Geology of the Nefsy Divide Quadrangle Crook County, Wyoming

GEOLOGICAL SURVEY BULLETIN 1121-E

Prepared on behalf of the U.S. Atomic Energy Commission

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By C. L. PILLMORE *and* W. J. MAPEL

CONTRIBUTIONS TO GENERAL GEOLOGY

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GEOLOGY OF THE NEFSY DIVIDE QUADRANGLE, CROOK COUNTY, WYOMING

By C. L. Pillmore and W. J. Mapel

ABSTRACT

The Nefsy Divide quadrangle includes about 215 square miles on the west side of the Black Hills in Crook County, Wyo.

Exposed sedimentary rocks, exclusive of surficial deposits, have an aggregate thickness of about 1,500 feet and consist mostly of sandstone, siltstone, and shale of Triassic, Jurassic, and Cretaceous ages. Triassic rocks comprise the upper part of the Spearfish formation; Jurassic rocks, the Sundance and Morrison formations; and Cretaceous rocks, the Lakota, Fall River, Skull Creek, Newcastle, Mowry, and lower part of the Belle Fourche formations. All formations are generally concordant; however, unconformities separate the Spearfish and Sundance formations and the Lakota and Fall River formations. Locally, sills of nepheline syenite porphyry as much as 40 feet thick intrude the Sundance, Morrison, and Fall River formations.

The sedimentary rocks are not greatly deformed by folding or faulting. They dip 1° to 2° SW. at most places, and steepen locally to as much as 20° in the northwest corner of the quadrangle. In the area of steeper dips two small domes having closures of 100 to 200 feet interrupt the otherwise simple structure. The northernmost dome is faulted on its north and west sides.

Uranium has been mined from small deposits in the northern part of the quadrangle, oil is produced from the Lakota formation at the shallow Barton oil field in the southern part, and bentonite is mined from the Clay Spur bentonite bed at the top of the Mowry shale in the southwestern part.

INTRODUCTION

LOCATION OF AREA

The Nefsy Divide quadrangle includes about 215 square miles on the west side of the Black Hills in Crook County, Wyo. (fig. 1). The quadrangle lies between long 104°30′ and 104°45′ W., and lat 44°15′ and 44°30′ N., and is about 6 miles west of Sundance, 10 miles east of Moorcroft, and 30 miles northwest of Newcastle, Wyo.

FIELDWORK AND ACKNOWLEDGMENTS

The quadrangle was mapped during 1956–58 as part of a study of a larger area on the west and north sides of the Black Hills. Geologic

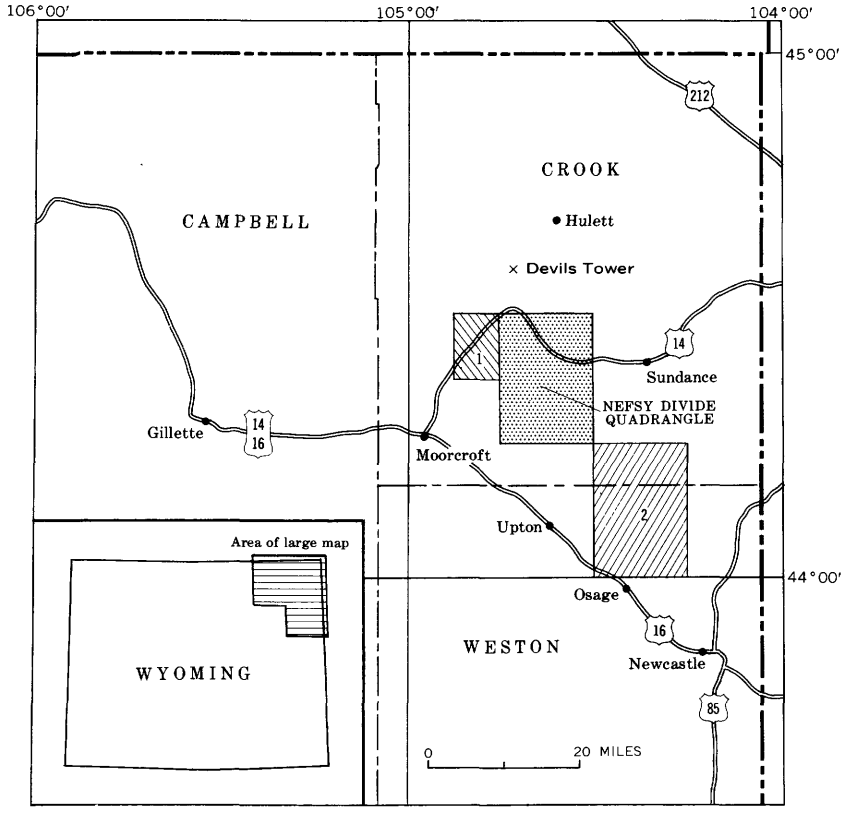

FIGURE 1.—Index map showing location of Nefsy Divide quadrangle (stippled) and adjacent areas mapped by the Geological Survey from 1954 to 1958. 1. Carlile quadrangle (Bergendahl and others, 1961). 2. Inyan Kara Mountain quadrangle (Mapel and Pillmore, 1962).

data were gathered by a combination of fieldwork and office study of aerial photographs. The fieldwork consisted of measuring stratigraphic sections with hand level and tape and locating geologic contacts on aerial photographs at select places. This information provided control for geologic mapping done subsequently with a Kelsh plotter. (Use of the Kelsh plotter in geologic studies has been discussed by Pillmore, 1957.) The resulting map was checked and modified in the field during the summer of 1958. This mapping was done on behalf of the Division of Raw Materials, U.S. Atomic Energy Commission.

Reconnaissance stratigraphic studies and geologic mapping were done in the quadrangle by C. S. Robinson, K. M. Waagé and P. K. Theobald at different times in 1954–55. Their field notes and maps were freely consulted during the present work and the use of this material is gratefully acknowledged.

PREVIOUS WORK

Little previously published work relates specifically to the geology of the Nefsy Divide quadrangle. Darton (1909) described the area in his report on the geology of the northern Black Hills and vicinity, and his map (scale 1:250,000) shows the general geologic features. W. W. Rubey and his coworkers mapped the quadrangle at a scale of 1:62,500 in 1922–24 and their manuscripts have been used with local modifications by other geologists in compilations of the geology of the Black Hills region (Love and Weitz, 1951; Zapp, 1952; Mapel and others, 1959). K. M. Waagé (1959) described outcrops in the quadrangle as part of a study of the stratigraphy of the Inyan Kara group in the Black Hills, and Mapel and Gott (1959) compiled a restored cross section through the quadrangle and nearby areas on the west side of the Black Hills to show correlations of the Lower Cretaceous sandstone beds.

Geologic mapping has been done since 1954 in the Inyan Kara Mountain 15-minute quadrangle which is adjacent to the Nefsy Divide quadrangle on the southeast (Mapel and Pillmore, 1962), and in the Carlile 7½-minute quadrangle on the west (Bergendahl and others, 1961).

GEOGRAPHY

SURFACE FEATURES AND RELIEF

The Nefsy Divide quadrangle lies on the southwest flank of the Bear Lodge Mountains, a small outlying mountain range at the north end of the Black Hills. Inyan Kara Creek flows northwestward diagonally across the central part of the quadrangle to join the Belle Fourche River near the northwest corner. Steep-sided, flat-topped buttes and divides characterize the land surface along and northwest of Inyan Kara Creek; rolling hills characterize areas in the southwest corner.

Altitudes range from about 3,900 feet on the Belle Fourche River to about 5,900 feet on the flanks of the Bear Lodge Mountains in the northeast corner.

CLIMATE, VEGETATION, AND WATER SUPPLY

The annual rainfall at Sundance, a few miles east of the quadrangle, averages about 19 inches, and the temperature ranges between annual extremes of about 100° and −30°F.

Dense stands of fir, pine, and aspen cover much of the northeastern part of the quadrangle and northward-facing slopes in other parts. Elsewhere the vegetation is mostly sagebrush, greasewood, and grasses.

The area is drained by the Belle Fourche River and its tributaries, of which the principal ones in the quadrangle are Inyan Kara, Miller, and Houston Creeks. The Belle Fourche River is a relatively large perennial stream; the creeks are mostly dry except in the spring and early summer.

SETTLEMENT AND INDUSTRY

The quadrangle is sparsely settled and contains only a few houses which are mostly along the main streams. U.S. Highway 14, which crosses the northeastern part of the quadrangle, and a network of dirt roads and trails provide easy access to nearly all parts of the area.

Wheat and hay are grown locally, but the main industry is raising cattle and sheep. Some timber is cut and sawed at small sawmills.

SEDIMENTARY ROCKS

Exposed sedimentary rocks exclusive of surficial deposits comprise about 1,500 feet of Triassic, Jurassic, and Cretaceous strata in the Nefsy Divide quadrangle. These beds overlie about 2,000 feet of unexposed sedimentary rocks ranging in age from Triassic to Cambrian. The distribution of rocks exposed in the quadrangle is shown on the geologic map (pl. 1), and a brief description of both the exposed and unexposed rocks is given in table 1.

Sandstone, siltstone, and shale make up most of the exposed sedimentary sequence; limestone, bentonite, gypsum, and coal are present in subordinate amounts. In general, the strata dip gently southwestward so that the oldest rocks are at the surface in the northeast corner of the quadrangle and the youngest rocks in the southwest corner. The upper part (Triassic) of the Spearfish formation of Permian and Triassic age comprises the oldest rocks exposed. It is overlain at outcrops a short distance north of the quadrangle by the Gypsum Spring formation of Jurassic age. At outcrops within the quadrangle, however, the Gypsum Spring is absent and the Sundance formation of Jurrasic age overlies the Spearfish formation, which is overlain in turn by the Morrison formation of Jurrasic age, the Lakota and Fall River formations, Skull Creek shale, Newcastle sandstone, and Mowry shale, all of Early Cretaceous age, and the Belle

TABLE 1.—*Generalized stratigraphic section of rocks in the Nefsy Divide quadrangle*

