron coal bed. The entry is timbered for about 200 feet from the surface, but within the mine the walls and roof stand with the help of only a few timbers. The mine operates only during the winter months and the output is about 25 tons per day.

The Kreselok mine, in sec. 2, T. 53 N., R. 82 W., consists of a timbered entry about 100 feet long which opens into a branching network of rooms and drifts in the Healy bed. The floor and roof are both coal. According to Mr. Kreselok, the owner, about 19,000 tons of coal were produced from this mine between 1919 and 1950. Minor amounts of coal were being removed by Mr. Kreselok in 1950 for personal use.

An adit at locality 88 in the NW¼ sec. 26, T. 52 N., R. 81 W., extends for about 150 feet into the Murray bed. The drift widens slightly at the end where coal has been taken from a small room. At locality 4 in the SE¼ sec. 3, T. 52 N., R. 82 W., a small strip mine was opened on the Healy bed by Mr. J. E. Rice in 1951 and 4,000 tons of coal were removed for testing at the U. S. Bureau of Mines coal hydrogenation-testing plant at Louisiana, Mo. (See pl. 15*B*.) Entries in other parts of the district were either caved or flooded at the time visited.

MINING POSSIBILITIES

The Buffalo-Lake De Smet area contains thick coal beds that offer possibilities for either strip mining or underground mining at many places. The thick deposits of coal in the Healy(?) and Healy coal beds near the north end of Lake De Smet are covered by overburden that ranges in thickness from 40 to about 400 feet and consists from place to place of unconsolidated sand and gravel, clinker, and relatively soft sandstone and shale. Three areas in this vicinity appear most favorable for further exploration by drilling to determine the feasibility of strip mining. The first is in the valley of Shell Creek in secs. 1 and 12, T. 52 N., R. 83 W. The Healy(?) bed here is overlain by as little as 40 feet of overburden consisting mostly of terrace gravel and clinker. The bed varies in thickness from 60 feet in drill hole GS–3 to as much as 222 feet in drill hole C. The variation in thickness is due chiefly to burning of varying amounts of coal from the upper part of the bed. A second locality favorable for testing is in the valley of Little Piney Creek in the N½ sec. 36 and parts of secs. 26 and 35, T. 53 N., R. 83 W. The overburden is less than 100 feet thick along the valley bottom and consists mostly of terrace gravel and soft shale. The Healy(?) bed which underlies this area may be as much as 224 feet thick in the Carl Hepp water well in the SE¼ sec. 26, where it includes coal and interbedded brown shale. The third area is in the small valley which crosses secs. 5 and 8, T. 52 N., R. 82 W. Here the Healy bed contains from 30 to 50 feet of coal including thin partings of shale, and is overlain by less than 100 feet of shale and sandstone.

Two areas in the southeastern part of the Buffalo-Lake De Smet area offer possibilities for strip mining:

(1) The Healy bed underlies part of a broad flat in secs. 5, 6, 7, and 8, T. 50 N., R. 81 W. Gale and Wegemann (1910, p. 163) report that an inclined adit (now abandoned) in the W½ sec. 5 encountered 10 feet of coal 25 feet below the surface at an elevation of about 4,620 feet. Inasmuch as the strata are nearly flat lying, the coal probably occurs beneath less than 80 feet of overburden in an area of about 1 square mile between the outcrop of the bed and the 4,700-foot contour. No detailed information other than the reported thickness of coal in the mine and an incomplete exposure of the bed in the SW¼ sec. 6 (loc. 2) is available.

(2) The Ucross bed underlies much of sec. 25, T. 50 N., R. 80 W., at an estimated depth of less than 40 feet. The land surface is a broad flat that slopes gently eastward toward Crazy Woman Creek. The coal is 10 to 12 feet thick where exposed in the stream bank of Crazy Woman Creek to the south. Locally, however, the bed is split by lenticular shale partings, and the area should be prospected by drilling to determine the amount and quality of coal.

Other areas of low relief which appear favorable for strip mining are: the valley of Clear Creek in the south-central part of T. 52 N., R. 81 W., underlain by the Murray bed; the valley of Dry Creek in the southwestern corner of T. 50 N., R. 81 W., underlain by the Dry Creek bed; and the valley of Dry Creek near the east edge of T. 50 N., R. 81 W., underlain by the Healy bed.

Thick coal beds which crop out on the ridges between tributaries to the larger streams pass under thick cover a short distance back from their outcrops at most places, and these beds can probably best be mined underground from entries along the outcrops.

RESERVES

The estimated original coal reserves in the Buffalo-Lake De Smet area in beds more than 2½ feet thick and under less than 1,000 feet of overburden total about 6.4 billion short tons. The reserves are itemized by township and bed on table 4. About half of the reserves are classified as measured and indicated, and the remainder are classified as inferred. Measured reserves consist of coal lying not more than a quarter of a mile from a measured section at an outcrop or in a drill hole. Indicated reserves consist of (1) coal extending from ¼ to 1 mile beyond the limits assumed for measured coal, depending on the persistence of the coal bed along its outcrop, or (2) coal that lies within half a mile from a point where coal is known to occur but where the thickness and quality of the coal have not been reliably defined. Because the amount of coal that could be classified as measured is very small, the measured and indicated categories have been combined in the tabulations. Inferred reserves lie beyond the limits assigned to indicated reserves and consist of coal for which quantitative estimates are based largely on broad knowledge of the geologic character of the bed.

The reserves in each category are further subdivided according to whether the coal is in beds 2½ to 5 feet thick, 5 to 10 feet thick, or more than 10 feet thick. Near the north end of Lake De Smet, where the coal was drilled but not cored, the ratio of coal to partings in the nearest cored drill hole is assumed to apply in calculating the reserves, and no subdivision is made according to the thickness of individual layers of coal.

The Healy and Healy(?) beds contain about 46 percent of the total estimated coal reserves in the Buffalo-Lake De Smet area. The other beds, in order of their importance, are the Ucross bed with 30 percent of the total reserve, the Cameron beds with 9 percent, the Murray bed with 8 percent, and the remaining beds with about 7 percent.

Persistent coal beds crop out in the Wasatch and Fort Union formations stratigraphically below the Ucross bed in areas to the north and east of the Buffalo-Lake De Smet area. Some of these beds may underlie parts of the Buffalo-Lake De Smet area; however, no data on which to base estimates of reserves are available for these beds and reserve estimates for them are not included in the totals.

TABLE 4.—*Estimated original coal reserves in the Buffalo-Lake De Smet area, Wyoming*

[In millions of short tons; 1,770 short tons per acre-foot assumed in all calculations. All coal is under less than 1,000 feet of overburden]

Bed	Measured and indicated reserves in beds—			Inferred reserves in beds—			Total reserves all classes
	2½ to 5 feet thick	5 to 10 feet thick	More than 10 feet thick	2½ to 5 feet thick	5 to 10 feet thick	More than 10 feet thick	
T. 53 N., R. 80 W.							
Healy		3.4	27.6				31.0
Schuman	7.8	1.1					8.9
Upper and Lower Cameron	5.2						5.2
Local bed about 150 ft below Healy	1.4						1.4
Murray	36.5	36.5					73.0
Local bed 35–50 ft below Murray	.6						.6
Ucross	9.2						9.2
Local bed 35–40 ft below Ucross	2.9						2.9
Total	63.6	41.0	27.6				132.2
T. 53 N., R. 81 W.							
Walters			0.1				0.1
Healy		2.4	210.7				213.1
Schuman	12.5						12.5
Local bed 50 to 60 ft below Healy	7.0						7.0
Upper and Lower Cameron	95.2	.5					95.7
Murray	6.0	156.7					162.7
Local bed 50 ft below Murray	1.4						1.4
Ucross			23.4			380	403.4
Total	122.1	159.6	234.2			380	895.9
T. 53 N., R. 82 W.							
Monument Peak		0.3	6.6				6.9
Walters	.9		.3	7.0		31.2	39.4
Local bed 40 ft above Healy		5.6					5.6
Healy	1.9		36.8			410	448.7
Healy(?)			[1] 17.0				17.0
Local bed 55 ft below Healy	.2						.2
Upper Cameron	11.6	.5		120			132.1
Murray					100		100
Ucross					62		62
Total	14.6	6.4	60.7	127	162	441.2	811.9

See footnote at end of table.

TABLE 4.—*Estimated original coal reserves in the Buffalo-Lake De Smet area, Wyoming*—Continued

Bed	Measured and indicated reserves in beds—			Inferred reserves in beds—			Total reserves all classes
	2½ to 5 feet thick	5 to 10 feet thick	More than 10 feet thick	2½ to 5 feet thick	5 to 10 feet thick	More than 10 feet thick	
T. 53 N., R. 83 W.							
Healy						5	5
Healy(?)			[1] 108			[1] 130	238
Total			108			135	243
T. 52 N., R. 80 W.							
Walters			29.5				29.5
Local bed 45 ft above Healy	.1						.1
Healy	7.0	1.8	241.9				250.7
Schuman	33.1	27.1		11			71.2
Lower Cameron	3.7						3.7
Local beds 150 to 160 ft below Healy	1.0						1.0
Murray	1.9						1.9
Ucross					140		140
Total	46.8	28.9	271.4	11	140		498.1
T. 52 N., R. 81 W.							
Walters			40.7				40.7
Healy		9.3	310.8				320.1
Schuman	.1						.1
Upper and Lower Cameron	8.3			62			70.3
Murray	6.3	72.9			74		153.2
Local bed 35 ft below Murray	.2						.2
Ucross	4.1		71.4			380	455.5
Total	19.0	82.2	422.9	62	74	380	1,040.1
T. 52 N., R. 82 W.							
Local bed 110 ft above Walters		0.7					0.7
Walters			2.0				2.0
Local bed 70 ft above Healy	.5						.5
Healy		6.7	387			38	431.7
Healy(?)			[1] 6.5				6.5
Upper Cameron	.4		10.7	89			100.1
Murray					34		34
Ucross						91	91
Total	.9	7.4	406.2	89	34	129	666.5
T. 52 N., R. 83 W.							
Healy(?)			[1] 225			[1] 40	265
T. 51 N., R. 80 W.							
Walters			2.3			1	3.3
Healy	1.1	5.0	139.6				145.7
Schuman	15.9						15.9
Local bed 10–20 ft below Schuman	3.8						3.8
Lower Cameron	6.1						6.1
Dry Creek	.3	5.5					5.8
Ucross	5.0					170	175
Total	32.2	10.5	141.9			171	355.6

See footnote at end of table.

TABLE 4.—*Estimated original coal reserves in the Buffalo-Lake De Smet area, Wyoming*—Continued

Bed	Measured and indicated reserves in beds—			Inferred reserves in beds—			Total reserves all classes
	2½ to 5 feet thick	5 to 10 feet thick	More than 10 feet thick	2½ to 5 feet thick	5 to 10 feet thick	More than 10 feet thick	
T. 51 N., R. 81 W.							
Walters			0.9				0.9
Healy		11.3	308.8				320.1
Lower Cameron	40.0	33.0	52.6	3.5	36		165.1
Murray		10.3			27		37.3
Ucross						280	280
Total	40.0	54.6	362.3	3.5	63	280	803.4
T. 51 N., R. 82 W.							
Healy			39.8				39.8
Lower Cameron		32.8	6.3				39.1
Total		32.8	46.1				78.9
T. 50 N., R. 80 W.							
Walters			0.02				0.02
Local bed 40 ft above Healy	.02						.02
Healy	.9	22.8	241.1				264.8
Timar	9.4						9.4
Local bed 25–30 ft above Cameron	1.2						1.2
Lower Cameron	6.5						6.5
Dry Creek	1.8						1.8
Ucross	2.8	8.0	5.1			6	21.9
Total	22.6	30.8	246.2			6	305.6
T. 50 N., R. 81 W.							
Healy	5.2	5.4	8.2			150	168.8
Ucross					95		95
Total	5.2	5.4	8.2		95	150	263.8
Grand total (rounded)	367	459	2,560	292	568	2,115	6,365

[1] Includes beds in all thickness categories.

DESCRIPTION OF BEDS BY TOWNSHIP

On the following pages, coal deposits are described for each of the townships in the Buffalo-Lake De Smet area underlain by coal-bearing beds of the Wasatch formation, beginning with the northernmost tier of townships and going from east to west. The locations at which sections of coal were measured are indicated on the geologic map (pl. 1) by numbers. The coal sections correspondingly numbered are shown on plates 16–23, and figures 3–6. Sections taken on the coal beds are numbered consecutively starting with number 1 in the northeast corner of each township and moving back and forth across the township from one tier of land sections to the next tier south.

T. 53 N., R. 80 W.

Most of T. 53 N., R. 80 W., is drained by Clear Creek which flows in a wide valley northeastward through the central part of the township. Piney Creek, a perennial stream of nearly equal size, joins Clear Creek from the west near the town of Ucross in the west-central part of the township. Flat agricultural lands border these streams and extend up the valleys of some of their larger tributaries, but the surface in the remainder of the area is broken by deep gullies and steep-sided ridges. The maximum relief is about 825 feet and the maximum altitude 4,730 feet (pl. 16).

Walters coal bed.—The Walters bed is the highest coal bed exposed in the township. It has burned at most places, producing thick deposits of clinker which cap high buttes in the south-central and northwestern parts of the area. The bed is unburned in an area of about 3 acres in sec. 33, but the coal is covered by slope wash and its thickness was not measured.

Healy coal bed.—The Healy coal bed crops out 165 to 175 feet below the Walters bed along the sides of high divides in the southwestern and northwestern parts of the township. At almost every locality measured, the bed contains more than 9 feet of coal. It contains 15 feet 4 inches of coal without partings at locality 34 in sec. 5, and 14 feet 11 inches at locality 200 in sec. 34. The Healy bed has burned along its outcrop at many places producing a conspicuous bed of clinker.

Schuman coal bed.—The Schuman coal bed crops out 25 to 30 feet below the Healy bed. It contains 5 feet 5 inches of coal, not including a 6-inch shale parting near the base at locality 27 in sec. 4, and 5 feet 2 inches of coal without partings at locality 194 in sec. 32. In secs. 26 and 27, the coal thins to less than 2 feet.

Cameron coal beds.—The Cameron coal beds are exposed 90 to 125 feet below the Healy bed on high ridges and divides over much of the township. The uppermost and most persistent of the Cameron beds averages slightly less than 2 feet thick, reaching a maximum measured thickness of 3 feet 3 inches at locality 149 in sec. 26. This coal generally is overlain by a bed of limestone as much as 1 foot thick which contains abundant shells of fresh-water mollusks. A second bed commonly occurs in the Cameron coal zone at an interval ranging from 4 to about 35 feet below the base of the upper coal. The average thickness of the lower bed is about 2½ feet. At locality 92 in sec. 17 a bed 13 feet below the Upper Cameron bed contains 4 feet 9 inches of clean coal, and at locality 36 in sec. 5 a bed 24 feet below the Upper Cameron bed contains 5 feet of coal but is broken by 3 thin partings of shale.

A bed of coal crops out locally about 150 feet below the Healy bed and about 50 feet below the upper bed of the Cameron zone in the northwestern corner of the township. This bed is at or slightly below the horizon of the Dry Creek coal bed in the southern part of T. 51 N., R. 80 W., to the south; however, it could not be traced in the intervening area. The bed, including a 10-inch parting of shale near the middle, is 5 feet 11 inches thick at locality 50 in sec. 7; it contains almost 5 feet of coal in 2 benches at nearby locality 39.

Murray coal bed.—The Murray bed crops out 190 to 200 feet below the Healy bed. It contains a total of more than 5 feet of coal at many localities but at most places is broken by several shale partings. At least 6 feet 3 inches of clean coal was noted at locality 58 in sec. 9 and 6 feet 2 inches at locality 215 in sec. 35. The Murray bed contains less than 3 feet of coal in the southwestern corner of the township and is represented by carbonaceous shale in the northeastern part at localities 60 in sec. 10 and 72 in sec. 14. The Murray bed is burned for a short distance along its outcrop in the NW¼ sec. 20.

A local bed, which crops out 35 to 50 feet below the Murray bed along the eastern side of the township, contains 3 feet 4 inches of coal at locality 128 in sec. 24 but is thinner and broken by partings nearby. A bed near the same horizon contains 2 feet 6 inches and 1 foot 10 inches of coal at localities 183 and 189, respectively, in sec. 31.

Ucross coal bed.—The Ucross coal bed crops out 85 to 100 feet below the Murray bed in a zone of carbonaceous shale that locally is as much as 35 feet thick. The coal occurs somewhat erratically in this zone, probably as a series of discontinuous lenses rather than as continuous beds. An aggregate thickness of 12 feet 9 inches of coal was found in an interval of about 23 feet at locality 177 in sec. 30, with one bench of coal 4 feet 10 inches thick. At many outcrops the bed contains more than 2 feet 6 inches of clean coal.

A coal bed in the northeastern part of the township, which crops out 35 to 40 feet below the Ucross bed, contains 3 feet 5 inches of coal at locality 12 in sec. 2 and is more than 2 feet thick at several nearby localities.

At locality 64 in sec. 12 a coal bed containing 2 feet 6 inches of coal crops out 105 feet below the Ucross bed a few feet above the level of Clear Creek. This is the oldest bed observed in the Buffalo-Lake De Smet area. North and east of this exposure, strata at this horizon are covered by terrace deposits and alluvium in the valley of Clear Creek. The bed is not exposed elsewhere in the township; however, a bed of coal and carbonaceous shale 7 feet thick at about the same horizon was reported about 125 feet below the Ucross bed in a water well in the N½ sec. 10.

T. 53 N., R. 81 W.

Piney Creek flows eastward across the northern part of T. 53 N., R. 81 W., in a valley ¼ to ½ mile wide, and Boxelder Creek, a large intermittent tributary, crosses the southern part diagonally emptying into Piney Creek from the southwest. The township is drained by these two streams and their intermittent tributaries except for about 8 square miles along the eastern edge which are drained by tributaries of Clear Creek. Areas of relatively flat agricultural land adjoin Piney and Boxelder Creeks; the remainder of the township is characterized by grass-covered knolls and hills of moderate relief. The main divides are high and steep-sided and are capped by resistant clinker. The maximum relief in the township is about 660 feet and the maximum altitude about 4,740 feet (pl. 17).

Walters coal bed.—The highest coal bed in the township is the Walters bed. Coal in the Walters bed has burned extensively to form thick deposits of clinker that cap high ridges and divides throughout the township. Isolated unburned areas occur at localities 10 in sec. 2 and 128 in sec. 33, where in incomplete exposures the coal is 6 feet 6 inches and 17 feet thick, respectively.

Healy coal bed.—The Healy bed, about 170 feet below the Walters bed, averages about 15 feet in thickness in T. 53 N., R. 81 W., with a maximum thickness of 18 feet of coal without partings at locality 118 in sec. 29. Small amounts of coal have been mined from the Healy bed for local use in the E½ sec. 23. At many places the bed has burned along its outcrop forming thick deposits of clinker.

Schuman coal bed.—The Schuman coal bed crops out 20 to 30 feet below the Healy bed along both sides of the Clear Creek-Boxelder Creek divide in the southeastern quarter of the township. It averages about 3 feet thick and reaches a maximum observed thickness of 3 feet 10 inches at locality 100 in sec. 24.

A coal bed crops out locally in the northern half of the township at an interval of 50 to 60 feet below the Healy bed. This bed is near the horizon of the Timar coal bed in Tps. 50 and 51 N., R. 80 W., but the Timar bed could not be traced in the intervening area. Its thickness averages about 4 feet of coal, with a maximum observed thickness of 5 feet 1 inch of clean coal at locality 38 in sec. 11. The bed thins southwestward and in the southern part of the township is represented by a bed of carbonaceous shale containing less than 2 feet of coal.

Cameron coal beds.—The Cameron coal beds crop out in a zone 95 to about 130 feet below the Healy bed. The uppermost bed in the zone, which is persistent over most of the township, is overlain at many places by a ledge-forming bed of limestone which is as much as 10 inches thick and is composed largely of the shells of fresh-water mollusks. The coal bed underlying this bed of limestone is less than 2 feet thick in the eastern part of the township, but it thickens westward, and a coal bed correlated with the upper bed is 4 feet 9 inches thick at locality 126 in sec. 31. The upper bed of the Cameron coal zone has been mined to a small extent at an abandoned mine south of Piney Creek in sec. 7 where the coal is reported to be about 6 feet thick.

At many places in the township, a second coal bed crops out in the Cameron zone at intervals ranging from 6 to about 30 feet below the upper bed. The lower bed contains 5 feet 4 inches of coal, excluding partings, at localities 13 and 19 in secs. 3 and 8, respectively. A coal bed 3 feet 9 inches thick, excluding partings, which occurs 41 feet below the upper bed at locality 45 in sec. 12, is included in the Cameron zone, although it appears to be somewhat lower stratigraphically than the lower bed as mapped elsewhere in the township.

Murray coal bed.—The Murray coal bed crops out 180 to 190 feet below the Healy bed in the valleys of Clear, Boxelder, and Piney Creeks. Its maximum observed thickness is 6 feet 11 inches, excluding partings, at locality 72 in sec. 15. The bed ranges in thickness from 2 feet 3 inches to 3 feet 3 inches along Clear Creek in the southeastern part of the township.

Local lenses of coal 50 feet below the Murray bed are 4 feet 8 inches thick at locality 52 in sec. 13 and 5 feet 2 inches thick at locality 60 in sec. 14.

Ucross coal bed.—The Ucross bed crops out at locality 53 in sec. 13 where 2 feet of coal is exposed near the level of Piney Creek. This coal may represent only the top of the bed. Twenty-three feet of coal was reported at the horizon of the Ucross bed in a water well drilled in the NE¼ sec. 21 in the valley of Boxelder Creek, and 22 feet of coal in a water well drilled in the SE¼ sec. 20.

T. 53 N., R. 82 W.

Most of T. 53 N., R. 82 W., is drained by Piney Creek which flows northeastward diagonally across the township in a broad open valley that is irrigated and farmed. The land rises from Piney Creek valley with increasing steepness to high even-topped divides covered with grass and brush, which parallel the creek in the northwestern and southeastern parts of the area. Intermittent streams in narrow valleys drain northward to Jim Creek in the northwestern corner of the township and southeastward to Boxelder Creek in the southeastern corner. The maximum relief is 790 feet and the maximum altitude about 5,060 feet (pl. 18).

Monument Peak coal bed.—The Monument Peak bed crops out in the southeastern part of the township about 150 feet below the summit of Monument Peak and the bed is represented by isolated remnants of clinker on high divides in the western part of the township. At locality 22 in sec. 26, the bed contains an aggregate of 19 feet 6 inches of coal and 5 feet 4 inches of shaly coal and partings. Gale and Wegemann (1910, pl. 9) report that it contains 16 feet of coal without partings in a caved mine entry in the N½ sec. 34. West of Piney Creek, at locality 15 in sec. 19, the Monument Peak bed is represented by alternating thin beds of coal, carbonaceous shale, and shaly coal in a zone 38 feet thick.

Beds of clinker are exposed 130 feet above the Monument Peak bed near the summit of Monument Peak and on another peak three-fourths mile to the southwest; clinker occurs locally 40 and 100 feet below the Monument Peak bed in secs. 27, 34, and 35. No coal is exposed at these horizons.

Walters coal bed.—The Walters coal bed, which lies 150 to 175 feet below the Monument Peak bed, has burned extensively in this township to form prominent beds of clinker that cap high divides along both sides of Piney Creek. The Walters bed contains 23 feet 6 inches of coal broken by many thin partings of shale at locality 19 in sec. 23. It contains but 4 feet 4 inches of clean coal at locality 2 in sec. 4, and in the southwestern part of the township it is represented by carbonaceous shale.

Healy coal bed.—The Healy bed, 165 to 190 feet below the Walters bed, has burned along its outcrop to produce thick clinker that conceals the bed at many places. Coal in the Healy bed is exposed at localities 1 in sec. 2, 3 in sec. 5, 14 in sec. 14, 23 in sec. 27, 24 in sec. 32, and 25 in sec. 33, and was found in cored drill holes in sec. 31 (pl. 12). Its minimum measured thickness at a complete exposure is 13 feet including thin partings of shale at locality 14, and its maximum thickness is 46 feet including thin partings in cored drill hole A–1.

The thick Healy(?) coal bed, described on pages 84–85, was found in 3 core holes (A–6, A–7, and A–8) drilled by the U. S. Bureau of Reclamation in the southwest corner of sec. 31. The coal is 119 feet thick in hole A–6, 123 feet thick in hole A–8, and at least 40 feet thick in hole A–7 which did not reach the bottom of the bed. Clinkered sedimentary rocks ranging in thickness from 101 to 128 feet extend from the ground surface downward to the top of the coal in all three holes, indicating that some unknown fraction of coal originally at the top of the bed has burned.

Four now-abandoned adits were dug into the Healy bed along the south side of Piney Creek in secs. 31, 32, and 33. According to the local residents the tonnage of coal removed was small.

A local bed about 40 feet above the Healy bed underlies the southern part of the Piney Creek-Boxelder Creek divide at localities 18, 20, 26, and 27. This bed contains 8 feet 3 inches of coal in a partial exposure at locality 18 in sec. 22 and 7 feet 8 inches of coal at locality 20 in sec. 26.

A coal bed crops out locally about 55 feet below the Healy bed near the junction of Piney Creek and Cameron Gulch in the northeastern part of the township. It is exposed at localities 4 and 13 where it contains 2 feet 3 inches and 3 feet 8 inches of coal, respectively. The bed could not be traced to nearby areas.

Upper Cameron coal bed.—The Upper Cameron bed is exposed 90 feet below the Healy bed along both sides of Piney Creek in the northeastern quarter of the township. The bed averages about 4 feet in thickness and contains 5 feet 5 inches of clean coal at locality 7 in sec. 12.

Unexposed coal beds.—Exposures in the adjoining township to the east indicate that the Murray coal bed with an average thickness of 5 feet of coal may lie 190 to 200 feet below the Healy bed under the eastern third of the township, and that the Ucross bed with an average thickness of about 5 feet may lie about 280 feet below the Healy bed under the southeastern part of the township.

T. 53 N., R. 83 W.

The east flank of the Bighorn Mountains rises steeply along the west border of T. 53 N., R. 83 W., and in the adjacent township to the west. The divide between the Tongue and Powder Rivers extends southeastward from the mountains and crosses the area diagonally from sec. 7 to sec. 24. Areas north of the divide are drained by Prairie Dog and Jim Creeks, and areas south of it are drained by Piney Creek and its tributary Little Piney Creek. Land adjacent to the larger streams is relatively flat, but in the remainder of the township the ground surface is characterized by steep, smoothly rounded, grass-covered hills cut locally by narrow ravines. The maximum relief is 2,280 feet and the maximum altitude 6,820 feet.

Walters(?) coal bed.—A coal bed tentatively correlated with the Walters bed crops out at locality 1 in sec. 36 in the banks of the Lake De Smet inlet canal (fig. 3). The bed here contains 8 feet 11 inches of coal in beds more than 6 inches thick in an interval of 62 feet. Clinker resulting from the burning of the Walters bed caps a ridge in the NE¼ sec. 13. Eastward from these exposures the Walters bed is represented by carbonaceous shale.

A bed of clinker is visible 80 feet below the Walters bed in sec. 13, but no exposures of coal were found at this horizon.

Healy coal bed.—A bed of clinker 170 to 180 feet below the Walters bed marks the horizon of the Healy bed in the northeastern part of the township. No exposures of coal were found. Coal in the Healy bed averages about 17 feet thick in the northern part of the township to

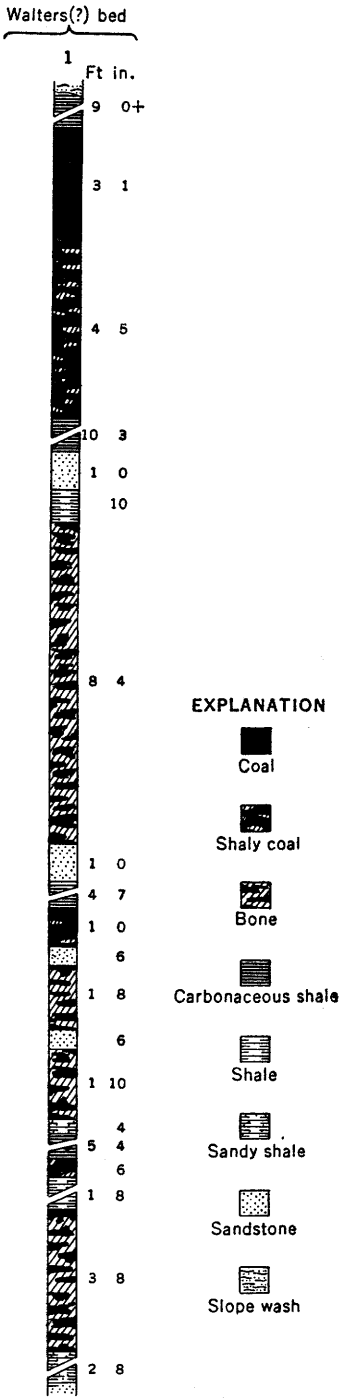

FIGURE 3.—Section of coal bed in T. 53 N., R. 83 W

the east, however, and it is possible that the Healy bed underlies a small area east of Murphy Draw in the township with about the same thickness.