System and series		Group, formation, and member		Thickness (ft)	Lithology
Tertiary and Quaternary		Alluvium, slope wash, and terrace gravel		----------	Surficial deposits of silt, sand, and gravel.
Cretaceous	Upper	Belle Fourche shale		100+	Grayish-black shale, siderite concretions in the basal part, several beds of bentonite; marine fossils.
	Lower	Mowry shale		170	Siliceous light-gray-weathering shale grading to dark-gray shale in basal 10–20 ft; marine fossils.
		Newcastle sandstone		30±	Light-gray sandstone, brown and gray carbonaceous shale and siltstone, gray bentonite.
		Skull Creek shale		250	Grayish-black shale; a few marine fossils.
		Inyan Kara group	Fall River formation	135–150	Brown-weathering fine grained to very fine grained sandstone, light- to dark-gray siltstone, dark-gray shale; intruded locally by sills of syenite porphyry.
			Lakota formation	70–160	Light-gray sandstone and conglomeratic sandstone, variegated sandy claystone; nonmarine fossils.
Jurassic	Upper	Morrison formation		65–120	Greenish-gray and grayish-red claystone, gray marl, grayish-white sandstone; calcareous in lower part; nonmarine fossils; intruded locally by a sill of syenite porphyry.
		Sundance formation	Redwater shale member	170	Greenish-gray shale, light-gray siltstone and sandstone, gray sandy limestone; glauconitic; marine fossils.
			Lak member	40–60	Pink and yellowish-gray nonresistant siltstone and very fine grained sandstone.
			Hulett sandstone member	70–80	Yellowish-gray ledge-forming sandstone; marine fossils; intruded locally by a sill of syenite porphyry.
			Stockade Beaver shale member	50–90	Greenish-gray shale, some light-gray sandstone at top; marine fossils.
			Canyon Springs sandstone member	0–25	Light-yellowish-gray calcareous sandstone, some greenish-gray siltstone locally; marine fossils.
	Middle	Gypsum Spring formation		0–20	White gypsum interbedded with red claystone.
Triassic		Spearfish formation		580–825	Red siltstone, sandstone, and claystone; thick gypsum beds in the lower half; no fossils.
Permian		Minnekahata limestone		40	Light-gray limestone; marine fossils locally.
		Opeche formation		70–90	Red siltstone; no fossils.
Pennsylvannian		Minnelusa formation		650–750	Light-gray and red sandstone, gray limestone and dolomite, red shale, local gypsum and anhydrite; marine fossils.
Mississippian		Pahasapa limestone		600	Massive light-gray limestone, locally dolomitic; marine fossils.
		Englewood limestone		50	Pinkish-gray moderately thin bedded limestone; marine fossils.
Ordovician		Whitewood dolomite		50	Light-gray to tan dolomite; marine fossils.
		Winnipeg formation (Carlson, 1958)		50	Light-yellowish-gray to greenish-gray siltstone underlain by greenish-gray shale; marine fossils.
Cambrian		Deadwood formation		300	Mostly brown sandstone, some greenish-gray siltstone and shale and gray limestone; marine fossils.
Precambrian		----------		----------	Metamorphic and igneous rocks.

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Fourche shale of Late Cretaceous age. All these formations are generally concordant, although an unconformity between the Spearfish and Sundance formations represents large parts of the Triassic and Jurassic systems; other unconformities are present within the Lakota formation and at the base of the Fall River formation.

Surficial terrace deposits of Tertiary and Quaternary age, and landslides, slope wash, and alluvium of Quaternary age cover the older rocks locally.

Rocks older than the Spearfish formation were not studied during this investigation. They have been described from outcrops or drill holes at nearby places in the Black Hills by many writers including Darton (1909, p. 12–31), Leatherock (1950), Agatston (1954), Andrichuk (1955, fig. 5), McCoy (1952, 1958), Brady (1931, 1958), Carlson (1958), Foster (1958), and Privrasky and others (1958).

Currently accepted ages of Jurassic and Cretaceous formations in the Nefsy Divide quadrangle in terms of European stages are given in the chart below.

Age of formations in the Nefsy Divide quadrangle

[After Cobban (1951, p. 2197), Sohn, (1958, p. 124), and Imlay, (1952, p. 80)]

	European stage		Formation
Upper Cretaceous	Cenomanian (part)		Belle Fourche shale
Lower Cretaceous	Albian		Mowry shale
			Newcastle sandstone
			Skull Creek shale
			Fall River formation
			Hiatus
	Aptian		Lakota formation
	Neocomian	Barremian	*Hiatus*
		Hauterivian	
		Valanginian	
		Berriasian	
Upper Jurassic	Portlandian		Morrison formation
	Kimmeridgian		
	Oxfordian		
	Callovian		Sundance formation

PERMIAN AND TRIASSIC SYSTEMS

SPEARFISH FORMATION

The Spearfish formation of Permian and Triassic age crops out as nonresistant red siltstone and silty sandstone in a small area in the valley of Miller Creek at the northeast corner of the quadrangle. The formation is 825 feet thick as measured in a well drilled on the Miller Creek dome in sec. 33, T. 52 N., R. 64 W., and it is 580 feet thick as measured in a well drilled about 2 miles southeast of the quadrangle in sec. 12, T. 49 N., R. 64 W. In outcrops east of the quadrangle, the formation consists of a lower unit, about 250 feet thick, of interbedded white gypsum, red siltstone, and red silty claystone, and an upper unit 250 to 350 feet thick of red siltstone and silty sandstone. Only the upper 200 to 300 feet of the formation is exposed in the quadrangle.

The lower gypsiferous part of the Spearfish is equivalent to the upper part of the Goose Egg formation of Burk and Thomas (1956), which is thought to contain equivalents of both the Phosphoria formation of Permian age and the Dinwoody formation of Early Triassic age of western Wyoming (Burk and Thomas, 1956; Privrasky and others, 1958). The upper part of the Spearfish, including the part exposed in the quadrangle, is generally considered Triassic in age. No fossils have been reported from the formation in the Black Hills.

JURASSIC SYSTEM

MIDDLE JURASSIC SERIES

GYPSUM SPRING FORMATION

No outcrops of the Gypsum Spring formation were found in the Nefsy Divide quadrangle, but the formation is present a short distance to the north and it seems likely that it may extend into the quadrangle beneath the surface. Where found nearby, the Gypsum Spring formation, which consists of red claystone and white gypsum, overlies the Spearfish unconformably, and is overlain unconformably by the Sundance formation. The following stratigraphic section was measured about 2 miles north of the Nefsy Divide quadrangle on the east bank of the Belle Fourche River near the place where the Gypsum Spring formation passes below stream level.

Gypsum Spring and parts of adjacent formations in the SW¼ sec. 25, T. 53 N., R. 66 W., Crook County, Wyo.

	Feet
Sundance formation (part):	
Stockade Beaver shale member (part):	
5. Shale, greenish gray, very calcareous; a few thin sandy layers; top 1 ft is shaly limestone and forms a ledge	11
Canyon Springs sandstone member:	
4. Sandstone, very light gray, mostly fine-grained with coarse grains, granules, and small pebbles of gray and brownish-gray chert in the bottom one-half foot, calcareous, friable; sharp uneven contact with underlying unit	7
Partial thickness, Sundance formation	18
Unconformity.	
Gypsum Spring formation:	
3. Gypsum and claystone, interbedded; gypsum is white, in lenticular beds as much as 1½ ft thick; claystone is red; forms local ledges	6
2. Claystone, red; persistent bed of white gypsum 1 ft thick at the base and stringers of gypsum throughout the unit	12
Thickness, Gypsum Spring formation	18
Unconformity.	
Spearfish formation (part):	
1. Sandstone and siltstone, interbedded, red with a few green streaks, thin gypsum stringers in fractures	25+

The Gypsum Spring formation is presumed to be Middle Jurassic in age based on its lithologic similarity to Middle Jurassic rocks in other parts of Wyoming (Imlay, 1947, p. 242–243; Mapel and Bergendahl, 1956, p. 89–90).

UPPER JURASSIC SERIES

SUNDANCE FORMATION

The Sundance formation is about 375 feet thick and crops out in the valleys of Inyan Kara, Miller, and Houston Creeks in the northern part of the quadrangle and at places along the east edge. The members of the formation are, in ascending order: the Canyon Springs sandstone, Stockade Beaver shale, Hulett sandstone, Lak, and Redwater shale, as defined by Imlay (1947).

The age and correlation of the Sundance formation in the Black Hills have been discussed by Imlay (1947, p. 244–266) who stated that the Lak and older members are Callovian, and the Redwater shale Oxfordian in age. Fossils have been found in all but the Lak member and include ammonites, pelecypods, and brachiopods (Imlay, 1947), foraminifera (Loeblich and Tappan, 1950 a, b), and ostracodes (Swain and Peterson, 1952).

The following stratigraphic sections, measured north and east of the quadrangle, respectively, show the lithology of the formation.

Sundance formation on the east side of Blacktail Creek in secs. 3 and 11, T. 53 N., R. 64 W., Crook County, Wyo.

Top of hill.

Sundance formation:

	Feet
Redwater shale member:	
26. Sandstone, moderate reddish-orange, fine- to medium-grained, calcareous, thin- to medium-bedded. (Top of the unit is about the top of the Sundance formation.)	2
25. Poorly exposed; appears to be mostly interbedded and interlaminated shale and sandstone; shale is greenish gray; sandstone is yellowish gray and very fine grained; contains a thin bed of gray limestone in lower part	24
24. Limestone, medium-gray, slabby; marine fossils abundant; forms a ledge	1
23. Shale, greenish-gray, sandy	1
22. Sandstone, light-yellowish-gray, very fine grained, very calcareous, thin-bedded, slabby; sparse glauconite; forms a ledge	3
21. Shale and sandstone, interbedded and interlaminated; shale is dark greenish gray and noncalcareous; sandstone is yellowish gray, very fine grained, calcareous, glauconitic, and friable	6
20. Limestone, medium-gray, marine fossils abundant, forms a ledge	1
19. Shale and sandstone, interbedded and interlaminated; shale is dark greenish gray and noncalcareous; sandstone is yellowish gray, very fine grained, calcareous and glauconitic	18
18. Limestone, medium-gray, sandy, glauconitic, fossiliferous, forms a blocky ledge	1
17. Shale and sandstone, interbedded and interlaminated; shale is greenish gray and noncalcareous; sandstone is yellowish gray, very fine grained, and calcareous; contains a few gray limestone concretions	40
16. Mostly covered; grayish-green sandy soil and fragments of green shale on slopes	70
15. Sandstone, light-yellowish-gray, very fine grained, calcareous, medium-bedded; abundant glauconite; forms a rounded ledge; contact with underlying unit is sharp	2½
Thickness, Redwater shale member (rounded)	170
Lak member:	
14. Siltstone, grayish-red, calcareous; a few thin beds of grayish-red, fine-grained sandstone near top; poorly exposed	40
Thickness, Lak member	40

Sundance formation on the east side of Blacktail Creek in secs. 3 and 11, T. 53 N., R. 64 W., Crook County, Wyo.—Continued

	Feet
Sundance formation—Continued	
Hulett sandstone member:	
13. Sandstone, pale-red; contains a few light-gray laminae, calcareous, fine-grained to silty, thin-bedded; forms a slope	18
12. Sandstone, grayish-red, fine grained to very fine grained, calcareous, thick-bedded, locally ripple-marked, a few beds inconspicuously crossbedded; forms a massive cliff	44
11. Sandstone, pale-red, fine grained to very fine grained, calcareous, thin- to medium-bedded; contains a few thin partings of grayish-green shale	14
Thickness, Hulett sandstone member	76
Stockade Beaver shale member:	
10. Shale with interbedded and interlaminated sandstone; shale is greenish gray and slightly calcareous; sandstone is yellowish gray, very fine grained, well sorted, and friable	9
9. Sandstone, light-yellowish-gray, very fine grained, calcareous, well-sorted; alternating medium and thin beds; forms a ledge	4
8. Shale; contains interbedded and interlaminated sandstone; shale is greenish gray and slightly calcareous; sandstone is light yellowish gray, very fine grained, and friable	18
7. Sandstone, light-yellowish-gray, very fine grained, calcareous, well sorted; alternating thick and thin beds; forms a rounded ledge	11
6. Shale; contains interbedded and interlaminated sandstone; shale is greenish gray, slightly calcareous and micaceous; sandstone is light yellowish gray, very fine grained, well sorted, calcareous and friable	8
5. Shale, greenish-gray, flaky; upper part poorly exposed	35
4. Limestone, greenish-gray, shaly; forms inconspicuous ledge	1
3. Shale, greenish-gray, calcareous; grades upward into overlying unit	4
Thickness, Stockade Beaver shale member	90
Canyon Springs sandstone member (?):	
2. Sandstone, light-gray, mostly fine grained but contains many coarse grains and few small pebbles of gray chert as much as one-half in. in maximum dimension, calcareous; forms a ledge	2
Thickness, Canyon Springs sandstone member (?)	2
Thickness (rounded), Sundance formation	380
Unconformity.	
Gypsum Spring formation (part):	
1. Shale, moderate-reddish-brown in lower part grading to pale-green in upper 1 ft., noncalcareous, hard	5+

Lower part of the Sundance formation and underlying rocks on the south side of Houston Creek, SW¼ sec. 7, T. 51 N., R. 63 W., Crook County, Wyo.