A water well drilled in 1944 in the SE¼ sec. 26 for Carl Hepp found 224 feet of coal and brown carbonaceous shale in alternating beds beneath 24 feet of gravel and shale (pl. 12). This coal and shale sequence is tentatively correlated with the Healy bed. Inasmuch as more than 100 feet of coal was penetrated in cored drill holes about 2 miles southeast of the Hepp well in the township to the south, this coal bed probably underlies most of sec. 36 and parts of adjacent sections in the township.

T. 52 N., R. 80 W.

The divide between Clear and Dry Creeks crosses T. 52 N., R. 80 W., in an arc extending from sec. 31 northeastward to sec. 21 and thence southeastward to sec. 25. This divide is marked by a chain of buttes capped by resistant clinker. Valleys and ravines heading on the outer side of the arc drain northwestward and northward toward Clear Creek, and those on the inner side drain southeastward toward Dry Creek. The larger valleys generally are broad and open, although their floors locally are trenched by gullies; the intervening ridges are steep-sided and narrow. The maximum relief is about 600 feet and the maximum altitude 4,800 feet (pl. 19).

Walters coal bed.—The highest and thickest bed of coal exposed in the township is the Walters bed. It crops out in several isolated areas along the Clear Creek-Dry Creek divide in the southwestern and central part of the township and on high divides in the northwestern part. Elsewhere the bed has burned to produce a thick cap rock of clinker. The bed contains an average thickness of 23½ feet of coal but characteristically is broken by many thin partings of shale. At locality 124 in sec. 31 it contains a maximum of 27 feet 9 inches of coal, not including 2 feet 1 inch of partings.

Healy coal bed.—The Healy coal bed crops out 160 to 175 feet below the Walters bed on the sides of high divides and spurs throughout T. 52 N., R. 80 W., and contains an average thickness of 15 feet of coal. Its maximum observed thickness is 22 feet 1 inch, not including shale partings, at locality 92 in sec. 22. Small amounts of coal have been dug from the outcrop near this locality for domestic use. A shale parting ranging in thickness from about 4 to 7 feet divides the coal in the Healy bed into 2 benches on the east-central border of the township at localities 100, 103, 109, 110, and 112 in secs. 24 and 25. The upper bench ranges in thickness from 2 feet 1 inch to 5 feet 9 inches, and the lower from 2 feet 3 inches to 5 feet. The upper bench is cut out by sandstone-filled channels at localities 101 and 102 in sec. 24.

Schuman coal bed.—The Schuman bed crops out 20 to 25 feet below the Healy bed in the northern and eastern parts of the township. Its thickness averages about 4 feet with a maximum of 8 feet 8 inches exclusive of a 5 inch parting at locality 33 in sec. 8.

Cameron coal beds.—The Cameron beds crop out northwest of the Clear Creek-Dry Creek divide in a zone 90 to 125 feet below the Healy bed. The uppermost coal bed in the zone is persistent over the northern half of the township, reaching a maximum thickness of 2 feet 6 inches of clean coal at locality 122 in sec. 29. It generally is overlain by a bed of limestone from 1 to 5 inches thick composed of the shells of fresh-water mollusks. A lower bed commonly occurs in the Cameron zone from 7 to 35 feet stratigraphically below the upper bed. The lower bed contains 3 feet 5 inches of clean coal at locality 36, and 3 feet 3 inches of clean coal at locality 37 in sec. 9.

Lenticular beds of coal crop out 150 to 160 feet below the Healy bed at localities 6, 40, 47, 50, 52, and 66 in the northeastern part of the township, and at localities 135 and 136 in the southeastern part. These beds are near the horizon of the Dry Creek bed in the township to the south but they cannot be traced for any great distance. The maximum observed thickness of coal at this horizon was 3 feet 1 inch at locality 66 in sec. 14.

Murray coal bed.—The Murray bed, 190 to 210 feet below the Healy bed, is the lowest coal exposed in the township. It crops out at several localities in the northern part of the township, but could not be traced south of the Clear Creek-Dry Creek divide. The Murray bed has an aggregate thickness of 7 feet 1 inch of coal at locality 60 in sec. 12 where the thickest bench measures 2 feet 10 inches.

Unexposed coal beds.—Exposures in adjacent townships to the north, west, and south suggest that the Ucross coal bed, about 90 feet below the Murray bed, may underlie the western one-third of T. 52 N., R. 80 W., with an average thickness of about 8 feet of coal.

T. 52 N., R. 81 W.

A high clinker-capped divide between Clear and Boxelder Creeks crosses T. 52 N., R. 81 W., from sec. 36 northeastward to sec. 4. Extending from it on either side, almost at right angles, are long narrow even-topped ridges separated by valleys which are steep sided near the divide but which become broad and open downstream. Clear Creek flows northward along the eastern side of the township and drains about two-thirds of the area; the northern part is drained by tributaries to Boxelder Creek. The maximum relief is about 840 feet and the maximum altitude about 4,980 feet (pl. 20).

Monument Peak bed.—A bed of clinker formed by burning of the Monument Peak coal bed crops out on the sides of a high hill on the divide between Clear and Boxelder Creeks in secs. 17, 18, 19, and 20, and on the tops of two lower hills nearby. A higher bed of clinker, about 120 feet above the Monument Peak bed forms the highest point in the township in sec. 20.

Walters coal bed.—Coal in the Walters bed is extensively burned and the resulting clinker, locally more than 80 feet thick, caps most of the Clear Creek-Boxelder Creek divide and many high outlying buttes and ridges. The Walters bed, where unburned, ranges in thickness, including partings of shale, from 24 feet at locality 12 in sec. 4 to 28 feet 3 inches at locality 15 in sec. 6.

Healy coal bed.—The Healy coal bed crops out 160 to 170 feet below the Walters bed along both sides of the Clear Creek-Boxelder Creek divide and on ridges in the eastern part of the township east of Clear Creek. The bed has burned extensively along its outcrop which is marked at many places by a prominent bed of clinker. Coal in the Healy bed probably averages about 15 feet thick with few or no partings. The bed contains 23 feet 8 inches of coal, not including 4 inches of shale partings in a partial exposure at locality 95 in sec. 34, and it contains 21 feet 1 inch of coal in a complete exposure at locality 92 in sec. 27. The bed thins northeastward to 11 feet 4 inches of coal with no partings at locality 41 in sec. 13.

Schuman bed.—The Schuman bed crops out 18 to 24 feet below the Healy bed along the eastern edge of the township. It contains 3 feet 6 inches of coal at locality 73 in sec. 24, but is thinner elsewhere and is not present in the southwestern part of the township. At locality 14 in sec. 5, a bed that contains 1 foot 6 inches of coal crops out 30 feet below the Healy bed and may correlate with the Schuman bed.

Cameron coal beds.—The Cameron coal beds crop out in a zone 90 to 120 feet below the Healy bed in the valley of Clear Creek and in sec. 6 in the valley of Boxelder Creek. At most places two coal beds are present in the zone. They are separated by 15 to 30 feet of non-coal-bearing rock. The upper bed at most places is overlain by a ledge-forming bed of limestone 1 to 5 inches thick which is made up of frgaments of fossils. Coal in the upper bed is 4 feet 3 inches thick in a partial exposure at locality 16 in sec. 6, but where measured elsewhere the upper bed is less than 2 feet thick. The lower bed ranges in thickness from 11 inches at locality 86 in sec. 26 to 3 feet 4 inches at locality 59 in sec. 22.

Murray coal bed.—The Murray bed crops out about 190 feet below the Healy bed along the valley of Clear Creek. It has a maximum observed thickness of 7 feet 2 inches of coal without partings at locality 88 in sec. 26. The bed splits at locality 76 in sec. 24 where an upper bench 5 feet thick and a lower bench about 2½ feet thick are separated by 2 feet 5 inches of shale. The interval between the upper and lower benches increases to 18 feet at locality 36 in the section to

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the north. Here the upper bench is 1 foot 3 inches thick and the lower bench 1 foot 1 inch thick. Farther northward, at locality 30 in sec. 12, the Murray bed, which apparently is represented by only the upper bench, is 9 inches thick.

A local lens of coal 35 feet below the Murray bed is 2 feet 4 inches thick at locality 33 and 3 feet thick at locality 34 in sec. 12.

Ucross coal bed.—The lowest coal exposed in the township is the Ucross bed 250 to 260 feet below the Healy bed. It crops out near stream level on the east side of Clear Creek in the northeastern part of the township. The bed contains 17 feet 3 inches of coal and thin partings of shale at locality 35 and 13 feet 1 inch of coal at locality 48 in sec. 13. Fifteen feet of coal was reported at the horizon of the Ucross bed in a water well drilled in the C S½NW¼ sec. 26. Partings of shale in the Ucross bed thicken northward, and at locality 1 in sec. 1 a total of 8 feet 7 inches of coal occurs in 4 beds in an interval of 31 feet, the thickest coal measuring 3 feet.

T. 52 N., R. 82 W.

T. 52 N., R. 82 W., is drained principally by Boxelder Creek which heads near the southeast corner and flows northward in a broad grass-covered valley. Tributaries of Piney Creek drain a small area in the northwest corner. Lake De Smet covers about 3 square miles on the divide between Boxelder and Piney Creek in the western part of the township. Clinker-capped buttes and divides rise steeply from broad open valleys east of the lake; low rolling hills occupy the remainder of the area. The maximum relief is 700 feet and the maximum altitude 5,050 feet (fig. 4).

Walters coal bed.—The Walters bed is completely burned in T. 52 N., R. 82 W., except perhaps under the highest part of the Boxelder Creek-Piney Creek divide. The resulting clinker caps high divides and buttes in the eastern and northern parts of the township.

A bed of coal which crops out about 110 feet above the Walters bed in sec. 4 is 5 feet thick in a partial exposure at locality 5. The coal is burned nearby. A bed of clinker about 240 feet above the Walters bed caps the highest point in the township in secs. 4 and 9.

Healy coal bed.—The Healy coal bed crops out 165 to 210 feet below the Walters bed in the northern and eastern parts of the township. It contains 19 feet 2 inches of coal, not including a 2-inch parting of shale, at locality 7 in section 12, and it has about the same thickness in partial exposures at localities 3 and 4 in secs. 2 and 3. The logs of holes drilled in the southeastern part of the township indicate that the Healy bed thickens along the east side of Lake De Smet. The Healy bed is 27 feet thick in hole 65, 45 feet thick in hole 66, and 112 feet thick in hole 305. Core hole GS–2A, drilled a few hundred feet

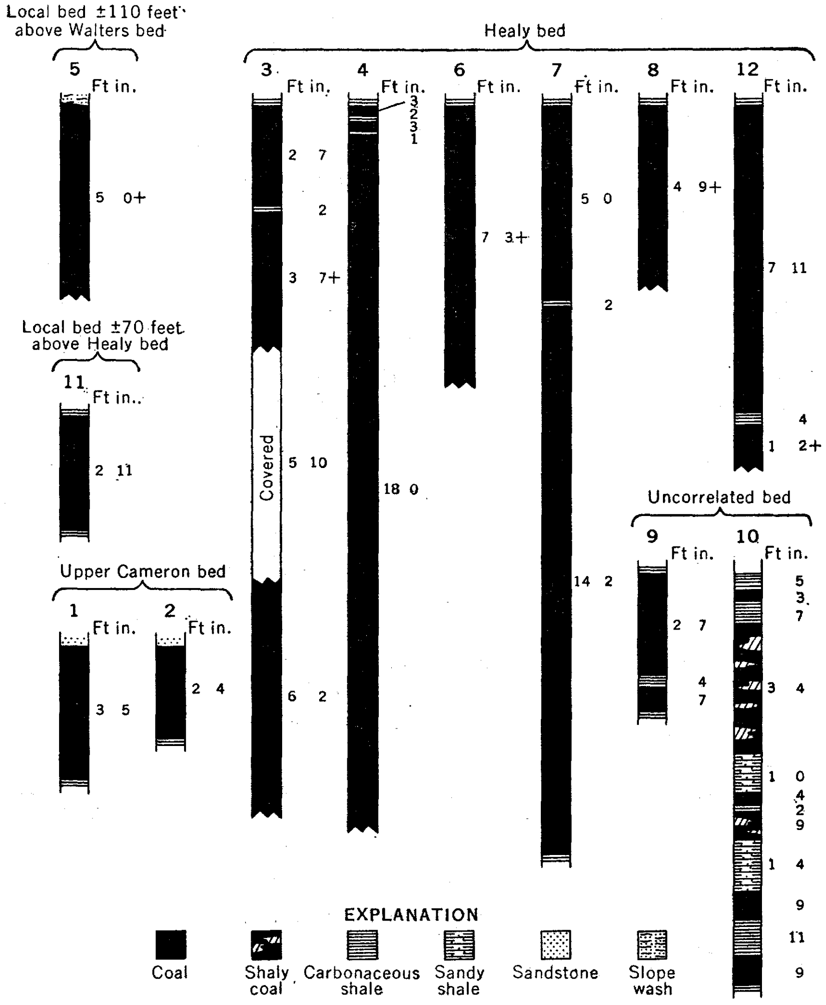


FIGURE 4.—Sections of coal beds in T. 52 N., R. 82 W.

east of Lake De Smet in sec. 8, found 53 feet of coal including a few thin partings of shale in the Healy bed. Core hole GS–3, drilled west of the lake in the SW¼ sec. 6, found about 60 feet of coal and thin partings of shale beneath 101 feet of clinker in a bed tentatively correlated with the Healy. Graphic logs of these and other holes drilled in the township are shown on plates 12 and 13. The thick Healy bed apparently interfingers southwestward with sandstone and shale within a short distance of Lake De Smet, as only a few thin stringers of coal and carbonaceous shale crop out at the horizon of the bed in the low hills that border the lake in the southwestern part of the township.

A bed of coal 2 feet 11 inches thick crops out at locality 11 in sec. 23 about 70 feet above the Healy bed. Clinker that resulted from burning of this bed covers an area of about a square mile in secs. 22, 23, 26, and 27.

A coal bed about 8 feet thick is visible about 40 feet above the Healy bed in secs. 35 and 36 of the township to the north. This bed may extend for a short distance into the northern part of T. 52 N., R. 82 W.

Upper Cameron coal bed.—The Upper Cameron bed is exposed 110 feet below the Healy bed at localities 1 and 2 in sec. 1 where it contains 3 feet 5 inches and 2 feet 4 inches of coal, respectively. The bed could not be traced southwestward from these localities because of a thick mantle of slope wash in the valley of Boxelder Creek; however, drillers logs of seismograph shotholes 62 and 64 in secs. 14 and 23 show a bed of coal 11 to 12 feet thick near the horizon of the Upper Cameron bed, and the bed may be continuous in the intervening area.

A bed of carbonaceous shale containing as much as 6 feet 2 inches of coal and shaly coal in thin benches crops out west of Lake De Smet at localities 9 and 10 in secs. 19 and 20. This bed is about 100 feet below clinker believed to have been produced by burning of the Healy bed. The lenses and stringers of coal and carbonaceous shale that crop out nearby, may be the basal part of the thick coal found in drill hole GS–3 and in other holes drilled in the adjacent township to the west.

Unexposed coal beds.—Exposures in townships to the north and east indicate that the Murray bed, about 180 feet below the Healy bed may extend under the northeastern part of T. 52 N., R. 82 W., with, an average thickness of 5 feet of coal, and that the Ucross bed, about 290 feet below the Healy bed, may extend under the northeastern part with an average thickness of 8 feet of coal.

T. 52 N., R. 83 W.

T. 52 N., R. 83 W., lies adjacent to the steep east flank of the Bighorn Mountains. The ground surface is hilly with the greatest relief near the mountains. Sandstone and shale of the Wasatch formation underlie about two-thirds of the township east of a broad ridge that extends from sec. 18 southeastward to sec. 33. Non-coal-bearing Mesozoic and Paleozoic rocks which flank the mountains are exposed in the southwestern corner. The maximum relief is 2,020 and the maximum altitude is 6,500 feet.

Healy(?) coal bed.—Holes drilled in secs. 1, 2, and 12 penetrated a thick bed of coal tentatively correlated with the Healy bed. The logs of these holes are shown on plate 12. The coal is partly burned and the resulting clinker caps low hills along the eastern side of secs. 1

and 12. The U. S. Bureau of Reclamation in 1948 and 1950 and the U. S. Geological Survey in 1950 each drilled two core holes through the total thickness of the bed in this township. Holes 7 and 200, drilled by the Bureau of Reclamation, found 134 feet and 126 feet, respectively, of coal and thin partings of shale and holes GS–1 and GS–6 found 118 feet and 115 feet, respectively, of coal and thin partings of shale. In hole GS–6, sec. 1, the coal is overlain by 176 feet of sandstone and shale and the thickness found probably represents the total thickness of coal originally deposited. In the other holes the coal is overlain by stream gravel or clinker ranging in thickness from 24 feet to 95 feet and at these places the upper part of the bed has been destroyed by erosion or burning.

J. E. Rice of Sheridan, Wyo., drilled 4 holes with rotary drilling equipment in the valley of Shell Creek in 1950. Hole C found 223 feet of coal beneath 40 feet of stream gravel and slope wash, and hole F found 126 feet of coal beneath 70 feet of stream gravel and shale. The remaining two holes, D and E, were drilled to depths of 85 and 90 feet, respectively, through gravel, shale, and coal but probably did not reach the base of the thick coal bed.

The extent of the coal westward beyond the area explored by drilling is unknown and data from hole D is inconclusive in establishing the southwestern margin of the bed; however, the upper part of the Healy(?) bed is burned and the lower part appears to grade laterally into sandstone and shale a mile or two southwest of hole D where exposures of the gently dipping bedrock permit examination of this horizon at the surface.

Thin beds of coal crop out at a few places along Shell Creek near stream level in sec. 12 and the SE¼ sec. 1, but coal in the exposed parts of these beds is less than 2 feet thick. They probably represent outcroppings of the upper part of the thick Healy(?) coal found nearby in drill holes.

T. 51 N., R. 80 W.

Most of T. 51 N., R. 80 W., is drained by the tributaries of Dry Creek, which flows in a broad valley northeastward through the central part of the township. The ground surface rises from this valley to a high clinker-capped divide between Dry and Clear Creeks in the northwestern part of the township and to a slightly lower divide between Dry and Crazy Woman Creeks in the southeast corner. Aside from the relatively smooth and level gound along Dry Creek and the mouths of its larger tributaries, the land surface is deeply dissected and rough with local areas of badlands in the southeastern part of the area. The maximum relief is about 720 feet and the maximum altitude about 4,800 feet (pl. 21).

Walters coal bed.—The Walters bed is the highest coal bed exposed in T. 51 N., R. 80 W. It crops out at locality 7 in sec. 4, and localities 14 and 15 in sec. 8 on the Dry Creek-Clear Creek divide where, at locality 14, it contains 27 feet 7 inches of coal not including several thin partings of shale. At most other places the Walters bed has burned, producing a thick clinker which caps buttes and divides in the northwestern and southeastern parts of the township.

Healy coal bed.—The Healy bed crops out northwest of Dry Creek 165–175 feet below the Walters bed and southeast of Dry Creek 155–165 feet below the Walters bed. At locality 53 near the middle of the township it contains a maximum of 23 feet of coal exclusive of several thin partings of shale. The bed thins northwestward to 10 feet 4 inches of coal at locality 13 in sec. 6. The coal splits eastward and at locality 130 in sec. 35 shale partings 3 feet 8 inches and 6 feet 7 inches thick divide the bed into 3 nearly equal benches of coal whose aggregate thickness is about 13 feet. At many places the bed has burned and its outcrop is marked by thick masses of clinker.

Schuman coal bed.—The Schuman bed crops out 15 to 25 feet below the Healy bed. It contains a maximum observed thickness of 4 feet 8 inches of coal in an incompletely exposed section at locality 52 in sec. 16 and is 4 or more feet thick nearby at localities 25, 31, 49, and 105. The bed thins southwestward to less than 2 feet in the southwestern part of the township.

A local bed 15 to 20 feet below the Schuman bed is exposed at several places along the Dry Creek-Crazy Woman Creek divide. It contains 4 feet 11 inches of coal at locality 122 in sec. 33 and is more than 3 feet thick in this vicinity at localities 98, 101, 107, and 128.

Timar coal bed.—The Timar bed, 55 to 60 feet below the Healy coal bed, is a thin but persistent coal found in all but the southwestern part of the township. It contains 3 feet 10 inches of coal but is broken by many partings at locality 89 in sec. 24. At most other localities it contains less than 2½ feet of coal. A bed containing 2 feet of coal crops out about 15 feet below the Timar bed at localities 85 in sec. 24, and 131 in sec. 35.

Lower Cameron coal bed.—A bed of coal tentatively correlated with the Lower Cameron coal bed in the township to the west crops out 100 to 110 feet below the Healy bed in the western and central parts of T. 51 N., R. 80 W. It is 4 feet 3 inches thick with no shale partings at locality 120 in sec. 32, but thins eastward and northward. This bed splits into an upper and lower bench separated by 3 to 13 feet of shale in the central part of the township, but neither bench contains more than 3 feet of coal.

Local lenses of coal lie about 45 feet below the Lower Cameron bed in the southeastern corner of the township at localities 103, 132, and 136. The coal at this horizon has a maximum thickness of 3 feet 2 inches at locality 136.

Dry Creek coal bed.—The Dry Creek bed is exposed about 165 feet below the Healy bed in the stream bank of Dry Creek at locality 121 in sec. 32, where it contains 8 feet 8 inches of coal not including partings. Outcrops of coal at localities 6 in sec. 3 and 135 in sec. 36 are near the same horizon and are tentatively correlated with the Dry Creek bed although the bed could not be traced across the intervening area.

Ucross coal bed.—The Ucross bed which lies 260 feet below the Healy bed in the township to the south is represented in T. 51 N., R. 80 W., by several thin beds of coal in a zone 20 to 40 feet thick exposed in the bank of Dry Creek at localities 34, 76, and 77. One of these beds at locality 76 in sec. 22 contains 4 feet 2 inches of coal, exclusive of a shale parting 1 inch thick near the top.

A local bed of coal is exposed 50 feet above the Ucross bed at locality 133 in sec. 36 where it contains 2 feet 10 inches of coal, not including a 6-inch parting of shale.

A local bed that contains 2 feet 1 inch of coal crops out 40 feet below the Ucross bed at locality 33 in sec. 13.

T. 51 N., R. 81 W.

Clear Creek flows northeastward in a broad valley across the central part of T. 51 N., R. 81 W. Narrow steep-sided ridges that trend almost at right angles to Clear Creek extend from a high divide between Clear and Dry Creek in the southeast corner and from the divide between Clear and Boxelder Creeks in the township to the west. The maximum relief is about 520 feet and the maximum altitude about 4,800 feet (pl. 22).

Walters coal bed.—Clinker produced by burning of the Walters bed covers high divides and isolated buttes in many parts of the township. The bed contains 34 feet 11 inches and 32 feet 2 inches of coal and shale partings at locality 24 in sec. 13 and locality 38 in sec. 23, respectively. The bed has been destroyed by burning or erosion except for small areas in the vicinity of these two outcrops.

A bed of clinker about 125 feet above the Walters bed caps a hill in the NE¼ sec. 34 on the highest part of the Clear Creek-Dry Creek divide.

Healy coal bed.—The Healy bed crops out 160 to 170 feet below the Walters bed on the sides of divides and buttes in many parts of the township. The Healy bed is estimated to be about 18 feet thick in T. 51 N., R. 81 W.; however, the bed generally is poorly exposed and no complete sections this thick were found. The Healy bed is 16 feet 1 inch thick, including partings, in an incomplete exposure at locality 13 in sec. 5 and 14 feet 11 inches thick, including partings, in an incomplete exposure at locality 25 in sec. 14. Small amounts of coal were mined from a now flooded adit near locality 39 in sec. 25. The workings at this place are reported to extend about 160 feet into the lower part of the bed. The Healy bed has burned extensively and its outcrop is marked at many places by a conspicuous band of clinker.

Schuman coal bed.—The Schuman bed lies about 20 feet below the Healy bed at localities 22 in sec. 9 and 26 in sec. 15. The bed is less than 2 feet thick at both localities, and was not seen elsewhere in the township.

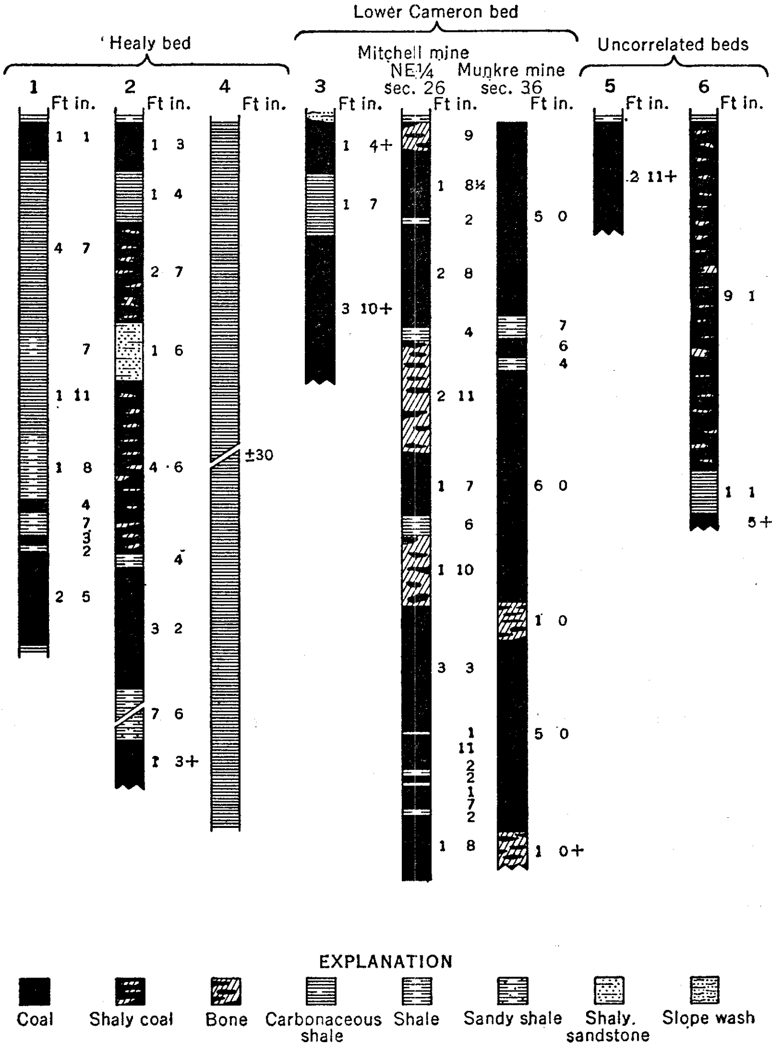
Lower Cameron coal bed.—A coal bed, correlated with the lower bed of the Cameron coal zone in the township to the north and referred to as the Lower Cameron bed, crops out about 120 feet below the Healy bed along both sides of Clear Creek. The Lower Cameron bed is about 2 feet thick in the northern and central parts of the township, but it thickens southwestward to 7 feet 11 inches at locality 32 in sec. 17, and to 9 feet 7 inches at locality 36 in sec. 20; these measurements include minor shale partings. It is 13 feet 9 inches thick in the Clear Creek Coal Co. mine at locality 37 in sec. 20.

Two thin coal beds separated by 9½ feet of non-coal-bearing rock crop out near the horizon of the Lower Cameron bed at locality 20 in sec. 9. The uppermost of these beds may correlate with the upper coal of the Cameron zone in the township to the north.

Unexposed coal beds.—Exposures in adjacent areas suggest that at least two important coal beds older than the Lower Cameron bed underlie parts of T. 51 N., R. 81 W. The first of these is the Murray bed which lies 180 feet below the Healy bed in the adjoining township to the north. The Murray bed may extend under the northern part of T. 51 N., R. 81 W., with an average thickness of about 6 feet. The Ucross bed, which crops out 270 to 280 feet below the Healy bed in the adjoining townships to the northeast and southeast is inferred to underlie most of the township with an average thickness of about 12 feet.

T. 51 N., R. 82 W.

Most of T. 51 N., R. 82 W., is drained by Rock and French Creeks, which flow southeastward to join Clear Creek near the town of Buffalo. The southwestern quarter of the township consists of high steep-sided flat-topped hills capped by resistant deposits of gravel. Elsewhere the land surface is gently rolling and grass-covered. The maximum relief is about 1,000 feet and the maximum altitude 5,480 feet (fig. 5).



Sections of coal in Mitchell and Munkre mines from Gale, H.S. and Wegemann, C.H., 1910. The Buffalo coal field, Wyoming: U.S. Geol. Survey Bull. 381-B, pl. 10

FIGURE 5.—Sections of coal beds in T. 51 N., R. 82 W.

Walters coal bed.—Clinker produced by burning of the Walters bed caps a high hill in the NW¼ sec. 1. West and south of this exposure, the Walters bed is represented by carbonaceous shale.

Healy coal bed.—The Healy bed, which in the adjoining township to the east lies 160 to 170 feet below the Walters bed, crops out on hills along both sides of Rock Creek in the southeastern part of T. 51 N., R. 82 W. The bed is burned at many places to form thick masses of clinker. At locality 2 in sec. 14 the bed contains 14 feet 8 inches of coal and shale in an upper bench and at least 1 foot 3 inches of coal in a lower bench, the two benches separated by 7 feet 6 inches of shale. Seismograph shotholes in sections 13 and 14 found from 9 to 56 feet of coal and shale partings near the horizon of the Healy bed. At locality 4 in sec. 25 south of Rock Creek the Healy coal bed is represented by a bed of brown carbonaceous shale 30 feet thick.