	Feet
Sundance formation (part):	
Hulett sandstone member (part):	
12. Sandstone, light-yellowish-gray, very fine grained, calcareous; alternating thin and thick beds; makes local ledges	9
Stockade Beaver shale member:	
11. Covered	6
10. Shale, dark-greenish-gray, seams and laminae of light-gray siltstone and very fine-grained sandstone	12
9. Covered	12
8. Shale, dark greenish-gray, slightly calcareous	21
Thickness, Stockade Beaver shale member	51
Canyon Springs sandstone member:	
7. Sandstone, grayish-yellow, very fine grained, calcareous, friable; nonresistant except for a few platy ledges in the top 2 ft.	11
6. Siltstone, greenish-gray, calcareous	4
5. Sandstone, yellowish-gray, very fine grained, calcareous, forms platy ledges	4
4. Sandstone, as in unit 5 above except friable and nonresistant; a few small gray chert pebbles in float, probably from this unit	6
Thickness, Canyon Springs sandstone member	25
Partial thickness, Sundance formation	85
Unconformity.	
Spearfish formation (part):	
3. Siltstone, dark-red, clayey, mostly noncalcareous; a bed, one-half foot thick, of red slabby calcareous siltstone about middle of the unit; a bed, 1 in. thick, of brecciated light-gray limestone 2 ft. below the top of the unit	9
2. Limestone, light-gray, brecciated, lenticular, forms inconspicious ledge	1
1. Siltstone, dark-red, noncalcareous, sandy; grades locally to very fine-grained sandstone	30
Partial thickness, Spearfish formation	40

Canyon Springs sandstone member.—The lower part of the Sundance formation crops out in the northern part of the Nefsy Divide quadrangle along Houston and Miller Creeks, but exposures are poor, and the Canyon Springs sandstone member at the base of the formation was not seen in the quadrangle. The member is 25 feet thick at an outcrop along Houston Creek 1½ miles east of the quadrangle, as shown by the second of the two stratigraphic sections given above, and at this place it consists of friable massive calcareous yellowish-

gray standstone which contains some greenish-gray siltstone in the middle part. The member thins to a bed, 7 feet thick, of friable grayish-white sandstone on the east side of the Belle Fourche River 2 miles north of the quandrangle, as shown by the stratigraphic section on page E8. Elsewhere north of the quadrangle, beds of sandstone that are probably equivalent to the Canyon Springs sandstone member crop out at the base of the Sundance formation, but commonly they contain much clayey material or are interbedded with thin layers of shale and limestone that have been assigned to the basal part of the overlying Stockade Beaver shale member (Imlay, 1947, p. 251).

The Canyon Springs sandstone rest disconformably on the Gypsum Spring or Spearfish formation. North of the quadrangle the basal contact of the Sundance formation is a slightly irregular surface overlain at many places by sandstone that contains scattered granules and pebbles of gray chert.

Stockade Beaver shale member.—The Stockade Beaver shale member of the Sundance formation ranges in thickness from 50 to 90 feet in two sections measured near the Nefsy Divide quadrangle. The member is thinner where it overlies a thick section of the Canyon Springs sandstone and, conversely, is thicker where the Canyon Springs sandstone is thin or absent. The Stockade Beaver shale member is mostly soft green calcareous shale, but includes thin sandstone and siltstone beds at the top. The contact with the Canyon Springs sandstone, although fairly abrupt, appears to be conformable.

Hulett sandstone member.—The Hulett sandstone member is 70 to 80 feet thick and is well exposed at many places along Miller Creek and near the junction of Inyan Kara Creek and the Belle Fourche River. It crops out but is less well exposed north of Houston Creek near the center of T. 51 N., R. 64 W. The member is mostly light-gray to light-yellowish-gray fine grained to very fine grained locally calcareous sandstone interbedded with some greenish-gray siltstone and shale at the base. The lower and upper parts are thin bedded and slabby, and locally are ripple marked; the middle part is more massive, and along Miller and Inyan Kara Creeks it forms conspicuous vertical cliffs as shown by figure 2. Along Houston Creek the sandstone is generally friable and forms only a few ledges on grass-covered slopes. The member grades downward into the underlying Stockade Beaver shale member through an interval of 5 to 15 feet by an increase in the number and thickness of siltstone and shale partings.

Lak member.—The Lak member of the Sundance formation is 40 to 60 feet thick and consists of pink and yellowish-gray very fine grained noncalcareous sandstone and siltstone that gradationally over-

FIGURE 2.—Part of the Hulett sandstone member of the Sundance formation along the Belle Fourche River, Nefsy Divide quadrangle.

lie the Hulett sandstone member. The Lak generally forms low rolling grass-covered hills. It is best exposed in road cuts along U.S. Highway 14 in the northwestern part of the quadrangle. Along Miller and Inyan Kara Creeks, the Lak is pink and is easily distinguished from the more resistant yellowish-gray Hulett sandstone on the basis of both color and topographic expression. North of Houston Creek in T. 51 N., R. 64 W., the Hulett and Lak members are predominantly yellowish gray and nonresistant, and they are difficult to differentiate. Farther north at the Miller Creek dome and at the head of Miller Creek the two members are poorly exposed and mapped as one unit.

Redwater shale member.—The Redwater shale member of the Sundance formation generally underlies rolling grass-covered hills and natural exposures are few. The member is about 170 feet thick and consists mostly of greenish-gray shale interbedded and interlaminated with light-gray calcareous siltstone and silty sandstone that locally weathers to brown curved fragments and plates. A few beds of coquinoid or oolitic limestone, generally one-half to 1 foot thick, are present in the upper part of the member. Glauconite is abundant in the member except for the upper 10 to 20 feet, and the contact of the Redwater with the underlying Lak member is marked by abundantly glauconitic sandstone or greenish-gray shale resting sharply

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on nonglauconitic sandstone or siltstone. The topmost bed of the Redwater nearly everywhere is a calcareous yellow-weathering sandstone, 2 to 5 feet thick, that can be traced for many miles along the west side of the Black Hills. Locally, the uppermost part of the Redwater shale member contains a few thin seams of gypsum, and in sec. 35, T. 52 N., R. 66 W., a bed of gypsum 4 feet thick crops out beneath the contact with the overlying Morrison formation, as shown by the following stratigraphic section:

Parts of the Morrison and Sundance formations in the SE¼SW¼ sec. 35, T. 52 N., R. 66 W., Crook County, Wyo.

[Measured by P. K. Theobald (written communication, 1955)]

	Feet
Morrison formation (part):	
12. Claystone, greenish-gray and grayish-red, calcareous	10.0
11. Marl, very light gray	1.5
10. Claystone, greenish-gray, silty, calcareous	4.0
9. Sandstone, grayish-white, very fine grained, calcareous, in thin contorted beds	0.5
8. Shale, greenish-gray, silty, calcareous	2.0
Partial thickness, Morrison formation	18.0
Sundance formation (part):	
Redwater shale member (part):	
7. Gypsum, white to pink, massive	4.0
6. Sandstone, grayish-brown, very fine grained, seams of gypsum one-eighth of an inch thick	1.0
5. Shale, greenish-gray, calcareous	0.5
4. Siltstone, yellowish-gray, very calcareous, thin-bedded	0.5
3. Sandstone, mostly yellow becoming gray in the bottom 1 ft, very fine grained, very calcareous, thin-bedded	4.8
2. Siltstone, light-gray, calcareous, thin-bedded, thin stringers, one-eighth of an inch thick, of chert	1.7
1. Shale, greenish-gray, silty, noncalcareous, glauconite	5.0
Partial thickness, Sundance formation	17.5

MORRISON FORMATION

The Morrison formation ranges in thickness from about 65 feet, near the junction of Houston and Little Houston Creeks, to about 120 feet near the mouth of Inyan Kara Creek. The formation weathers locally to badlands and is well exposed at many places along the east side of Inyan Kara Creek. Variations in the thickness and lithology of the Morrison are shown by the columnar sections (pl. 2).

The Morrison is divided into two parts. The lower part averages about 60 feet thick and consists mostly of grayish-green and grayish-red calcareous silty claystone. The lower 25 feet of this unit is gen-

erally sandy and contains one or more cross-laminated ripple-marked beds, 1 to 4 feet thick, of grayish-white very fine grained calcareous sandstone. Nodules and beds, a few inches thick, of light-gray argillaceous limestone and marl are common throughout the lower part of the formation.

The upper part of the Morrison formation consists of noncalcareous claystone that is green in the lower part, grading upward to dark brownish gray. This part of the formation ranges in thickness from 0 to about 50 feet, and commonly is 20 to 40 feet thick. It is less than 10 feet thick at places along Little Houston Creek (pls. 1 and 2, locs. 16, 42, 43), and it is absent locally along Road Creek (loc. 29) where a sandstone-filled channel at the base of the overlying Lakota formation cuts into the Morrison. It appears to be missing near the mouth of Corral Creek (loc. 56). At this locality, however, silty and sandy claystone assigned to the base of the Lakota formation may be equivalent to nonsandy claystone that in nearby areas was assigned to the upper part of the Morrison.

The Morrison grades downward into the underlying Sundance formation; the contact, which is at the top of a persistent bed of yellow-weathering sandstone, generally can be defined within about 1 foot.

The following section is typical of the formation along Inyan Kara Creek; other stratigraphic sections are given on pages E15–E27 with descriptions of the overlying Lakota formation.