A bed of clinker occurs about 80 feet above the Healy bed in secs. 12 and 13. The clinker may be traced eastward for a short distance into the township to the east. The coal that produced the clinker grades westward into carbonaceous shale in sec. 12.

Lower Cameron coal bed.—The Lower Cameron coal bed crops out in an incomplete exposure at locality 3 in sec. 25 where it contains at least 5 feet 2 inches of coal excluding partings. Coal produced from the nearby Mitchell and Munkre mines probably came from this bed. According to Gale and Wegemann (1910, p. 162), the Mitchell mine in the NE¼ sec. 26 was worked from an inclined adit driven to a depth of about 125 feet, and the Munkre mine in the NE¼ sec. 35 and the SW¼ sec. 36 was worked from a shaft 85 feet deep.

Uncorrelated beds.—A bed of coal at least 2 feet 11 inches thick crops out at the level of Clear Creek at locality 5 in sec. 35, and a bed of shaly coal and shale 10 feet 7 inches thick is exposed in a coulee at locality 6 in sec. 36. Neither of these beds could be traced to nearby areas.

T. 50 N., R. 80 W.

Dry Creek flows northward along the west edge of T. 50 N., R. 80 W., and Crazy Woman Creek flows northeastward across secs. 35 and 36. The two streams are separated by a broad clinker-capped divide that trends northeastward across the central part of the township. The land surface is gently rolling in the southern part but becomes more broken in the northern part. The maximum relief is about 575 feet and the maximum altitude is 4,700 feet (pl. 23).

Walters coal bed.—The Walters coal bed, which is the highest coal bed exposed in the township, has burned extensively to produce thick masses of clinker which cap the Dry Creek-Crazy Woman Creek divide and many outlying buttes and ridges. The bed contains 15 feet 10 inches of coal, exclusive of partings, in an isolated unburned area at locality 50 in sec. 19.

Healy coal bed.—The Healy bed, 155 to 170 feet below the Walters bed, crops out along the sides of the Dry Creek-Crazy Woman Creek divide and on hills west of Dry Creek in sec. 6. The bed contains a maximum observed thickness of 25 feet of coal, exclusive of partings, at locality 51 in sec. 21, and it is 10 or more feet thick at several other localities in the central and northern parts of the township. The coal thins rapidly in the southeastern part of the township, and at locality 70 in sec. 26 the Healy bed consists of about 9 feet of carbonaceous shale containing 1 foot 11 inches of coal.

A bed of coal 5 feet 3 inches thick, including minor shale partings, crops out 40 feet above the Healy bed at locality 6 in sec. 1, but the bed could not be traced to nearby areas.

Beds of clinker crop out between the Healy and Walters beds at several places in the township, notably in secs. 31 and 32 where clinker about 100 feet stratigraphically above the Healy bed caps several low hills. Where unburned, none of the coals that produced the clinkers are as much as 2 feet thick.

Timar coal bed.—The Timar bed crops out 55 to 60 feet below the Healy bed along the eastern side of the Crazy Woman Creek-Dry Creek divide. At locality 7 in sec. 1 the coal occurs in an upper bench 5 feet 3 inches thick and a lower bench 2 feet 9 inches thick separated by about 4½ feet of shale. A third bed 8 feet lower contains 2 feet 4 inches of coal. The Timar bed thins southward and is less than 2 feet thick in the southern part of the township.

Lower Cameron coal bed.—A bed of coal correlated with the Lower Cameron coal bed of T. 51 N., R. 81 W., crops out about 100 feet below the Healy bed along the eastern side of T. 50 N., R. 80 W. At most places this bed is from 2 to 3 feet thick, with a maximum observed thickness of 5 feet of coal, including 2 feet 4 inches of shaly coal in the upper part of the bed, at locality 25 in sec. 11. The bed is 3 feet 11 inches thick at nearby locality 30.

A local coal bed 25 to 30 feet above the Lower Cameron bed crops out discontinuously in the southeastern and northeastern parts of the township. This bed contains 4 feet 5 inches of coal, excluding partings, at locality 8 in sec. 1, and it is about 3 feet thick at localities 85, 90, 99, 102, and 104 in secs. 34, 35, and 36.

Dry Creek coal bed.—The Dry Creek bed is exposed 160 to 165 feet below the Healy bed in the southeastern corner of T. 50 N., R. 80 W. It has a maximum observed thickness of 3 feet 6 inches of coal at locality 92 in sec. 34. Lenses of coal at localities 4 and 10 in sec. 1 and at localities 44 and 64 in secs. 14 and 24, respectively, are near the stratigraphic position of the Dry Creek bed, but they could not be traced for more than a few hundred feet.

Ucross coal bed.—The lowest coal bed exposed in T. 50 N., R. 80 W., is the Ucross bed which lies about 250 to 260 feet below the Healy bed and crops out near the level of Crazy Woman Creek in the southeastern corner of the township and at other points along the township's eastern edge. The Ucross bed contains 11 feet 5 inches of coal, excluding partings, at locality 107 a short distance east of sec. 36, but the bed thins northward to about 4 feet at locality 1 in sec. 1.

Local lenses of coal as much as 2½ feet thick are exposed 50 to 70 feet above the Ucross bed at localities 3, 9, 33, 35, and 36 in secs. 1, 12, and 13.

T. 50 N., R. 81 W.

Most of T. 50 N., R. 81 W., is drained by Dry Creek and its intermittent tributaries, the largest of which is Nigger Creek. A small area in the northwestern part is drained by streams tributary to Clear Creek. A high gravel-topped divide extends along the southern and western side of the township, and steep-sided clinker-capped hills occupy the interstream area between Nigger and Dry Creeks. Rolling hills and brush- and grass-covered flats characterize the remainder of the township. The maximum relief is about 800 feet and the maximum altitude about 5,120 feet (fig. 6).

Walters coal bed.—The Walters bed is the stratigraphically highest coal bed exposed in T. 50 N., R. 81 W. Coal in the Walters bed has burned over large areas forming thick deposits of clinker. The bed crops out at locality 3 in sec. 9, where it is 7 feet thick and consists of alternating layers of carbonaceous shale and shaly coal. Neither coal nor clinker was found at the horizon of the Walters bed in the southwestern part of the township.

Healy coal bed.—The Healy bed lies 160 to 170 feet below the Walters bed and crops out near the level of Dry Creek and its tributaries in the northwestern part of the township. Slope wash conceals the bed in most places, but where the coal has burned the horizon is marked by masses of resistant clinker. The bed's maximum observed thickness is 18 feet 7 inches of coal, exclusive of partings, at locality 1 in sec. 1. The bed could not be traced into the southeastern part of the township where it may be represented by carbonaceous shale.

Unexposed coal beds.—The Ucross coal bed, about 260 feet below the Healy bed in the township adjoining to the east, may underly the northeastern part of T. 50 N., R. 81 W., with an average thickness of about 7 feet.

T. 50 N., R. 82 W.

No coal is exposed in T. 50 N., R. 82 W.; however, coal beds which crop out in the townships to the north and east may underlie at least part of it. The Healy bed crops out in sec. 6 of the township to the east and may extend underground beneath secs. 1 and 12. The Lower Cameron bed, found 85 feet below the surface in the Munkre mine in sec. 36 of the township to the north, probably also is present underground in the northwestern part of T. 50 N., R. 82 W.

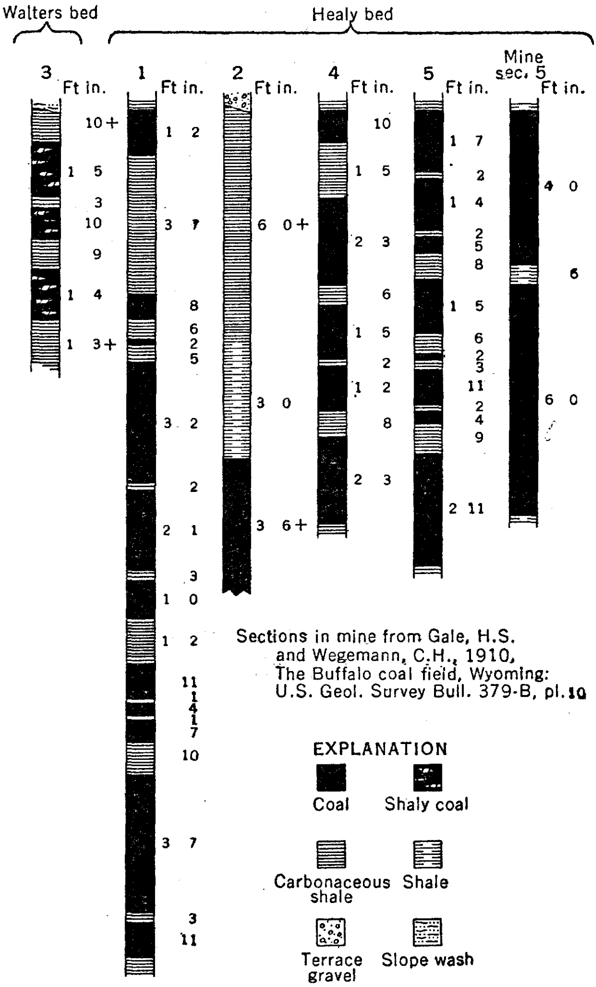


Figure 6.—Sections of coal beds in T. 50 N., R. 81 W.

LABORATORY DESCRIPTIONS OF CORES

Following are descriptions of the coal cores from six holes drilled near the north end of Lake De Smet. Holes GS–1, GS–2A, GS–3, and GS–6 were drilled by the Geological Survey and the core descriptions were furnished by J. M. Schopf and J. R. Gill. Hole A–6 was drilled by the U. S. Bureau of Reclamation, and the cores were also described by Schopf and Gill. Hole 7 was drilled by the U. S. Bureau of Reclamation and the cores described by personnel of the U. S. Bureau of Mines.

HOLE GS–I

Location: Near center of S½NE¼NE¼, sec. 1, T. 52 N., R. 83 W., Johnson County, Wyo.

	Ft	in
Overburden; silt, sand and gravel	24	
Coal reported in drilling; no cores submitted for laboratory study or sampling	27	
Shale with some coal reported in drilling; no cores submitted for laboratory study	3	
Coal probable, but no core recovered	5	
Coal, moderately medium banded, about 29 percent woody; top 2 in. includes coal crushed in drilling		10⅝
Loss in coring above 61 ft	1	1⅜
Coal, like that below		1¾
Shale, black		2½
Coal, abundantly medium and thick banded, about 39 percent woody	1	2¾
Loss in coring above 66 ft	3	5
Coal, broken in drilling		2½
Shale, black		7½
Coal, moderately thick banded, about 24 percent woody	1	6¾
Loss in coring above 71 ft	2	7¼
Coal, moderately thick banded, about 28 percent woody	1	3
Shale, black	1	1½
Coal, abundantly thick banded, about 51 percent woody	1	4¼
Loss in coring above 76 ft	1	3¼
Coal, moderately medium and thick banded, about 27 percent woody. Dip on base of bed, 12°	3	11⅝
Loss in coring above 81 ft	1	⅜
Coal, abundantly medium and thick banded, about 45 percent woody, with megascopic resin blebs at 81 ft 5 in. Bedding at top of bed nearly horizontal		10¾
Loss in coring above 82 ft 6 in		7¼
Coal, sparsely thin banded, about 10 percent woody. Dip on base of bed, 10°		4
Shale, black		5¾
Coal, about 38 percent woody		2¼
Loss in coring above 86 ft	2	6
Coal, dominantly thick and very thick banded, about 60 percent woody		1½
Shale, black with woody fragments		5½
Coal, dominantly thick and very thick banded, about 61 percent woody, resin blebs ⅛- to ¼-in. diameter scattered between 86 ft 8½ in. to 87 ft 10 in. Dip on base of bed, 11°	2	6
Loss in coring above 91 ft	1	11
Coal, abundantly medium- and thick-banded, about 34 percent woody		7¼
Loss in coring above 92 ft		4¾
Shale and coal crushed in drilling		1½
Coal, sparsely thin banded, about 8 percent woody, resin blebs ¼-in. diameter at 92 ft 4 in. and 92 ft 8 in		9
Shale, black		1
Coal, about 21 percent woody		2¾
Shale, black		1

HOLE GS–I—continued

	Ft	in
Coal, as above		1¾
Shale, black		½
Coal, dominantly thick and very thick banded, about 68 percent woody. Dip on base of bed, 11°	1	5
Shale, black		3½
Coal, moderately thin and medium banded, about 27 percent woody. Bedding at top of bed nearly horizontal		9¼
Loss in coring above 99 ft	3	¾
Coal, abundantly medium and thick banded, about 39 percent woody	1	6¼
Loss in coring above 101 ft 6 in		11¾
Shale, black		2
Coal, abundantly medium and thick banded, about 33 percent woody	1	7½
Shale, black. Bedding at base of bed nearly horizontal		5½
Loss in coring above 106 ft	2	3
Coal, abundantly medium and thick banded, about 38 percent woody, with pyritic lenses ⅛ to ¼ in. thick at 106 ft 5 in., 106 ft 7 in., 107 ft 1 in., 108 ft 1 in., and 108 ft 4 in.; megascopic resin blebs at 108 ft 1 in	2	4¾
Loss in coring above 108 ft 6 in		1¼
Coal, dominantly thick and very thick banded, about 62 percent woody		8½
Loss in coring above 111 ft	1	9½
Shale, black		1½
Coal moderately thick banded, about 18 percent woody. Bedding at top of bed nearly horizontal		9¼
Shale, black coaly		3¼
Coal, 95 percent woody derived from a large tree trunk		2¾
Shale, black, coaly, with large woody fragments	1	4¼
Coal, abundantly medium and thick banded, about 37 percent woody, with thin fusain streak at 116 ft 3 in. and fusain ½ in. thick at 117 ft 11½ in. (the thickest occurrence of fusain in this core). Dip on base of bed, 8°	4	7
Shale, black, coaly		4¾
Coal, derived entirely from a large tree trunk		6¼
Loss in coring above 121 ft	1	9
Coal, abundantly medium and thick banded, about 51 percent woody	1	2¼
Shale, black. Bedding at base of bed nearly horizontal		4¾
Coal, abundantly medium and thick banded, about 31 percent woody, with ⅛- to ¼-in. diameter resin blebs scattered at 124 ft 8 in	2	8¾
Loss in coring above 126 ft		8¼
Coal, abundantly medium and thick banded, about 33 percent woody	1	7¼
Coal, moderately medium and thick banded, about 25 percent woody	1	4¾
Loss in coring above 131 ft	2	0
Coal, moderately medium banded, about 20 percent woody, with thin fusian streak at 131 ft 1 in. and a few ¼-in. resin blebs at 131 ft 4 in. Bedding at top of bed nearly horizontal	1	4
Shale, black		8¼

HOLE GS–1—continued

	Ft	in
Coal, abundantly medium and thick banded, about 40 percent woody, with ¼-in. resin blebs at 136 ft 3½ in. Bedding at base of bed nearly horizontal	5	5¼
Loss in coring above 139 ft		6½
Coal, moderately medium banded, about 22 percent woody	2	6½
Shale, black, with large woody fragments		7½
Shale, black, pyritic		5½
Loss in coring above 144 ft. Depth 144 ft at base of this unit	1	4½

Gray shale reported on drill stem below 144 ft; gray sandy shale recovered from 151 ft to final depth of 156 ft; no laboratory study of material below 144 ft.

HOLE GS–2A

Location: Near center of N½NE¼NW¼SE¼, sec. 8, T. 52 N., R. 82 W., Johnson County, Wyo.

Remarks: The bedding as observed in this core is almost horizontal.

	Ft	in
Shale, gray and brown with thin coaly streaks overlying coal	66	
Coal, abundantly thick banded, about 40 percent woody; thin fusain at 67 ft 1 in	1	3½
Loss in coring at about 68 ft		8¼
Coal, abundantly thick banded, about 33 percent woody, with scattered resin blebs in coal at 70 ft	2	8
Loss in coring above 71 ft		4¼
Coal, abundantly thick banded, about 36 percent woody, with scattered resin blebs in upper part; thin fusain streaks at 71 ft 3½ in., 72 ft 2 in., and 72 ft 6 in	4	1
Loss in coring above 76 ft		11
Coal, abundantly thick and very thick banded, about 56 percent woody, with ¼-in. shale streaks at 77 ft 6½ in. and at 78 ft 2 in.; thin fusain at 77 ft 6 in. and 79 ft 1 in	4	8½
Loss in coring above 82 ft	1	3½
Coal, moderately medium and thick banded, over 15 percent woody, with a thin white clay streak at 82 ft 6 in. and thin fusain partings at 82 ft ¾ in. and 83 ft.; scattered resin blebs in lower part of coal	2	¾
Shale, black, clayey below 84 ft ¾ in		4½
Coal, abundantly medium and thick banded, about 35 percent woody, with thin ¼-in. shaly streaks at 85 ft 1¼ in., 86 ft ¾ in., and 86 ft 5¾ in	2	7¼
Coal, moderately medium and thick banded, about 28 percent woody, with thin fusain streaks at 88 ft 9 in. and 89 ft 10½ in	3	6½
Loss in coring above 92 ft	1	5
Coal, abundantly thick banded, about 55 percent woody, with ⅛-in. to ⅜-in. diameter resin blebs at 92 ft 7 in. and 94 ft 8 in	4	6¼
Shale band, black, at 92 ft 9 in		¾
Loss in coring above 97 ft		5
Coal, moderately medium banded, about 25 percent woody, with scattered resin blebs between 98 ft 8 in. to 100 ft	3	2½
Broken coal core		8½

HOLE GS-2A—continued

	Ft	in
Loss in coring above 102 ft	1	1
Coal above 104 ft., sparsely thin and medium banded, about 4 percent woody, with thin fusain streaks at 103 ft 7½ in. and scattered resin blebs at 103 ft 9½ in. and 104 ft 3 in	2	0
Coal below 104 ft, abundantly medium and thick banded, about 40 percent woody; small pyritic spherulites noted at 106 ft 2 in	2	7½
Shale, crushed and with some coal, occurs below 104 ft 9⅞ in		2½
Loss in coring above 107 ft		2
Coal, moderately medium and thick banded, about 30 percent woody, with some resin blebs at 108 ft 6 in	2	4
Coal and shaly coal, moderately thin and medium banded, about 17 percent woody, with thin fusain streak at 110 ft 8 in.; core is cut by a number of glossy slip planes and slickensides	2	6½
Coal, moderately medium and thick banded, about 25 percent woody; probably high ash content	1	¼
Shale, dark		1
Coal, as noted above		3⅝
Shale, dark		2½
Coal, as noted above	2	2½
Shale, dark		2⅝
Coal, as noted above		8¼
Coal, impure shaly		2
Loss in coring; condition of core suggests most of loss occurred at this position		9⅜
Shale, clayey, white		1
Coal, impure pyritic		2¼
Coal, as noted above		4⅛
Coaly shale, brown		¾
Coal, as noted above. Depth 118 ft 10 in. at base of this unit		7¼
Shale, dark clayey, above soft friable sandstone. Soft gray shale and sandstone reported below coal to final depth of 146 ft 6 in.; no laboratory study.		

HOLE GS-3

Location: Near center of W½SW¼, sec. 6, T. 52 N., R. 82 W., Johnson County, Wyo.

Remarks: Apparent dip of bedding in core ranges from approximately normal to as much as 30° at 120 ft 2½ in.; 30° at 128 ft; 22° at 130 ft 8 in.; 22° at 134 ft 2 in.; and 22° at 136 ft 9 in. Dips of lesser magnitude, approaching horizontal, are found in intervals between the more extreme dips indicated.

	Ft	in
Overburden of unconsolidated gravel and sand above 17 ft	17	0
Clinker reported in drilling; no cores submitted for laboratory study	81	0
Gray clay and coal; no laboratory study	3	0
Coal, scant recovery; no laboratory study	5	6
Coal, little or no recovery; no cores submitted for laboratory study or sampling to 118 ft 8⅜ in. Drill connections at 112 ft, 115 ft, and 117 ft 6 in	12	3

HOLE GS-3—continued

	Ft	in
Coal, abundantly medium and thick banded, about 36 percent woody; resin blebs, 1/8 to 1/4 in., scattered, at 118 ft 8 in., 119 ft 1 in., 119 ft 7 in.; thin fusain streak at 119 ft 10 in. and 122 ft 7½ in. Bedding at base of bed nearly horizontal	4	6⅝
Loss in coring above 123 ft 8⅜ in		5⅜
Siltstone, light-gray		1¼
Coal, moderately medium and thick banded, about 25 percent woody; resin blebs scattered at 125 ft 8 in. and 126 ft 5 in. Dip on top of bed, 9°. Dip on base of bed, 6°	2	9⅝
Shale, black		1
Coal, moderately thin and medium banded, about 18 percent woody; resin blebs at 127 ft. Dip on base of bed, 4°		6
Shale, black		½
Coal, abundantly medium and thick banded, about 40 percent woody; thin fusain bands at 127 ft 9½ in. and 128 ft 10½ in. Bedding at top of bed nearly horizontal. Dip on base of bed, 30°	1	½
Loss on coring above 128 ft 8⅜ in		5⅛
Coal, abundantly medium and thick banded; about 38 percent woody; resin blebs scattered between 129 ft 7 in. and 130 ft 2 in. and at 131 ft, and 131 ft 8 in.; thin fusain streak at 132 ft. Dip on top of bed, 9°	3	9⅛
Shale, dark-gray		1½
Coal, moderately medium and thick banded; about 21 percent woody; thin fusain streak at 133 ft 2 in. Bedding at base of bed nearly horizontal		8
Loss in coring above 133 ft 4⅝ in		1⅝
Coal, abundantly thick and very thick banded; about 55 percent woody. Dip on top of bed, 7°. Dip on base of bed, 18°	2	3⅞
Loss in coring above 136 ft		3½
Coal, like that above. Dip on base of bed, 22°		7¾
Shale, black, with thin woody streaks above 136 ft 9½ in		1½
Coal, abundantly medium and thick banded; about 40 percent woody; resin blebs, ¼ in., at 137 ft 1 in., 139 ft 2 in., and 140 ft 4 in.; thin fusain streaks at 136 ft 10½ in., 138 ft 7 in.; pyritic band, ⅛ in. thick, at 138 ft 2½ in. Dip on top of bed, 22°. Dip on base of bed, 6°	4	2¼
Loss in coring above 141 ft		½
Coal, abundantly thick and very thick banded; about 41 percent woody; thin fusain streak at 141 ft 1 in	2	8½
Loss in coring above 144 ft 7¼ in		10¾
Coal, abundantly medium and thick banded; about 33 percent woody. Dip on base, 10°	4	7
Loss in coring above 149 ft 3⅝ in		1⅜
Shale, black		¾
Coal, abundantly medium banded; about 33 percent woody; thin fusain streak at 150 ft 3 in	1	8⅛
Loss in coring above 151 ft 5½ in		5

HOLE GS–3—continued

	Ft	in
Coal, moderately thin and medium banded; about 28 percent woody; thin fusain streak at 152 ft 3 in.; resin blebs, yellow, ¼-in. diameter, at 153 ft 2 in. Dip on top of bed, 9°	2	4¾
Loss in coring above 154 ft 2⅜ in		4⅛
Coal, moderately medium banded; about 23 percent woody; thin fusain streaks at 158 ft 3½ in. and 158 ft 8 in.; resin blebs at 158 ft 8½ in.; ⅛-in. pyritic lens at 158 ft 11½ in. Dip on top of bed, 8°. Bedding at base of bed nearly horizontal. Depth 159 ft 8½ in. at base of this unit	5	6⅛
Shale, black, pyritic		3½
Sandstone, light-gray, pyritic		6
Loss in coring above 160 ft 8⅜ in		2⅜
Core lost, friable sandstone interpreted by driller from 160 ft 8⅜ in. to 166 ft; gray sandy shale recovered from 166 ft to 175 ft; no laboratory study below 160 ft 8⅜ in.		

HOLE GS–6

Location: Near center of SW¼NW¼, sec. 1, T. 52 N., R. 83 W., Johnson County, Wyo.

Remarks: Apparent dip of bedding in core ranges from approximately horizontal to as much as 40° at a depth of 173 ft 3½ in., 22° at 208 ft 11 in., 25° at 218 ft 5 in., 32° at 230 ft 1⅜ in., and 30° at 248 ft 2¾ in. and 279 ft 7½ in. (Dips of lesser magnitude, approaching horizontal, intervene between all the more extreme dips cited.)

	Ft	in
Sandstone, light-gray, coarse- to fine-grained with thin streaks of brown carbonaceous siltstone; overlies coal to depth of 172 ft	172	0
Clay shale, black, with a few woody fragments		6½
Coal, moderately medium banded, about 25 percent woody with pyritic lenses ¼ to ⅜ in. thick at 172 ft 10 in. and 173 ft 1 in. Dip on top of bed, 13°	1	1⅞
Shale, black		2⅝
Coal consisting of one woody trunk. Dip on base of bed, 10°		⅞
Shale, black		2¼
Coal abundantly medium and thick banded, about 45 percent woody. Dip on base of bed, 22°		6½
Shale		⅜
Coal, abundantly medium banded, with one very thick band, probably from a large tree trunk; coal about 41 percent woody. Resin blebs about ¼-in. diameter occur at 175 ft 2½ in. and 175 ft 5 in	1	10¾
Shale, black		1⅜
Coal, about 50 percent woody with scattered resin blebs. Dip on top of bed, 24°		4½
Shale, black, coaly near the top with scattered woody fragments		10
Loss in coring above 182 ft	4	½
Shale, black, with woody fragments		3¾
Coal, moderately medium banded, about 25 percent woody. Dip on top of bed, 27°		3⅛

HOLE GS-6—continued

	Ft	in
Siltstone, light-gray to buff, with contorted woody fragments		9½
Coal, abundantly medium and thick banded, about 48 percent woody, with ⅛-in. white clay streak at 184 ft 5 in. Dip on top of bed, 14°. Dip on base of bed, 15°	1	10
Loss in coring above 186 ft		9½
Shale, light-gray, with a few woody fragments	1	6⅞
Coal, abundantly medium and thick banded, about 50 percent woody, with resin blebs at 188 ft 2 in. Bedding at top of bed nearly horizontal	1	4⅛
Shale, black with woody fragments		3⅝
Coal, moderately medium banded, about 15 percent woody		8⅝
Shale, gray, coaly in part		6½
Coal, derived from a single woody trunk		4
Shale, dark-gray		8¼
Coal, completely woody, above 191 ft 7⅛ in. Bedding at top of bed nearly horizontal		1⅛
Coal, moderately medium banded, about 16 percent woody		4⅝
Clay shale, gray		2¼
Coal, derived from a single woody trunk		3½
Shale, dark		1
Coal, woody with pyritic lens ¼ in. thick		3
Shale, dark, with woody fragments		3½
Coal, sparsely medium banded, about 10 percent woody, with pyritic lens ⅛ in. thick at 192 ft 4 in		8¾
Pyritic band		1½
Coal, abundantly medium and thick banded, about 35 percent woody, with frequent resin blebs ¼-in. diameter from 194 ft 2 in. to 194 ft 10 in		11⅝
Loss in coring above 195 ft		1⅛
Coal, moderately medium and thick banded, about 26 percent woody, with a thin fusain streak at 195 ft 1 in	2	4¾
Shale, black, coaly		3⅝
Coal, about 50 percent woody		2
Shale, black, coaly, with large woody fragment at 198 ft 3½ in		9⅝
Coal, dominantly very thick banded, about 70 percent woody, derived from a few large tree trunks; resin blebs ¼-in. diameter at 199 ft 6 in. and 199 ft 10 in	1	2¾
Shale, black, and siltstone, gray, with woody fragments in the darker matrix		7¼
Shale and coal crushed in drilling		1½
Coal, about 24 percent woody		3¾
Pyritic band		1¼
Shale, black, in part coaly, with woody bands		6½
Coal, moderately medium and thick banded, about 26 percent woody, with yellow resin blebs ¼-in. diameter at 201 ft 8 in. and 202 ft ¼ in	3	5¼
Partially mineralized (siliceous?) wood, grain badly distorted. Dip on top of bed, 12°	1	4¼

HOLE GS-6—continued

	Ft	in
Coal, abundantly medium and thick banded, about 37 percent woody, with thin fusain streaks at 206 ft 10 in. and 207 ft		8
Shale, black		2
Coal, moderately thin and medium banded, about 20 percent woody, resin blebs ¼-in. diameter scattered from 207 ft 5 in. to 207 ft 9 in., and shale streak ⅛ in. thick at 207 ft 10 in. Dip on top of bed, 13°. Dip on base of bed, 15°		11
Clay shale, black, with numerous woody fragments		7½
Coal, abundantly medium and thick banded, about 50 percent woody. Dip on top of bed, 22°		3⅝
Shale, black and gray with thick woody fragments		7½
Loss in coring above 210 ft		3⅞
Shale, dark, with resin blebs		1
Coal, moderately thin and medium banded, about 16 percent woody		6¼
Shale, brown with small vitrain streaks		8¾
Coal, moderately medium banded, about 20 percent woody, with ¼ in. gray shale streak at 211 ft 8 in. and thin fusain lenticle at 212 ft ½ in. Dip on top of bed, 18°. Dip on base of bed, 12°		9⅛
Shale, black, woody fragments in top 3 in., blebs of resin at 212 ft 2 in. and 212 ft 4 in		10½
Coal, dominantly thick and very thick banded, with resin blebs ⅛- to ¼-in. diameter at 213 ft 7 in. and 214 ft; a coaly tree trunk 7½ in. thick occurs below 212 ft 11½ in. Dip on base of bed, 22°	2	½
Shale, black		2⅞
Coal, attrital, about 10 percent woody		1½
Shale, black, coaly		3¾
Coal, moderately medium banded, about 18 percent woody. Dip on base of bed, 25°		6⅛
Shale, black, coaly towards top	1	5⅝
Coal, moderately medium banded, about 20 percent woody, with fusain band ⅜ in. thick below 217 ft 9 in. Dip on top of bed, 10°		6
Shale, black		7¼
Loss in drilling above 220 ft	1	2¾
Shale, black, with a few woody fragments above 222 ft ¾ in	2	¾
Coal, abundantly medium and thick banded, about 57 percent woody, shale lenticles at 222 ft 3¾ in. and 222 ft 1½ in	1	9¼
Shale, black, with numerous woody fragments in upper and lower parts, resin blebs at 224 ft 7 in	2	6¾
Coal, moderately medium banded, about 25 percent woody, ¼-in. fusain lenticle at 226 ft 7¼ in. Dip on base of bed, 23°	1	4
Shale, black, with frequent woody fragments	1	3
Coal, dull luster, with frequent woody fragments. Dip on base of bed, 20°		3½
Shale, black		3¾
Loss in drilling above 230 ft 1⅜ in		6⅜
Coal, abundantly medium banded, about 40 percent woody. Dip on top of bed, 32°. Dip on base of bed, 36°		9⅛
Shale, black with woody fragments		4