Morrison formation near the mouth of Huett Canyon, about the center of the N½ sec. 6, T. 51 N., R. 65 W., Crook County, Wyo.

[Loc. 26, pls. 1 and 2]

	Feet
Top of the hill.	
Lakota formation (part):	
14. Poorly exposed; scattered outcrops of friable yellowish-gray siltstone, locally mottled orange red	10
13. Sandstone, light-gray; locally stained yellow and orange red, mostly fine grained; containing lenses of coarse grained to pebbly sandstone in the basal 5 ft.; crossbedded; locally carbonaceous and thin bedded in the top 5 ft.; forms a cliff	35
12. Mostly covered; some slumped blocks of coarse grained to pebbly sandstone containing brown woody fragments	12
Partial thickness, Lakota formation	57
Morrison formation:	
Upper part:	
11. Claystone, dark-gray to brownish-black, noncalcareous; much fossil wood (*Araucarioxylon* sp.) in the float apparently from the lower half of the unit	27
10. Claystone, dark-greenish-gray, noncalcareous	3

Morrison formation near the mouth of Huett Canyon, about the center of the N½ sec. 6, T. 51 N., R. 65 W., Crook County, Wyo.—Continued

	Feet
Morrison formation—Continued:	
Lower part:	
9. Claystone, light-green and pale-yellow, calcareous; some stringers of gypsum near the top	6
8. Claystone, greenish-gray, noncalcareous	4
7. Claystone, light-greenish-gray and pale-yellow, very calcareous	2
6. Claystone, mostly greenish-gray with some grayish-red bands; calcareous, silty and sandy in the bottom third; a few lenses and nodules of light-gray clayey limestone	59
5. Sandstone, very light gray; weathers brown locally; very fine grained, calcareous, ripple marked, slabby; forms a ledge	1
4. Poorly exposed; appears to be mostly greenish-gray calcareous silty claystone	8
3. Sandstone, very light gray, very fine grained, calcareous; forms rounded ledges	8½
2. Poorly exposed; some light-gray very fine grained, calcareous sandstone with partings of greenish-gray shale in the lower part	3½
Thickness, Morrison formation	122
Sundance formation (part):	
Redwater shale member (part):	
1. Sandstone, moderate-yellow, fine grained to very fine grained, very calcareous, friable, thin-bedded	10

Tabular concretions as much as 1 foot in diameter composed of radiating fibrous calcite crystals crop out near the top of the lower, calcareous part of the formation at localities 56 and 57 (pls. 1 and 2), and barite concretions 1 to 3 inches in diameter were found at about the same horizon at locality 57.

Fossils from the Morrison formation include ostracodes, charophytes, dinosaur bones, a few pelecypods, and silicified wood. Except for the wood, all fossils so far reported from the formation in the Black Hills are from the lower calcareous part. Their age has been regarded as Kimmeridgian (Late Jurassic) by Reeside (*in* Yen, 1952, p. 22–26), Peck (1957, p. 8), and Sohn (1958, p. 122).

Ostracodes collected from the formation at several places in the quadrangle and identified by I. G. Sohn (written communication, 1958) include "*Metacypris*" spp.; *Darwinula* sp.; new genus smooth, large; and new genus smooth, small. Fossil wood from the upper noncalcareous part of the formation at localities 26 and 57 (pls. 1 and 2) is referred by R. A. Scott to the genus *Araucarioxylon* but is too poorly preserved for specific identification. Charophytes collected from the formation a short distance north of the quadrangle in sec. 5, T. 52 N., R. 64 W., were identified by R. E. Peck (written com-

munication, 1957) as *Aclistochara bransoni* Peck, *A. jonesi* Peck, *Latochara concinna* Peck, *L.* cf. *L. concinna* Peck, and *L. latitruncata* Peck.

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

INYAN KARA GROUP

Inyan Kara group is the name introduced by Rubey (1930, p. 4) for dominantly sandy and silty beds lying between the Morrison formation below and the Skull Creek shale above. In earlier reports, the Inyan Kara group commonly was divided into 4 formations which, in ascending order, were: the Lakota, Minnewaste, Fuson, and Fall River or Dakota formations. The Minnewaste is a local limestone bed at the south end of the Black Hills, and, where it is absent, much uncertainty and confusion has resulted in applying the other three names in the Black Hills.

Two formations are recognized in the Inyan Kara group in the Nefsy Divide quadrangle. These are the Lakota and Fall River formations, as redefined by Waagé (1959); the two formations are separated by a regional unconformity. The names Minnewaste and Fuson are restricted by Waagé to members in the upper part of the Lakota formation in the southern Black Hills.

LAKOTA FORMATION

The Lakota formation, as redefined by Waagé (1959, p. 32–33) and mapped during the present investigation, is 100 to 120 feet thick in most parts of the Nefsy Divide quadrangle. It thickens northward to about 160 feet near the mouth of Arch Creek and has about the same thickness near the head of Miller Creek. It is as little as 71 feet thick along Inyan Kara Creek in sec. 35, T. 51 N., R. 65 W. The formation consists of complexly interfingering sandstone, conglomeratic sandstone, claystone, some limestone, and intermediate rock types, which are exposed in cliffs, ledges, and steep slopes above the less resistant Morrison formation. Some variations in the thickness and lithology of the Lakota are shown by the columnar sections (pl. 2).

In the southern two-thirds of the quadrangle, the lower part of the Lakota formation consists mostly of fine grained to very fine grained light-gray evenly bedded sandstone, interbedded with claystone, shale, and siltstone. This part of the formation is commonly carbonaceous and at several places along the east edge of the quadrangle it contains thin streaks of coal. According to Stone (1912, p. 22), a bed of coal 4 feet thick crops out in this part of the formation on Coal Divide in sec. 10, T. 50 N., R. 64 W.; an abandoned mine in

the E½ sec. 10 marks the site of this deposit. No coal was seen by the writers in nearby outcrops of the Lakota and this bed is probably of very limited extent. Units 1 through 9 in the following partial section comprise the lower part of the formation and indicate its carbonaceous content about 1 mile east of Beaver Creek and 4 miles southeast of the mine on Coal Divide, just outside the quadrangle boundary.

Lakota formation east of Beaver Creek, in the SW¼ sec. 25, T. 50 N., R. 64 W., Crook County, Wyo.

	Feet
Fall River formation (part):	
12. Sandstone, yellowish-gray, very fine grained, thin-bedded; a few thin seams impregnated with dark-brown iron oxides; forms a ledge	7
Unconformity.	
Lakota formation (part):	
11. Covered (contact between the Fall River and Lakota formations probably near the top of this interval)	18
10. Sandstone, light-gray to yellowish-gray, mostly fine grained, becoming medium- to coarse-grained in the basal 3 to 4 ft, conspicuously crossbedded; forms massive rounded ledges	30
Local unconformity.	
9. Sandstone, light-gray to yellowish-gray, becoming dark-gray at the top, fine grained to very fine grained, in tabular beds 6 in. to 4 ft thick	7½
8. Claystone, medium-gray, silty, contains irregular thin beds of yellowish-gray fine grained sandstone that are locally stained pink; some thin sandstone seams impregnated with dark-brown iron oxides	3
7. Covered	3
6. Shale, coal, and claystone as follows:	
Shale, brown, carbonaceous 2.2	
Coal 0.4	
Shale, brown, carbonaceous 2.0	
Coal, shaly 0.4	
Shale, brown, carbonaceous 4.0	
Claystone, grayish-black 2.0	
Total	11
5. Sandstone, brownish-gray, fine grained; a few irregular partings of brownish-gray claystone; in blocky beds about 1 ft thick	4
4. Claystone, grayish-black, carbonaceous	2½
3. Sandstone, light-gray, fine grained to very fine grained, many partings of dark-gray carbonaceous shale	5½
2. Sandstone, light-gray, locally stained yellow, fine grained to very fine grained; locally forms a blocky ledge	1½
1. Claystone, medium-gray, very silty	2
Partial thickness, Lakota formation	88
Base of exposure.	

The coal-bearing sequence in the lower part of the Lakota grades westward into calcareous sandstone and laminated brown-weathering calcareous shale that locally contains abundant ostracodes, charophytes, and gastropods. These beds are exposed in the lower valley of Houston Creek and at places farther north along Inyan Kara Creek (pls. 1 and 2, locs. 16, 45, 56). Overlying the calcareous and fossiliferous beds and making up the remaining lower part of the formation are several feet of sandstone interbedded with sandy claystone mottled green, purple, and red. The claystone unit extends from Houston Creek northward at least to Road Creek in the northwestern part of the quadrangle.

The upper part of the Lakota formation consists mostly of a bed of friable light-gray sandstone 20 to 50 feet thick which forms a prominent cliff in most parts of its outcrop area, but which locally may be soft and nonresistant, as shown in figure 3. The sandstone is mostly fine to medium grained, becoming coarser grained toward the base. Commonly the basal part has lenses and seams of conglomerate consisting of granules and small pebbles of chert and quartzite. In addition to the conglomerate, this unit differs at most places from sand-

FIGURE 3.—Lakota and parts of adjacent formations on the east side of Inyan Kara Creek, locality 56. White band at the top of the Lakota is a persistent conglomeratic sandstone. Jm, Morrison formation; Kl, Lakota formation; Kf, Fall River formation.

FIGURE 4.—High-angle crossbeds characteristic of some thick sandstones in the Lakota formation, Nefsy Divide quadrangle.

stone in the lower part of the formation by being conspicuously crossbedded, with crossbeds dipping at angles of as much as 30° in sets mostly 6 inches to 2 feet thick (fig. 4). The conglomeratic sandstone unit rests on an uneven erosion surface, which separates the upper and lower parts of the formation; this unconformity has been traced across most of the southern part of the Nefsy Divide quadrangle (pl. 2) and for several miles to the southeast in the adjacent Inyan Kara Mountain 15-minute quadrangle.

In the northern third of the Nefsy Divide quadrangle, north of about the latitude of Road Creek, the basal part of the Lakota grades laterally into light-gray mostly fine- to medium-grained cliff-forming sandstone. This sandstone resembles beds in the upper part of the formation by being conspicuously crossbedded and by having discontinuous conglomeratic lenses containing granules and small pebbles of chert and quartzite. The basal sandstone is as much as 50 feet thick under the northern part of HK Divide, and is about 70 feet thick at places under the north end of Sunny Divide farther to the east. The same bed averages about 70 feet thick in the Carlile 7½-minute quadrangle to the west (Bergendahl and others, 1961). Claystone and sandy claystone above this basal sandstone locally contain polished chert and quartzite pebbles and cobbles as much as 6 inches in longest dimension.

In all parts of the quadrangle, the uppermost few feet of the Lakota characteristically is gray sandy or clayey siltstone that weathers red, purple, yellow, orange, or white or combinations of these colors. This unit generally contains very abundant tiny ferruginous red or yellow spherulites that average about 1 mm in diameter.

The dip direction of crossbeds in the Lakota formation was determined at 37 localities in and near the quadrangle and the results are

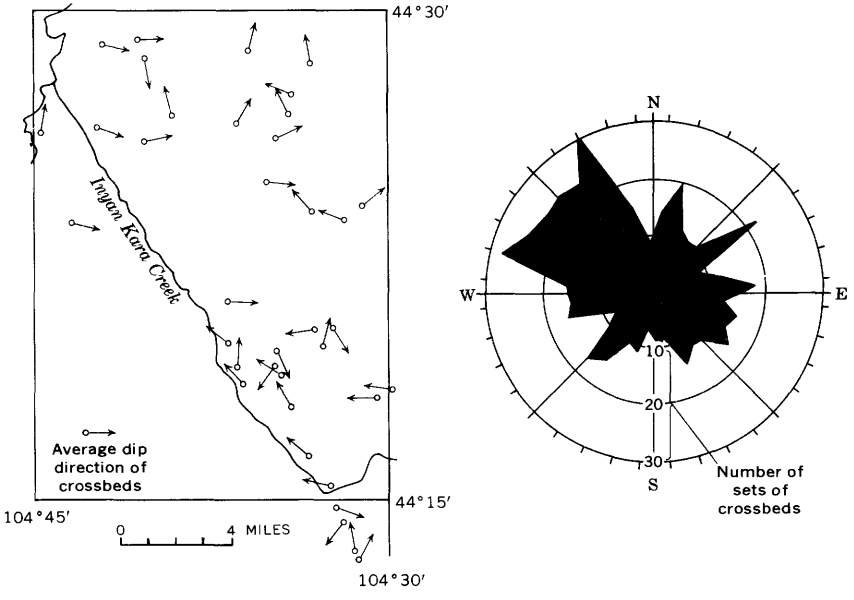

FIGURE 5.—Dip direction of crossbeds in the Lakota formation, Nefsy Divide quadrangle and vicinity. Map and diagram summarize dip directions of 548 sets of crossbeds at 37 localities.

summarized on figure 5. Readings on at least 10 sets of crossbeds at each locality were averaged in calculating the dip direction. Dips in any direction may be found but a definite orientation of dips to the northwest is evident if all the readings are considered. The data suggest that in the Nefsy Divide quadrangle, crossbedded sandstone of the Lakota was deposited by meandering streams flowing generally to the northwest.

The four stratigraphic sections below give some details of lithology of the Lakota formation and adjacent beds. Plate 2 shows the correlation of the units described.

Lakota and parts of the Morrison and Fall River formations north of East Creek, NE¼ sec. 19, T. 52 N., R. 65 W., Crook County, Wyo.

[Loc. 3, pls. 1 and 2]

Top of the hill.

Fall River formation (part):

Lower part (part):

	Feet
16. Sandstone, light-gray; weathers brown; fine grained to very fine grained; forms slabby ledges at the crest of the hill	2
15. Covered	34
14. Sandstone, light-yellowish-gray, very fine grained, ripple-marked; contains a few scattered nodules cemented with iron oxides; forms a single massive ledge	6
13. Covered	16
12. Sandstone, light-yellowish-gray, very fine grained, cross-laminated, ripple-marked, in beds mostly 1–6 in. thick; forms a ledge	6
11. Partly covered; mostly dark-gray silty shale, locally carbonaceous, nonresistant	16
Partial thickness, Fall River formation	80

Unconformity.

Lakota formation:

10. Siltstone, medium-gray, locally mottled red and yellow, clayey, nonresistant	20
9. Sandstone, light-gray to light-yellowish-gray, mostly fine grained to very fine grained containing stringers of coarse-grained to granule sandstone, locally carbonaceous; forms a cavernous ledge	18

Local unconformity.

8. Sandstone, very light gray, very fine grained, slightly carbonaceous, friable, nonresistant	5
7. Covered	31
6. Partly covered; scattered exposures of green claystone locally mottled red, variably sandy	7
5. Sandstone, light-gray and yellowish-gray, very fine grained, very friable, nonresistant	5
4. Claystone, dark-gray at the base; green at the top	5
3. Sandstone, very light gray, locally stained yellow, mostly fine grained to medium grained, coarse grained to pebbly in the bottom 2 to 4 ft, conspicuously crossbedded, friable, forms minor ledges	33
Thickness, Lakota formation	124

Local unconformity.

Morrison formation (part):

2. Claystone, green and grayish-green, dark-grayish-brown in the top 3 ft, noncalcareous	15
1. Claystone, banded greenish gray and grayish red, calcareous, locally silty; a few thin beds and nodules of light-gray marl	45
Partial thickness, Morrison formation	60

Base of the exposure.

Lakota and Morrison formations and part of the Fall River formation north of Corral Creek, NW¼ sec. 21, T. 51 N., R. 65 W., Crook County, Wyo.

[Loc. 56, pls. 1 and 2]

	Feet
Fall River formation (part):	
Lower part (part):	
23. Sandstone, light-gray, very fine grained, slightly carbonaceous, in beds about 6 in. thick; a bed of gray silty shale about 1 ft. thick at the middle of the unit separates it into two prominent ledges; ripple-marked at top	18
22. Siltstone and sandstone, light-gray to light-grayish-yellow, very fine grained, very thin bedded; some interlaminated dark-gray silty shale in lower half, makes a slope	7
21. Siltstone, light-gray, thin-bedded, a few iron oxide-cemented seams; forms blocky ledges	3½
20. Shale, medium- to dark-gray, slightly silty, slightly carbonaceous	3½
Partial thickness, Fall River formation	31
Unconformity.	
Lakota formation:	
19. Sandstone, very light gray, faintly mottled yellow and pink; basal 5 to 10 ft. mostly medium to coarse grained; scattered granules and pebbles as much as one-half in. in longest dimension; fine grained in middle and upper parts; a few scattered coarse grains at the top; friable, crossbedded	31
Local unconformity.	
18. Claystone, greenish-gray and red, sandy in middle and lower parts	40
17. Sandstone, grayish-white, fine grained to very fine grained, calcareous, friable; contains a few thin irregular seams of green claystone; forms ledges locally	7
16. Claystone, dark-gray in lower part, greenish-gray and red in upper part; noncalcareous in lower part, becoming calcareous in upper part; very sandy in top 3 to 4 ft	9
15. Claystone and clayey sandstone, olive-gray; becomes more sandy at top	10
14. Shale, brownish-gray to olive-gray, calcareous; contains abundant ostracodes and a few gastropods. Ostracodes include *Cypridea* spp., "*Metacypris*" spp., *Darwinulla* sp., large smooth form genus undetermined, small smooth form genus undetermined; fossils identified by I. G. Sohn, USGS loc. 25646	1
13. Limestone, light-gray to grayish-white, interbedded greenish-gray claystone, silty; contains abundant ostracodes and a few gastropods in upper part. Ostracodes include *Cypridea longispina* Peck, 1941, *Cypridea* sp., "*Metacypris*" spp., large smooth form genus undetermined; fossils identified by I. G. Sohn, USGS loc. 25644	9
12. Claystone, greenish-gray, sandy, mostly calcareous becoming noncalcareous in upper part; beds of light-gray argillaceous limestone mostly less than 6 in. thick, about 6, 13, and 17 ft. above base	22

Lakota and Morrison formations and part of the Fall River formation north of Corral Creek, NW¼ sec. 21, T. 51 N., R. 65 W., Crook County, Wyo.—Con.

	Feet
Local unconformity—Continued	
11. Claystone, mostly greenish-gray, containing bright-green, yellowish-gray, and reddish-purple bands, locally sandy, noncalcareous, some polished pebbles weathering out on the slope	18
Thickness, Lakota formation	147
Morrison formation:	
10. Claystone, greenish-gray, calcareous, lenses of argillaceous grayish-white limestone and a few spherical to tabular limestone concretions having fibrous crystals radiating from the centers	16
9. Sandstone, light-gray, very fine grained, calcareous, lenticular, upper part locally forms slabby ledges	6
8. Claystone, greenish-gray, calcareous	2
7. Sandstone, light-gray, very fine grained, friable, calcareous, clay pellets in basal 1 to 2 ft	8
6. Claystone, greenish-gray, calcareous, locally sandy; a lens 1 ft thick of light-gray very fine grained sandstone about 18 ft above the base; a few lenses of light-gray nodular limestone in top 2 ft	40
5. Limestone, light-gray, dense, forms a ledge	2
4. Claystone, dark-greenish-gray, calcareous	3
3. Limestone, grayish-white containing contorted gray laminae, sandy: contains vugs filled with coarsely crystalline calcite	2½
2. Claystone, greenish-gray, calcareous	1
Thickness (rounded), Morrison formation	80
Sundance formation (part):	
Redwater shale member (part):	
1. Sandstone, grayish-yellow, fine grained, calcareous, shaly at base; forms a minor ledge	3

Lakota and Morrison formations and part of the Fall River formation in road cuts and on the adjacent hillside west of Newman Divide, NE¼ sec. 2, T. 50 N., R. 65 W., Crook County, Wyo.

[Loc. 38, pls. 1 and 2]

	Feet
Top of the hill.	
Fall River formation (part):	
Lower part (part):	
19. Siltstone, light-gray, very thin bedded, locally carbonaceous; some interbedded yellowish-gray very fine grained sandstone in upper part	20
18. Shale, dark-gray, carbonaceous, silty	1
Partial thickness, Fall River formation	21

Lakota and Morrison formations and part of the Fall River formation in road cuts and on the adjacent hillside west of Newman Divide, NE¼ sec. 2, T. 50 N., R. 65 W., Crook County, Wyo.—Continued

	Feet
Unconformity.	
Lakota formation:	
17. Siltstone, light-gray and yellowish-gray, clayey; contains small ferruginous spherulites	6
16. Sandstone, light-gray, mostly fine- to medium-grained, some scattered coarse grains and granules, friable, crossbedded; forms ledges	22
Local unconformity.	
15. Claystone, mostly green with red, yellow, and purple bands; sandy, grading locally to clayey fine-grained sandstone	23
14. Claystone, pale-green, slightly sandy at top	10
13. Sandstone, very light gray, very fine grained: a few partings and seams of gray sandy claystone	8
12. Siltstone, light-gray, slightly carbonaceous	2
Thickness, Lakota formation	71
Morrison formation:	
11. Claystone, green in lower half, gray to grayish-brown in upper half; contains scattered light-gray-weathering clay nodules that locally contain seams and crystals of barite	38
10. Claystone, yellow, very calcareous	4
9. Claystone, greenish-gray; some thin beds of light-gray argillaceous limestone	13
8. Marl, yellow, thin-bedded	5
7. Partly covered; mostly greenish-gray and grayish-red calcareous claystone; a few thin beds of light-gray argillaceous limestone.	16
6. Sandstone, very light gray, very fine grained, calcareous, cross-laminated; forms slabby ledges	6
5. Partly covered; mostly greenish-gray silty and sandy calcareous claystone	22
4. Limestone, gray, sandy, forms a prominent blocky ledge	1½
3. Claystone, greenish-clay, calcareous	3
2. Siltstone and shale, interlaminated; light-gray and greenish-gray.	2
Thickness (rounded), Morrison formation	110
Sundance formation (part):	
Redwater shale member (part):	
1. Siltstone, yellow, calcareous	1
Base of the exposure about creek level.	