HOLE GS-6—continued

	Ft	in
Coal, abundantly medium banded, about 36 percent woody, with 1/8-in. shale streak at 231 ft 5 in. and 1/4-in. resin blebs at 232 ft to 232 ft 2 in.; 3/4-in. fusain band at 233 ft. Dip on top of bed, 18°. Dip on base of bed, 21°	2	3 1/2
Siltstone, light-gray, carbonaceous with small woody fragments		3 1/2
Coal, moderately medium banded, about 29 percent woody, with thin fusain streaks at 233 ft 10 in., 234 ft 2 in., 234 ft 11 in., and 235 ft 9 in.; resin blebs 1/4-in. diameter at 235 ft 11 in. Dip on base of bed, 30°	2	4 1/4
Shale, black, with scattered woody fragments		10
Loss in coring above 238 ft 8 3/4 in	1	8 3/4
Shale, dark, with occasional woody fragments		11 1/4
Coal, abundantly medium and thick banded, about 43 percent woody, with resin blebs at 240 ft 1 in	1	1 1/4
Loss in drilling above 242 ft 8 3/8 in	1	11 3/8
Coal, moderately medium banded, about 16 percent woody, with thin fusain lenticle at 242 ft 11 in. Scattered resin blebs 1/8- to 1/4-in. diameter from 242 ft 9 in. to 243 ft 5 in. Bedding at top of bed nearly horizontal. Dip at base of bed, 5°		11 1/4
Shale, black, with fragments of fusain and woody debris		4 3/4
Coal, abundantly medium and thick banded, about 31 percent woody, thin fusain lenticles at 244 ft 1 in. and 244 ft 7 in.; resin blebs 1/4- to 1/8-in. diameter scattered from 245 ft to 245 ft 6 in. Bedding at top of bed nearly horizontal. Dip on base of bed, 23°	2	6 3/4
Loss in drilling above 247 ft 2 3/8		7 1/4
Shale, dark, with numerous small woody fragments		4 1/2
Coal, dominantly medium and thick banded, about 86 percent woody. Dip on top of bed, 10°		8
Shale, black, with woody fragments		5
Coal, moderately medium banded, about 20 percent woody. Dip on top of bed, 30°. Dip on base of bed, 26°	1	1/4
Shale, black, with numerous woody fragments		5
Coal, sparsely thin banded, about 4 percent woody. Dip on top of bed, 20°. Dip on base of bed, 37°		4 1/2
Shale, soft, black		4
Coal, dominantly thick and very thick banded, about 82 percent woody, thin fusain streak at 252 ft 1 in. Dip on top of bed, 26°. Dip on base of bed, 18°	1	4 1/4
Shale, black, with woody fragments		2 5/8
Coal, moderately medium banded, about 35 percent woody, with resin blebs 1/8- to 1/4-in. diameter at 252 ft 7 in. Dip on top of bed, 26°	1	2
Loss in drilling above 254 ft 3 5/8 in		9
Coal, derived from a single woody stem. Dip on base of bed, 16°		2 1/4
Shale, dark, abundant woody fragments		4 1/4
Coal, abundantly medium banded, about 34 percent woody with thin fusain lenticle at 255 ft 4 in. Dip on top of bed, 20°		7 5/8
Shale		3/8

HOLE GS-6—continued

	Ft	in
Coal, abundantly medium and thick banded, about 31 percent woody, thin fusain band at 255 ft 6½ in., resin blebs ¼- to ⅛-in. diameter at 255 ft 9 in. and 256 ft 1 in. Dip on top of bed, 22°. Dip on base of bed, 30°	2	2¾
Shale, black, few woody fragments		5⅜
Coal, dominantly thick and very thick banded, about 80 percent woody. Dip on base of bed, 25°	1	2⅛
Shale, black, few woody fragments		2¼
Coal, dominantly thick and very thick banded, about 84 percent woody. Dip on base of coal, 28°	1	1¾
Shale, black, many woody fragments		4¼
Loss in drilling above 262 ft		11½
Coal, moderately medium and thick banded, about 28 percent woody, ¼-in. resin bleb at 264 ft 10 in	3	7¾
Shale, black, few woody fragments		7¾
Coal, moderately medium banded, about 25 percent woody, resin bleb at 266 ft 10 in. Dip on base of bed, 24°		8
Clay shale, gray, with moderate number of woody fragments		9½
Coal, moderately medium and thick banded, about 28 percent woody, with thin fusain streaks at 268 ft 2¼ in., 269 ft 4 in., and 269 ft 6 in.; resin blebs ¼-in. diameter at 270 ft 2 in. Bedding at top of bed nearly horizontal. Bedding at base of bed, 12°	2	8¼
Clay shale, with woody fragments. Dip at base of bed, 12°		5¼
Loss in drilling above 272 ft	1	1½
Coal, abundantly medium and thick banded, about 46 percent woody	1	2½
Clay shale, black		8¼
Coal, moderately medium and thick banded, about 28 percent woody, ⅛-in. resin blebs at 276 ft, thin fusain lenticle at 276 ft 3 in. Dip on top of bed, 15°	2	5
Shale, black, with few woody fragments and resin blebs		4¾
Coal, abundantly medium and thick banded, about 33 percent woody. Dip on base of bed, 20°	1	9¼
Siltstone, light-gray, with large woody fragments		4¼
Coal, with ½-in. band of fusain at 278 ft 11½ in		1¾
Loss in drilling above 279 ft 3⅝ in		3⅞
Coal, broken		2⅜
Band of pyritic wood		1½
Coal, abundantly thick and very thick banded, about 50 percent woody, above 282 ft 3⅝ in	2	8⅛
Shale and coal crushed in drilling		2½
Coal, moderately medium banded, about 27 percent woody. Dip on top of bed, 13°	1	5
Loss in drilling above 285 ft	1	1
Shale, black, with small bones of vertebrate fossils at 285 ft 8½ in		11½
Coal, sparsely medium banded, about 5 percent woody		7⅜
Clay shale, gray		11½

HOLE GS-6—continued

	Ft	in
Loss in drilling above 292 ft. Depth 292 ft at base of unit	4	5½
Clay, light-gray, very firm, reported below coal to 300 ft; below 300 ft shale, carbonaceous, with shell fragments to total depth of 310⅗ ft.; no laboratory study made.		

HOLE A-6

Location: Near center of east line, NE¼SW¼SW¼, sec. 31, T. 53 N., R. 82 W., Johnson County, Wyo.

Remarks: Apparent dip of bedding in core ranges from approximately normal at 188 ft to as much as 30° at 132 ft 6 in. and 45° at 199 ft 4 in. Dips of lesser magnitude, some approaching horizontal, intervene between all extreme dips cited.

	Ft	in
Overburden of soil and clinker above coal	101	7¼
Coal(?) very hard and brittle, not cored	3	4¾
Shale(?) not cored	1	0
Coal(?) very hard and brittle, not cored	6	6
Coal, abundantly medium banded, about 33 percent woody		4¼
Shale, dark gray, with woody fragments and ¼-in resin blebs		4¾
Loss in coring above 114 ft 2½ in		11½
Coal, sparsely thin to medium banded, about 3 percent woody, ⅛-in. fusian streak at 115 ft 6 in. and 115 ft 7 in., ⅛- to ¼-in. resin blebs at 119 ft 5 in. to 119 ft 7 in., and ⅛- to ¼-in. resin blebs at 120 ft 7 in	6	6
Shale, dark-gray, with woody fragments and small resin blebs		2¾
Coal, nonbanded		3
Loss in coring above 122 ft ¼ in	1	
Coal, sparsely medium banded, about 9 percent woody		2¾
Shale, dark-gray to black, with numerous woody fragments	2	9
Coal, sparsely, medium and thick banded, about 14 percent woody. Dip on base of bed, 30°	7	4
Loss in coring above 133 ft 1½ in		7½
Shale, dark-brown to black, with numerous woody fragments		6½
Coal, moderately medium banded, about 22 percent woody, ⅛- to ¼-in. resin blebs at 134 ft 5 in. and 134 ft 9 in. to 135 ft	1	9
Shale, black, carbonaceous		8½
Coal, abundantly very thick banded, about 50 percent woody. Dip on top of bed, 20°	1	2¼
Shale, dark-gray		3
Coal, moderately medium and thick banded, about 20 percent woody, ¼-in. fusain streak at 139 ft 9 in. Dip on top of bed, 20°	3	¼
Loss in coring above 141 ft 2⅞ in		7⅞
Coal, moderately medium banded, about 20 percent woody, with ⅛- to ¼-in. resin blebs scattered throughout		8¼
Shale, dark-brown to black		1½
Coal, abundantly medium and thick banded, about 36 percent woody	2	7
Shale, dark gray-black, with numerous woody fragments		8¼
Coal, moderately medium banded, about 18 percent woody	3	4½
Clay, gray, soft, plastic	1	9

HOLE A-6—continued

	Ft	in
Loss in coring above 151 ft 2¾ in		9⅜
Clay, dark-gray to black, soft		7
Shale, black, with numerous wood fragments		3¾
Coal, moderately medium banded, about 17 percent woody	4	2
Loss in coring above 156 ft 11 in		7½
Coal, sparsely medium banded, about 7 percent woody		7¾
Clay shale, black, with numerous woody fragments	2	¾
Coal, moderately medium and thick banded, about 26 percent woody	1	6½
Loss in coring above 162 ft 2½ in	1	½
Coal, moderately medium and thick banded, about 23 percent woody, ⅛-in. fusain streak at 163 ft 4 in., ¼-in. streak at 165 ft 5 in., and ⅛-in. streak at 166 ft 4 in.; ¼-in. resin blebs at 165 ft 10 in. to 166 ft 1 in. and 170 ft 2 in. to 170 ft 5 in.; 17 in. of woody coal at 168 ft 6 in. to 169 ft 11 in., possibly representing an upright stump	9	3½
Loss in coring above 171 ft 8¼ in		2¼
Coal, moderately medium and thick banded, about 21 percent woody, ⅛- to ¼-in. resin blebs at 174 ft 2 in. to 174 ft 6 in., 175 ft 6 in., and 176 ft 2 in. to 177 ft 5 in	7	6⅛
Shale, black		2½
Loss in coring above 181 ft 8⅜ in	2	3½
Coal, abundantly medium and thick banded, about 30 percent woody, ¼-in. resin blebs at 183 ft 8 in. to 184 ft 2 in., ¼-in. fusain streak at 184 ft 7½ in. and ⅛-in. streak at 187 ft 10 in	7	9⅛
Siltstone, white		1½
Coal, abundantly medium and thick banded, about 36 percent woody, ¼-in. resin blebs at 193 ft 7 in. to 193 ft 11 in. and 194 ft 5 in., thin fusain streak at 199 ft 6½ in	15	6½
Shale, black, with numerous woody fragments		2½
Coal, moderately medium and thick banded, about 26 percent woody, ⅛-in. resin blebs at 213 ft 8 in. to 213 ft 9 in	14	5⅜
Shale, dark-gray		1
Coal, sparsely medium banded, about 13 percent woody. Depth 220 ft 1⅜ in. at base of this unit		3
Shale, silty and sandy, gray, moderately to slightly consolidated, more carbonaceous and darker toward top; no laboratory study made	8	0

HOLE 7

Location: Near center of NW¼SE¼NE¼, sec. 1, T. 52 N., R. 83 W., Johnson County, Wyo.

Remarks: 121 ft 9 in. of core was received from 95 ft to 224 ft 11 in. depth interval; 20 ft 2 in. of claytsone and bone was rejected for analytic purposes from the core received; material apparently lost in drilling accounts for 8 ft 2 in.; the sample included a total thickness of 101 ft 7 in. coal.

	Ft	in
Overburden; clinker	95	0
Coal		8
Bone		3
Coal		2½
Claystone and bone	1	3

HOLE 7—continued

	Ft	in
Coal		10½
Bone and shale		1½
Coal	2	8
Bone and claystone		6
Coal (⅝-in. loss in drilling)	7	1½
Claystone		7
Coal		5½
Claystone		1
Coal	2	2½
Claystone		2
Coal	1	5½
Coal and clay		3
Coal		2
Claystone		1½
Coal		11½
Coaly claystone		1½
Coal		1½
Claystone		6½
Coal		1
Claystone		3½
Coal	3	2½
Bone and claystone		5½
Coal	1	6
Bone		3½
Coal		4
Claystone		2
Coal		1½
Claystone	1	2½
Coal	1	½
Claystone		3½
Coal		11¼
Pyrites		¾
Coal	9	10
Claystone		2¾
Coal		1¾
Clay		2
Coal	2	8
Bone		1½
Coal	1	2½
Coaly claystone		1
Coal	2	7
Claystone		1½
Coal	3	1½
Bone		3½
Coal		10½
Claystone		2½
Coal	1	4½
Claystone		4

HOLE 7—continued

	Ft	in
Coal	5	11½
Claystone		½
Coal	1	3
Claystone	2	1½
Coal		7
Claystone		6
Coal		8
Ironstone		3½
Coal	2	2
Clay (2¾-in. loss in drilling)	1	3½
Coal		3
Claystone		2½
Coal	1	½
Claystone		1¼
Coal		3
Claystone		1½
Coal (3¾-in. loss in drilling)	9	5½
Claystone	1	9¼
Coal (7-in. loss in drilling)	10	8
Claystone		4
Coal	1	4¾
Claystone		9¾
Coal		9½
Bone		3¼
Coal	2	1
Claystone		2
Coal	3	2¾
Claystone		6½
Coal	1	3¾
Claystone		2¼
Coal	3	11
Bone		1½
Coal	1	4½
Bone		3¼
Coal		5¾
Claystone		3
Coal		5
Bone		5
Coal (1½-in. loss in drilling)	6	6½
Claystone		10
Coal (1 in. loss in drilling)	3	9¾
Bone	1	½
Coal	5	1¼
Claystone		¾
Coal		3½
Clay		¾
Coal		3¼
Claystone. Depth 224 ft 11 in. to base of this unit		5¾
Sandstone. Bottom of core	4	1

OIL AND GAS POSSIBILITIES

Oil and gas have been produced at several places along the western margin of the Powder River Basin in the vicinity of the Buffalo-Lake De Smet area. Some of the producing fields are the Ash Creek oil field, about 35 miles north of Buffalo, the Billy Creek gas field (now depleted) about 18 miles south of Buffalo, the North Fork Powder River oil field, about 35 miles south of Buffalo, and the Sussex-Meadow Creek oil and gas field, about 50 miles south of Buffalo. Formations which contain oil or gas in these or other fields on the west side of the Powder River Basin include the Cody shale (Shannon sandstone member), the Frontier formation, the Newcastle sandstone, the Cloverly, Morrison, and Sundance formations, the Tensleep sandstone, the Amsden formation, and the Madison limestone. These formations are present underground and are potential producers of oil or gas in the Buffalo-Lake De Smet area.