Lakota and Morrison formations and parts of the Fall River and Sundance formations, north side of Dark Canyon, NW1/4 sec. 2, T. 49 N., R. 64 W., Crook County, Wyo.

[Loc. 22, pls. 1 and 2]

Top of the hill.

	Feet
Fall River formation (part):	
Lower part (part):	
29. Poorly exposed; appears to be mainly interbedded yellowish-gray very fine grained sandstone and medium- to dark-gray siltstone; locally impregnated with iron oxides	15
28. Sandstone, yellowish-gray, fine grained to very fine grained, micaceous, mostly in beds less than 1 ft thick; forms blocky ledges	8
27. Siltstone, medium-gray, hard, slightly carbonaceous locally.	3
Partial thickness, Fall River formation	26

Unconformity.

Lakota formation:	
26. Claystone, very dark red, mottled light gray, purple, and yellow; abundant ferruginous spherulites about 1 mm in diameter in the top 3 ft	10½
25. Covered	12
24. Sandstone, light-yellowish-gray, fine grained, nonresistant	4
23. Poorly exposed: appears to be mostly sandstone as in unit 24 above	5
22. Sandstone, yellowish-gray, fine grained to medium grained; containing some coarser layers and a few scattered granules and pebbles, crossbedded; forms a cliff	27
Local unconformity.	
21. Claystone, medium-gray, silty and sandy	2½
20. Sandstone, light-gray, fine grained, friable; forms minor ledges	5
19. Claystone, medium-gray, very silty	1½
18. Sandstone, light-gray, stained yellow and red-orange locally, fine grained, inconspicuously crossbedded; forms massive ledges	35
17. Shale, dark-brown to dark-gray, silty, carbonaceous	3
Thickness, Lakota formation	106

Section below offset about 200 yards west

Morrison formation:	
16. Claystone, dark-greenish-gray, noncalcareous	16
15. Claystone, dark-greenish gray containing a few thin dusky-yellow streaks, calcareous	10
14. Claystone, grayish-yellow and greenish-gray in alternating bands, silty, calcareous to very calcareous; forms a conspicuous yellow band on the hillside	21
13. Claystone, greenish-gray and purplish-gray, calcareous, slightly silty, several thin lenses of light-gray clayey limestone; a limestone bed 15 ft above the base contains abundant *Unio nucalis* Meek and Hayden; fossils identified by W. A. Cobban, USGS loc. D1157	33

Lakota and Morrison formations and parts of the Fall River and Sundance formations, north side of Dark Canyon, NW¼ sec. 2, T. 49 N., R. 64 W., Crook County, Wyo.—Continued

Section below offset about 200 yards west—Continued

	Feet
Morrison formation—Continued	
12. Limestone, light-gray, dense, clayey, lenticular; forms a ledge	2
11. Claystone, grayish-red, and greenish-gray	9
10. Limestone, as in unit 12 above	1½
9. Claystone, grayish-red, calcareous	5
8. Sandstone, light-gray to white, very fine grained, very calcareous, thin-bedded, ripple-marked; forms slabby ledge	½
7. Claystone, dark greenish-gray, calcareous	2
6. Sandstone, very light gray, very fine grained, calcareous, thin-bedded, ripple-marked; forms hard ledges	4
5. Claystone, greenish-gray, calcareous, slightly sandy	1½
4. Limestone, light-gray, dense	½
3. Shale, greenish-gray, noncalcareous, a few laminae of light-gray sandstone	1
Thickness, Morrison formation	107
Sundance formation (part):	
Redwater shale member (part):	
2. Sandstone, moderate-yellow, fine grained to very fine grained, calcareous; partings of greenish-gray shale in middle and upper parts	5½
1. Shale and sandstone, interlaminated; shale is grayish green, noncalcareous; sandstone is light gray, very fine grained, calcareous	15
Partial thickness (rounded), Sundance formation	20

The rocks at the Lakota-Morrison contact differ from place to place because of lateral lithologic changes in the Lakota formation. In general, the contact is placed at the base of the first sandstone or first carbonaceous bed above the typical calcareous claystone and limestone of the Morrison. Where this sandstone is a thick conglomerate, as in most of the northwestern part of the quadrangle, the contact is an unconformity and is easily recognized. Elsewhere, no obvious physical break separates the two formations and the contact is more or less arbitrarily chosen to separate predominantly sandy beds in the Lakota formation from predominantly clayey beds in the Morrison formation.

The Lakota formation is not abundantly fossiliferous, although at some places in the Black Hills it contains fossil cycad, fern, and conifer foliage described by Fontaine (1899), ostracodes described by Sohn (1958), charophytes described by Peck (1957, p. 10–11), and a few fresh-water mollusks and dinosaur bones. These fossils indicate an Early Cretaceous (Aptian?) age for the formation. Fossils col-

lected in the Nefsy Divide quadrangle are from the lower part of the formation and include the following (identified by I. G. Sohn, written communication, 1958):

Localities 16 and 45, plates 1 and 2 (USGS locs. 25643, 26940, and 26941)

Ostracodes:
- *Cypridea* sp.
- *Iliocypris*? sp.
- "*Bairdiocypris*" *trapezoidalis* Roth, 1933
- "*Metacypris*"? sp.
- Genus indet. large, smooth
- Genus indet. small, smooth

Estheriid crustacean *Cyzicus*
Undetermined low-spired gastropods

Locality 56, plates 1 and 2 (USGS locs. 25644 and 25645)

Ostracodes:
- *Cypridea longispina*? Peck, 1941
- *Cypridea* spp.
- "*Metacypris*" spp.
- Genus indet. large, smooth
- Genus indet. small, smooth

Undetermined low-spired gastropods

FALL RIVER FORMATION

The Fall River formation consists of 135 to 150 feet of sandstone, siltstone, and shale, exposed on divides and broad dipslopes in all but the southeastern part of the quadrangle. The formation is divided on the geologic map (pl. 1) into two parts; the contact between the two parts is at the base of a thick rim-forming sandstone bed.

The lower part of the formation is 80 to 95 feet thick and consists mostly of light- to dark-gray siltstone and silty shale interbedded and interlaminated with beds less than 1 inch to several feet thick of light-gray to light-yellowish-gray very fine grained sandstone (fig. 6). The unit is mostly nonresistant and generally forms steep grassy slopes above forested ledges and cliffs of the Lakota formation. Silty and shaly beds in the basal 10 to 20 feet of the formation are mostly dark gray, fissile, and carbonaceous with abundant carbonized plant fragments. These beds rest unconformably on a nearly plane surface cut on the underlying light-colored beds of the Lakota formation (fig. 7).

Firmly cemented beds of tan-weathering very fine grained sandstone or siltstone commonly form a pair of persistent ledges in an interval of 20 to 40 feet above the base of the formation. Sandstone at

FIGURE 6.—Interbedded siltstone and massive sandstone in the lower part of the Fall River formation, Nefsy Divide quadrangle.

this horizon locally thickens, and at localities 30 and 31 a bed of friable fine-grained sandstone as much as 30 feet thick occupies most of the basal part of the formation.

The basal part of the overlying upper part of the Fall River is massive to inconspicuously crossbedded, generally very fine to fine grained friable sandstone that forms ledges and cliffs at the crests of high divides. This sandstone, which is 15 to 30 feet thick in the Nefsy Divide quadrangle, was called the Keyhole sandstone member of the Fall River formation by Davis and Izett (1958). Locally the basal part of the bed interfingers with underlying thin-bedded siltstone and shale. At a few places this basal unit of the upper part of the Fall River is mostly thin bedded and is not easily separated from the underlying part of the formation.

The uppermost 20 to 40 feet of the Fall River is thin-bedded siltstone, sandstone, and shale and is generally poorly exposed at the base of dipslopes formed on the more resistant sandstone just described.

FIGURE 7.—Sharp, even contact (behind the shovel) of the Lakota and Fall River formations, west side of Inyan Kara Creek, locality 55.

Both the upper and lower parts of the Fall River are characterized by nodules and seams 1 or 2 inches thick of siltstone or sandstone impregnated with dark-brown iron oxides. Many siltstone and thin sandstone beds are cross laminated and ripple marked, and bedding surfaces of many thin beds are covered by raised markings resembling worm trails and burrows.

The two stratigraphic sections below describe the lithology of the Fall River formation in the northern and southern parts of the quadrangle, respectively; the lithology in other areas is shown on the graphic sections (pl. 2).

Part of the Fall River formation on Sunny Divide, about the center of the S½ sec. 34, T. 52 N., R. 65 W., Crook County, Wyo.

[Loc. 7, pls. 1 and 2]

Top of the ridge.

Fall River formation (part):

	Feet
Upper part (part):	
10. Covered grassy slope; probably sandstone, as in unit 9 below	12
9. Sandstone, light-yellowish-gray to light-gray, fine grained to very fine grained, friable, beds mostly 1 to 3 ft thick, inconspicuously crossbedded; scattered nodules cemented with iron oxides; forms prominent rounded ledges	14
Lower part:	
8. Covered	13
7. Siltstone, light- to dark-gray, interlaminated with dark-gray silty shale; carbonaceous in middle part; a few thin seams cemented with iron oxides; nonresistant	38
6. Sandstone, light-yellowish-gray to light-gray, fine grained to very fine grained, friable; beds as much as 2 ft thick, lenticular; forms a massive ledge	14
5. Sandstone, light-yellowish-gray, very fine grained; beds mostly ½ to 6 in. thick; locally forms slabby ledges	8
4. Siltstone, medium-gray, and shale	5
3. Covered	10
2. Siltstone, medium- to dark-gray, shaly, carbonaceous	4
Partial thickness, Fall River formation	118

Unconformity.

Lakota formation (part):

1. Claystone, gray, mottled yellow and red, silty, contains abundant small ferruginous spherulites	3

Parts of the Fall River and Lakota formations opposite Norris Divide SE¼ sec. 30, T. 50 N., R. 64 W., Crook County, Wyo.

[Loc. 46, pls. 1 and 2]

Top of the hill.

Fall River formation (part):

	Feet
Upper part (part):	
17. Sandstone, yellowish-gray, fine grained to very fine grained, crossbedded; some thin seams impregnated with iron oxides; forms rounded ledges	8
16. Poorly exposed; in part dark-gray shale	3½
15. Sandstone, yellowish-gray, fine grained to very fine grained, crossbedded; some fragments of dark-gray shale in lower part, a few seams cemented with iron oxides; forms rounded ledges that weather back on slope	13½

Parts of the Fall River and Lakota formations opposite Norris Divide SE¼ sec. 30, T. 50 N., R. 64 W., Crook County, Wyo.—Continued

	Feet
Fall River formation (part)—Continued	
Lower part:	
14. Covered	10
13. Siltstone and shale, interbedded and interlaminated; siltstone is light to medium gray, fucoidal; shale is dark gray; a few thin beds of light-gray very fine grained sandstone	38
12. Sandstone, grayish-yellow, very fine grained, in beds as much as 6 in. thick; forms a slabby ledge	4½
11. Covered	11
10. Sandstone, light-gray, very fine grained to silty, in beds as much as 1 ft. thick, cross-laminated; forms a ledge	4½
9. Siltstone, medium- to dark-gray; a few thin laminae of grayish-yellow very fine grained sandstone and dark-gray silty shale; locally carbonaceous	22½
8. Siltstone, light-gray, blocky, carbonaceous	1½
Partial thickness, Fall River formation	117
Unconformity.	
Lakota formation (part):	
7. Claystone, medium-gray to olive-gray, silty to slightly sandy, small ferruginous spherulites in basal 1 to 2 ft	4½
6. Sandstone, light-gray and moderate-yellow, fine grained, friable; nonresistant	5
5. Claystone, medium-gray to olive-gray, silty	3
4. Sandstone, grayish-yellow to grayish-orange, fine grained, friable; forms a minor ledge	2
3. Shale, dark-gray, soft	3½
2. Claystone, olive-gray, sandy	3½
1. Sandstone, grayish-yellow to dark-yellowish-orange, fine grained, in beds 6 in. to 2 ft. thick; forms massive ledges	10
Partial thickness (rounded), Lakota formation	19
Base of the exposure.	

The age of the Fall River formation is generally regarded as Early Cretaceous (Albian). Fossils are rare aside from plant fragments and the trails and burrows of unidentified organisms. The nonmarine pelecypod *Protelliptio douglassi* Stanton was found in coaly shale in the basal foot of the formation along Cabin Creek, about 1 mile northwest of the quadrangle. A sandstone bed in the lower part of the formation locally contains cone-shaped structures made up of sandstone pellets clustered around a central axis which, according to J. B. Reeside, Jr. (written communication, 1956), resemble in a general way the marine organism *Halymenites*.

The Fall River formation resembles lithologically, and probably grades laterally into, the basal sandy part of the marine Colorado shale in central Montana, and into the marine sandstone, siltstone, and shale that make up the so-called rusty beds in the upper part of the Cloverly formation in central Wyoming (Cobban, 1951, p. 2175; Waagé, 1958, p. 76).

SKULL CREEK SHALE

The Skull Creek shale is about 250 feet thick and consists of soft flaky black shale, a few seams of silty shale and siltstone, scattered red-weathering siderite concretions, and, in the upper part, some yellowish-gray cone-in-cone limestone concretions. The formation crops out southwest of Arch Creek where it forms low rolling hills sparsely covered with grass and sagebrush. It rests conformably on the Fall River formation. The contact is drawn on top of interbedded siltstone, sandstone, and shale which is transitional between the two formations, and can usually be determined in good exposures within 2 or 3 feet stratigraphically.

W. W. Rubey and C. R. Longwell (written communication, 1954) collected *Inoceramus bellvuensis* Reeside from near the middle of the Skull Creek shale in the center of sec. 33, T. 50 N., R. 65 W. (USGS loc. 11335), and they found *Lingula* n. sp., *Modiolus* n. sp., and fish bones in silty seams 75 and 150 feet above the base in sec. 28 of the same township (USGS locs. 12051 and 12061). The fossils were identified by J. B. Reeside, Jr. Foraminifera have been reported from the formation by Crowley (1951, p. 83), Skolnick (1958, p. 280–284), and Eicher (1958, p. 81). The age of the Skull Creek is Albian (Cobban, 1951, p. 2197).

NEWCASTLE SANDSTONE

The Newcastle sandstone, which averages about 30 feet thick in nearby areas, is poorly exposed in the Nefsy Divide quadrangle. A sandstone bed near the top of the formation forms a broad bench and caps a few hills in the northeastern part of T. 50 N., R. 66 W. Farther south, however, the formation is less resistant and is represented by a band of light-colored sandy soil on gentle slopes between outcrops of the underlying Skull Creek and overlying Mowry shales. The partial section below was measured along Wyoming State Highway 116 about 7 miles south of the quadrangle and is probably representative of the formation in the mapped area.

Newcastle sandstone in the S½ sec. 7, T. 48 N., R. 64 W., Weston County, Wyo.

Top of the hill.

Newcastle sandstone (part):	Feet
8. Sandstone, light-gray; weathers light brownish orange; very fine grained, firmly cemented, thin-bedded, slabby; forms ledges. (Base of overlying Mowry shale probably within 5 ft. of top of unit)	2
7. Shale, black; grades upward in top 6 in. into plastic purplish-gray claystone	4
6. Bentonite, orange-gray	.2
5. Shale, black, carbonaceous	2
4. Siltstone, grayish-yellow; contains plant impressions	5
3. Claystone, greenish-gray in lower part, purplish-gray in upper part; silty and sandy, bentonitic	7
2. Bentonite, olive-green, locally mottled dark red	3
Partial thickness (rounded), Newcastle sandstone	23
Skull Creek shale (part):	
1. Shale, black, soft; red-weathering siderite concretions at base; unit cut by a steeply dipping sandstone dike 1 to 4 in. thick and 50 to 75 ft. long	8

MOWRY SHALE

The Mowry shale is a resistant siliceous shale about 170 feet thick. It crops out in a broad ridge which is mostly bare of soil but which supports a generous growth of pine trees. The base of the formation, which generally is covered by slope wash, consists of soft black-weathering shale, 10 to 20 feet thick, called the Nefsy shale by Collier (1922, p. 82). A bed of very fine grained sandstone or siltstone a few inches thick overlies this unit locally and is overlain in turn by hard siliceous shale that weathers to brittle silvery gray chips and contains many thin beds of light-gray and light-yellowish-gray bentonite. A partial section of the Mowry 108 feet thick examined in a fresh cut in the SE¼ sec., 11, T. 50 N., R. 66 W., contains 26 bentonite beds that range from 0.05 to 1.4 feet in thickness and have an aggregate thickness of 12 feet. The top of the formation is the top of a persistent bentonite bed 2.5 feet thick called the Clay Spur bentonite (or "Commercial") bed. The Mowry is quarried and used for surfacing material on many of the roads in the vicinity.

Fish scales are abundant in the Mowry but other fossils are rare. Cobban (1951, p. 2179) credits Collier with finding impressions of the ammonites *Metengonoceras* and *Gastroplites* in the formation a few miles south of the quadrangle.

UPPER CRETACEOUS SERIES

BELLE FOURCHE SHALE

The basal 100 to 200 feet of the Belle Fourche shale is exposed in the southwest corner of the quadrangle. The formation consists of soft black shale with several beds of bentonite and, in the lower part, many siderite concretions that weather dark red. The Belle Fourche shale is thinly covered by vegetation and its dark color contrasts sharply with the light-gray-weathering shale of the underlying Mowry. Details of the lithology at the contact of the Belle Fourche and Mowry are shown by the following stratigraphic section:

Contact of the Belle Fourche and Mowry shales in sec. 26, T. 50 N., R 66 W., Crook County, Wyo.

Top of the hill.

	Feet
Belle Fourche shale (part):	
12. Shale, black, soft, contains dark-gray siderite concretions that weather dark red	9.0
11. Bentonite, grayish-yellow, shaly	.1
10. Shale, as in unit 12 above	6.1
9. Bentonite, grayish-yellow, shaly	.1
8. Shale, black	1.7
7. Bentonite, light-gray	.5
6. Shale, black, hard, brittle	2.8
5. Bentonite, light-yellowish-brown	.1
4. Shale, black, hard, brittle	1.0
Partial thickness, Belle Fourche shale	21.4
Mowry shale (part):	
3. Bentonite, light-olive-green to light-gray, top 0.5 ft shaly ("Clay Spur bed")	2.9
2. Sandstone, light-gray, very fine grained	.1
1. Shale, black, hard, brittle	1.0
Partial thickness, Mowry shale	4.0

Base of the exposure.

The lower part of the Belle Fourche shale has no known fossils; marine invertebrates are found at a few places in the upper part (Cobban, 1951, p. 2182).

TERTIARY AND QUATERNARY SYSTEMS

TERRACE GRAVEL

Poorly consolidated stream-laid deposits of silt, sand, and gravel cover small areas at different levels above the main streams. The highest and oldest gravels, presumed to be Tertiary in age, lie 350 feet or more above the present streams and include deposits on McFarland Divide in sec. 9, T. 52 N., R. 64 W.; on Sunny Divide in secs. 22 and 34, T. 50 N., R. 64 W.; and on Coal Divide in T. 50 N., R. 64 W. Lower and younger gravels of probable Quaternary age cap nearly flat surfaces at altitudes of from 40 to 150 feet above the Belle Fourche River and Miller Creek at the north edge of the quadrangle, and on the divide between Arch and Willow Creeks at the south edge.

The correlation and the age assigned to the gravel deposits are based on the physiographic relations of the deposits. Darton (1909, p. 51, pl. 4) described the high deposit on Sunny Divide as an outlying remnant of the White River formation of Oligocene age which he recognized at about the same altitude at other places in the northern Black Hills. Alden (1932, pl. 1) less specifically classified the high gravels as stream terraces and alluvial fans of Oligocene or Miocene age. The younger and lower deposits in the Nefsy Divide quadrangle are stream terraces probably deposited during Pleistocene interglacial stages, in common with other, widespread terraces in nearby parts of the northern Great Plains (Alden, 1932, pl. 1).

The deposits on McFarland Divide, which are nearly 700 feet above nearby Miller Creek, manifest themselves mostly as pebbles. A few cobbles, as much as 6 inches in maximum dimension, of quartzite, chert, and some igneous rock, are scattered on the ground surface. The maximum thickness of the deposits is probably less than 5 feet.

The deposits on Coal and Sunny Divides are about 350 feet above nearby main streams. A pit 7 feet deep in one of the deposits on Coal Divide shows tan calcareous silt containing irregular lenses of poorly sorted sand, pebbles, and a few cobbles. The coarser fragments are as much as 6 inches in maximum dimension and consist mostly of siltstone and sandstone impregnated with dark-brown iron oxides. The deposit on Sunny Divide has a thickness of at least 10 feet, and it resembles those on Coal Divide except that it contains, in addition, fragments of quartzite and limestone.

The largest of the younger gravel deposits is at least 10 feet thick and in sec. 13, T. 52 N., R. 66 W., about 40 feet above the stream level. Most of the larger fragments comprising the gravel are less than 1 inch in maximum dimension, although the deposit contains a few cobbles and some boulders as much as 18 inches long. Quartzite,

siltstone cemented with brown iron oxides, chert, and limestone make up most of the pebbles and cobbles. Much of the material was derived from the Sundance, Lakota, and Fall River formations.