Except for two deep test wells drilled in 1952 and 1953, the oil and gas possibilities of the Buffalo-Lake De Smet area have not been explored by drilling. Neither of the two test wells was successful. The Continental Oil Co. No. 1 Unit well in the SW¼ sec. 24, T. 50 N., R. 82 W., was plugged and abandoned in the Morrison formation at a depth of 13,205 feet. The G. L. Reasor No. 1 Tarbet well in the SW¼ sec. 4, T. 51 N., R. 83 W., was plugged and abandoned in the Tensleep sandstone at a depth of 11,041 feet. The sites of both wells were located by the use of seismic data.

The surface formation in the vicinity of the Continental Oil Co. well in sec. 24, T. 50 N., R. 82 W., is the fine-grained facies of the Wasatch formation. It dips gently eastward at about 1°. No anticlinal folding is apparent in this area, although individual beds are difficult to trace, and gentle folds similar to those that occur in the Wasatch formation farther to the east might easily be missed in mapping.

The G. L. Reasor well in sec. 4, T. 51 N., R. 83 W., is located on a slight structural terrace in the Wasatch and Fort Union formations (structure section *DD'*, pl. 10). Dips of the surface rocks in the vicinity of the well flatten eastward from nearly vertical in the Parkman sandstone to about 6° E. in the Kingsbury conglomerate member of the Wasatch. Farther eastward, the dips steepen in the fine-grained facies of the Wasatch formation. Inasmuch as both the Kingsbury conglomerate member of the Wasatch and the upper conglomeratic member of the Fort Union formation probably represent ancient alluvial fans that thin rapidly eastward, a fold expressed as a structural terrace in these rocks near the mountains may have closure in the older rocks at depth.

Three angular unconformities occur near the Bighorn Mountains in rocks younger than the Lance formation of Late Cretaceous age. The unconformities show uplift of the mountains and possible simultaneous folding of pre-Tertiary rocks in adjacent parts of the Powder River Basin during three separate stages in early Tertiary time. Anticlines or faults formed in rocks of pre-Tertiary age during these movements might be completely hidden beneath gently dipping beds in the upper part of the Wasatch formation or might be shown only by indefinite surface structure.

Several gentle anticlinal folds in the Wasatch formation are shown on plate 1 by structure contours drawn with an interval of 50 feet on the base of the Healy coal bed. One of these folds, in the southern part of T. 53 N., R. 80 W., has a surface closure of between 50 and 100 feet, and another in the northeastern part of T. 52 N., R. 82 W., has a surface closure of about 50 feet. No information is available to indicate the relation of these folds to the structure of older rocks at depth.

The possibility of stratigraphic traps for the accumulation of oil or gas in the Buffalo-Lake De Smet area is suggested by lateral changes in the thickness or lithology of several potential oil or gas-bearing formations. The available information is insufficient to predict accurately the location of such traps, although a few generalizations might be made.

A sandstone at the base of the Amsden formation is 133 feet thick, including partings and streaks of shale, in the Carter Oil Co. No. 3 Rider well, sec. 17, T. 48 N., R. 82 W., a few miles south of Buffalo (Bramlette, 1949, p. 83). This bed is about 90 feet thick at its outcrop at the North Fork of Crazy Woman Creek about 10 miles southwest of Buffalo (Hose, 1954). A sandstone at the same stratigraphic position is only 13 feet thick at the South Fork of Rock Creek, 12 miles northwest of Buffalo. Such variations in thickness in relatively short distances suggest the possibility of stratigraphic traps in the lower part of the Amsden formation.

Bramlette (1949, p. 83) states that the Tensleep sandstone in the Carter Oil Co. No. 3 Rider well contains numerous zones of red shale, limestone, and dolomite in strong contrast to the massive relatively uniform character of the formation in outcrops along the nearby mountain front to the west. Rapid variations basinward in the lithology of the Tensleep sandstone such as are indicated by this comparison suggest a possibility for stratigraphic traps in the Tensleep sandstone.

Upper Cretaceous marine formations of the Buffalo-Lake De Smet area in general become less sandy basinward with the result that the equivalent rocks are almost barren of sandstone in outcrops along the western flank of the Black Hills about 70 miles east of Buffalo. In particular, the Parkman sandstone, sandstone beds in the Greenhorn calcareous member of the Cody shale, and sandstone beds in the upper part of the Frontier formation do not persist across the Powder River basin. Additional subsurface data will be needed to establish the eastern edge of sandstone deposition, and thereby locate favorable areas for stratigraphic traps in these rocks.

SAND AND GRAVEL

Sand and gravel have been quarried at several places from stream terrace and alluvial deposits that cover large areas in the Buffalo-Lake De Smet area. Gravel pits also have been dug in poorly cemented beds of conglomerate in the White River formation(?) and in the Kingsbury conglomerate member of the Wasatch formation. Most of the material has been used for highway subgrade or for road surfacing, although sand and gravel from the stream bed of Bull Creek is washed and sized at a small plant about 5 miles south of Buffalo in sec. 26, T. 50 N., R. 82 W., and sold locally for plaster sand and concrete aggregate. Deposits of gravel in other parts of the area also may be suitable for concrete aggregate as shown by the following information gathered by the Yellowstone District office of the U. S. Bureau of Reclamation.

Location of deposit: Adams commercial plant, 5 miles north of Buffalo, sec. 26, T. 50 N., R. 82 W.
Date sampled: March 2, 1951.

Screen analysis

Sand			Coarse aggregate		
Screen size No.	Percent retained		Screen size (inches)	Percent retained	
	Individual	Cumulative		Individual	Cumulative
4	1	1	6	0	0
8	11	12	3	0	0
16	14	26	1½	0	0
30	21	47	¾	28	28
50	33	80	⅜	45	73
100	17	97	[1]	22	95
[2]	3	100	[3]	3	98
FM 2.63					

[1] No. 4. [2] Pan. [3] No. 5.

Description.—Gravel particles range in shape from angular to rounded, averaging subrounded. About 20 percent is flat. The gravel is composed predominantly of limestone. Smaller proportions of granite, gneiss, and sandstone, and some quartzite and chert are present. Physically unsound particles constitute less than 2 percent of the gravel. Chert, a rock type deleteriously reactive with high-alkali cement, constitutes less than 0.5 percent of the gravel. The sand particles range from angular to rounded, averaging subangular in shape. The coarse sand fractions are composed predominantly of limestone with smaller amounts of quartzite, granite, gneiss, sandstone, and chert. The finer sand fractions are composed predominantly of individual grains of quartz, feldspar, and calcite with smaller amounts of mica, hornblende, and rock types present in the coarse fractions. Chert constitutes less than 1 percent of the sand.

Conclusions.—Preliminary examination of this material indicates that it is suitable for use in concrete provided proper gradings are obtained and an air-entraining agent is used.

Location of deposit: Wyoming State Highway Department pit, SE¼ sec. 1, T. 52 N., R. 83 W., and SW¼ sec. 6, T. 52 N., R. 82 W.
Date sampled: March 3, 1951.

Screen analysis

Sand			Coarse aggregate		
Screen size No.	Percent retained		Screen size (inches)	Percent retained	
	Individual	Cumulative		Individual	Cumulative
8	13	13	6	0	0
16	20	33	3	3	3
30	22	55	1½	35	38
50	19	74	¾	19	57
100	16	90	⅜	27	84
(1)	10	100	(2)	16	100
FM 2.65			FM 7.82		

1 Pan. 2 No. 4.

Description.—The gravel particles range in shape from angular to rounded, averaging subrounded. The gravel is composed predominantly of limestone. Smaller proportions of syenite, sandstone, chert, metamorphic rocks, and clinker are present. Physically unsound particles constitute 2 percent of the gravel. Chert and clinker, materials which are deleteriously reactive with high-alkali cement, constitute less than 1 percent of the gravel. The sand particles range from angular to subrounded, averaging angular in shape. The finer sand fractions are composed predominantly of individual grains of calcite with smaller amounts of clinker, quartz, mica, and feldspar.

Conclusions.—Preliminary examination indicates that this sand is not first quality but may be used in concrete provided the sand is washed to remove excess silt, proper gradings are obtained, and an air-entraining agent is used.

Location of deposit: Bed of Piney Creek, center of the E½ sec. 31, T. 53 N., R. 82 W.

Date sampled: March 2, 1951.

Screen analysis

Sand			Coarse aggregate		
Screen size No.	Percent retained		Screen size (inches)	Percent retained	
	Individual	Cumulative		Individual	Cumulative
8	16	16	6	0	0
16	27	43	3	3	3
30	31	74	1½	47	50
50	12	86	¾	24	74
100	9	95	⅜	16	90
(1)	5	100	(2)	10	100
FM 3.14.			FM 8.17.		

[1] Pan. [2] No. 4.

Description.—The gravel particles range from angular to rounded, averaging subangular in shape. The gravel is composed predominantly of granite and gneiss. Smaller proportions of quartzite, metamorphic rocks, limestone, sandstone, chert, and clinker are present. Physically unsound particles constitute about 30 percent of the gravel. Material only fair in quality constitutes about 30 percent. Chert and clinker, materials deleteriously reactive with high-alkali cement, constitute 2 percent of the gravel. The sand particles range from angular to subrounded, averaging subangular in shape. The coarse sand fractions are composed predominantly of metamorphic rock fragments with smaller amounts of granite, clinker, coal and wood fragments, quartz, and feldspar. The fine sand fractions are composed predominantly of individual grains of quartz with smaller amounts of feldspar, clinker, wood, and mica. About 15 percent of the sand particles are physically unsound. Coal and wood constitutes 5 percent of the sand and clinker constitutes 1 percent of the sand.

Conclusions.—Preliminary examination of this material indicates that it is not first quality and contains a high proportion of organic materials.

Location of deposit: Bed of Piney Creek, 100 feet north of U. S. Highway 14 bridge near Ucross, sec. 18, T. 53 N., R. 80 W.
Date sampled: Not recorded.

Screen analysis

Sand					Coarse aggregate		
Screen size No.	Percent retained				Screen size (inches)	Percent retained	
	Individual		Cumulative			Individual	Cumulative
	Pit run	*Washed*	*Pit run*	*Washed*			
8	22	24	22	24	6	0	0
16	26	26	48	50	3	0	0
30	24	28	72	78	1½	49	49
50	14	14	86	92	¾	27	76
100	5	4	91	96	⅜	14	90
[1]	9	4	100	100	[2]	10	100
FM 3.19		3. 40			FM 8.15.		

[1] Pan. [2] No. 4.

Description.—The gravel particles range from subangular to subrounded in shape, the average being subangular. The gravel is composed predominantly of granite, and gneiss, limestone and dolomite, clinker, and metamorphic rock fragments. Very small amounts of sandstone, siliceous limestone, petrified wood, and chert are present. The coarse sand particles are granite, clinker, limestone, and metamorphic rock fragments, with minor amounts of ferruginous concretions and chert. The finer sand fractions are composed of feldspar, quartz, hornblende, with minor amounts of chert and iron oxide. Traces of garnet and uncommon types of amphibole are present. Particles which are physically unsound constitute 13 to 15 percent, and deleterious types range from 1 to 2 percent.

Conclusions.—The sand is not first quality but may be used provided excess silt is removed and proper gradings are obtained. There was insufficient gravel in the sample for complete testing but examination of the gravel available indicates that it is of questionable quality.

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CLINKER

Clinker is widely used as railroad ballast and road surfacing material in the Powder River Basin region and several pits have been worked intermittently in the Buffalo-Lake De Smet area to obtain clinker for these uses. The largest pits are along a low bluff in sec. 5, T. 50 N., R. 81 W., about 4 miles east of Buffalo, and other smaller pits are located northwest of Lake De Smet in the northeastern part of T. 52 N., R. 83 W. Very large amounts of clinker are available in the area as a result of the widespread burning of the Healy and Walters coal beds, and much of the material, although mostly on the tops of high divides, can easily be reached along the present roads and trails.

GYPSUM

Deposits of white granular gypsum occur in the Buffalo-Lake De Smet area in the upper part of the gypsum and red shale sequence of Permian age. The formation contains individual beds of gypsum ranging in thickness from a few inches to 30 feet in a zone which at the South Fork of Rock Creek has a thickness of 70 feet. Small amounts of gypsum have been quarried from this formation near the headwaters of J. A. Creek in the S½ sec. 31, T. 53 N., R. 83 W. Outcrops of the gypsum-bearing rocks dip eastward at angles greater than 45° at most places, and therefore long narrow pits or underground mining would be necessary to extract large tonnages.

BENTONITE

Thin beds of bentonite crop out in the Mowry shale, the Frontier formation, the Cody shale, and the Bearpaw shale. Though most of the beds are less than 3 feet thick, there is one bed of bentonite 6 feet thick at the base of the Frontier formation, and another 4 feet thick near the top of the black shale member of the Mowry shale. When wet the bentonite swells, with the result that the material commonly spreads outward over adjacent beds and forms conspicuous bands of light-colored gumbo soil. The thicker beds dip eastward at high angles, commonly as much as 80°, and therefore could not be mined on a large scale by stripping.

GOLD

Small amounts of gold have been mined from prospects at the contact between the Flathead sandstone and Precambrian granite and gneiss near the head of Kelly Creek, southwest of Buffalo. The gold occurs as a placer deposit both in the Flathead sandstone and in cracks and joints in the underlying Precambrian rocks. The value of gold produced from the Kelly Creek prospects from 1900 to 1947 totals less than $5,000 (Fischer and others, 1947). No gold mining or prospecting was in progress at the time the area was visited in 1950–51.

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