QUATERNARY SYSTEM

LANDSLIDE MATERIAL

Shale and claystone of the Redwater shale member of the Sundance formation and the overlying Morrison formation are soft and plastic when wet and many landslides have formed in these rocks on steep slopes. A series of coalescing slides in the Redwater shale member of the Sundance and overlying formations covers about 2 square miles in the southwest part of T. 52 N., R. 65 W., and other large slides, mostly involving the same rocks, were mapped along Miller Creek and elsewhere in the quadrangle.

SLOPE WASH

Slope wash consisting of clay and silt covers a broad flat west of Tomcat Creek in the southeastern part of the quadrangle. Similar deposits have accumulated on slopes and flats at other places in the quadrangle but are too small and discontinuous to be shown on the geologic map (pl. 1).

ALLUVIUM

Unconsolidated alluvial deposits of silt, sand, and gravel cover the floor of most of the main valleys. Generally the streams are incised a few feet into these deposits so that only a narrow band of ground immediately adjacent to the streams is flooded during high water; the remaining parts of the deposits might more properly be called low stream terraces. The deposits along the Belle Fourche River are locally more than 20 feet thick (Whitcomb and others, 1958, fig. 3, p. 258).

IGNEOUS ROCKS

Intrusive igneous rocks of probable Tertiary age crop out at four places in the northeastern part of the quadrangle. The igneous rocks are part of a larger group of intrusive bodies composed of syenite porphyry and related rock types exposed in the Bear Lodge Mountains adjacent to the quadrangle on the northeast (Smith *in* Darton, 1905, p. 5).

The northernmost igneous body in the quadrangle is a sill (fig. 8) about 40 feet thick and several hundred yards long at the base of the Hulett sandstone member of the Sundance formation exposed in the valley of the North Fork of Miller Creek (sec. 14, T. 52 N., R. 64 W.). About 1 mile to the southwest, another igneous body covers an area of about a third of a square mile on the divide between the North and

FIGURE 8.—Syenite porphyry sill underlying the Hulett sandstone member of the Sundance formation along the North Fork of Miller Creek, sec. 14, T. 52 N., R. 64 W., Crook County, Wyo. Arrow shows top of the sill.

South Forks of Miller Creek (secs. 26 and 27, T. 52 N., R. 64 W.). The contact of the igneous and sedimentary rocks was not seen, but judging from the map relations, the igneous body is a sill intruded into the lower part of the Fall River formation which forms the adjacent parts of the divide. Another igneous body, presumably a sill at least 10 feet thick is exposed in two isolated outcrops about 150 feet apart in the valley of the South Fork of Miller Creek (sec. 2, T. 51 N., R. 64 W.). Another sill, about 30 feet thick and several hundred feet long, intrudes the lower part of the Fall River formation on Port Divide, north of Houston Creek (secs. 9 and 10, T. 51 N., R. 64 W.).

Sedimentary rocks adjacent to the sills are not appreciably altered except for being slightly hardened at the contact.

All four igneous bodies are classified as nepheline syenite porphyry or nepheline trachyte prophyry. The rock is mostly greenish gray to

medium gray. The porphyry has an aphanitic to very fine grained groundmass, and the phenocrysts are generally less than 5 mm long, but in places as much as 25 mm long. The phenocrysts are feldspar, pyroxene, and nepheline. The principal minerals identified in thin sections are orthoclase (with perhaps some sanidine or anorthoclase), aegirite-augite and augite, nepheline, and some magnetite and apatite (C. S. Robinson, oral communication, 1959). Some of these minerals are altered to zeolites, chlorite, and calcite.

The age of the igneous rocks is not known, but presumably they were intruded during uplift and folding of the Black Hills in Late Cretaceous or early Tertiary time.

STRUCTURE

The Nefsy Divide quadrangle is on the west flank of the Black Hills uplift, a broad anticlinal fold about 140 miles long and 70 miles wide in northeastern Wyoming and western South Dakota. Rocks on the west side of the Black Hills dip westward into the Powder River Basin, a major structural depression that occupies at least 160,000 square miles west of the Black Hills in Wyoming and Montana. Figure 9 shows the relation of the Nefsy Divide quadrangle to these and other structural features of northeastern Wyoming.

The configuration of sedimentary rocks in the Nefsy Divide quadrangle is shown on plate 1 by geologic sections and by structure contours, which are drawn at intervals of 50 feet on the top of the Lakota formation. For the most part, the strata are only slightly disturbed by folding and faulting. The regional dip is 1° to 2° SW., except in the northeast corner of the quadrangle where dips increase abruptly to about 5° at many places, and to as much as 15° locally. The more steeply dipping rocks form part of the southwest flank of the large Bear Lodge dome which lies mostly outside the quadrangle. Two small domes, the Miller Creek and Houston Creek domes, border the area of steeper dips. Faults with displacements of as much as 300 feet cut the sedimentary rocks on the flanks of the Miller Creek dome; faults in other parts of the quadrangle have displacements of less than 25 feet.

The principal deformation of sedimentary rocks in the Black Hills, including rocks of the Nefsy Divide quadrangle, probably occurred during Late Cretaceous or Early Tertiary time, as pointed out by Darton (1909, p. 76) and subsequent writers.

Miller Creek dome and nearby faults.—The Miller Creek dome is a sharp fold, roughly circular in outline, that brings the lower part of the Sundance formation to the surface along a small tributary of the

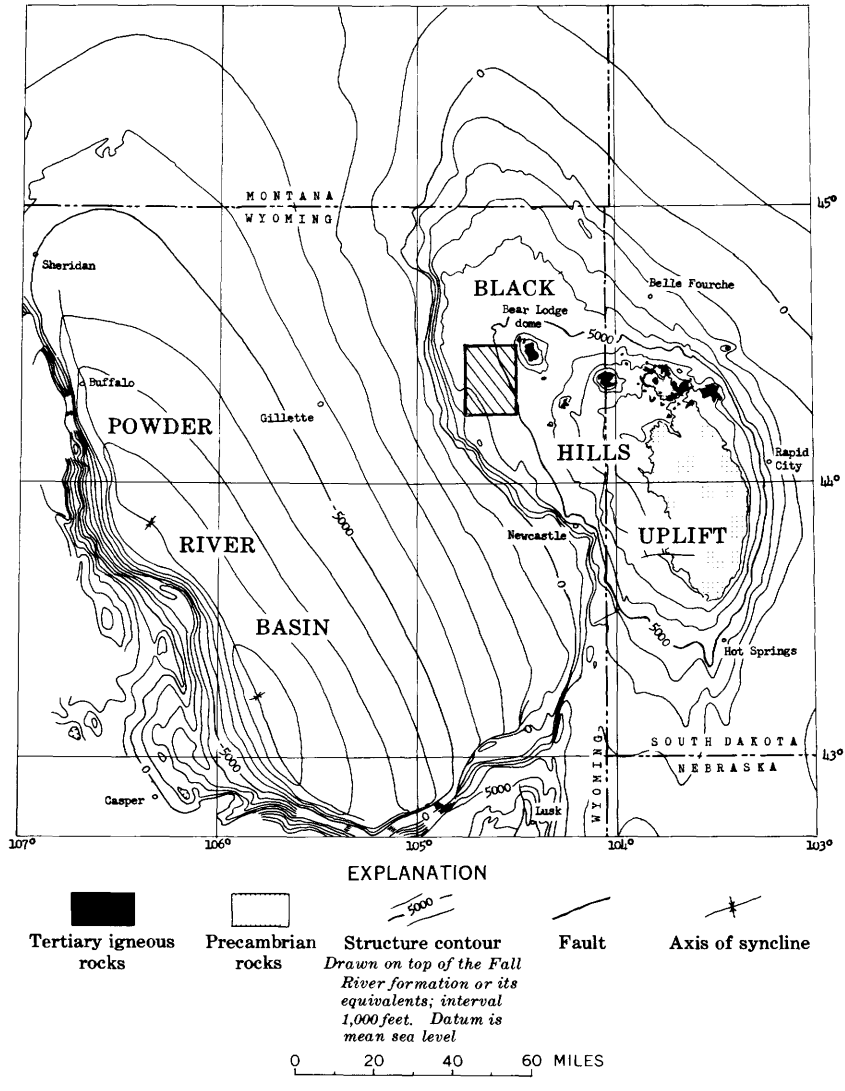

FIGURE 9.—Map showing location of Nefsy Divide quadrangle (crosshatched) in relation to major structural features of northeastern Wyoming and adjacent areas. Data from Zapp (1952), Noble (1952, p. 32), and Dobbin and Erdmann (1955).

South Fork of Miller Creek and near the head of Arkansas Creek. The fold is about 1½ miles across and has about 250 feet of closure in rocks exposed at the surface.

A series of northwestward-trending parallel faults, downdropped on the west, terminate the Miller Creek dome on the west side. The main fault is at least 1½ miles long and has a maximum displacement

of about 300 feet. At places it drops the upper part of the Lakota formation on the west against the Redwater shale member of the Sundance formation on the east. The fault branches at its south end and both branches die out in the Morrison formation. A second fault a few hundred feet west of the main fault cuts the Lakota and Fall River formations and has as much as 50 feet displacement.

A group of faults trends northeastward across the north flank of the Miller Creek dome. The southernmost of these faults, and the principal one, is about 1 mile long, has a maximum of about 150 feet displacement and is downdropped on the south. It locally brings the Lakota formation on the south against the Redwater shale member of the Sundance formation on the north. A second, roughly parallel fault a short distance to the north has the opposite displacement, being downdropped on the north probably less than 100 feet.

Houston Creek dome.—The Houston Creek dome lies about 2 miles southeast of the Miller Creek dome in the valley of Houston Creek. It is almost circular and is about 1 mile in diameter. The fold has about 100 feet of closure at the surface. The deformed surface rocks belong mostly to the Sundance formation and the oldest beds exposed are part of the Stockade Beaver shale member of the Sundance.

Other faults.—Aerial photographs show faint linear elements in sec. 26, T. 52 N., R. 64 W., which are interpreted as a branching fault that cuts the Lakota, Sundance, and Morrison formations and has a possible displacement of about 20 feet.

A fault cuts the Morrison-Sundance contact at the corner common to secs. 26, 27, 34, and 35, T. 50 N., R. 64 W. with a displacement of about 5 feet.

Relation of folds to igneous intrusion.—Darton (1909, p. 73) suggested that several conspicuous domes in the sedimentary rocks of the northern Black Hills were formed by the intrusion of igneous rocks. He stated: "No igneous rocks appear, but as the dome structure is precisely similar to that in uplifts in which erosion has exposed the igneous core, it is difficult to ascribe them to any other cause." Both the Miller Creek and Houston Creek domes resemble in size and shape nearby domes that are known to be intruded by igneous rocks, and igneous activity in the area is shown by the several sills near the folds and by a large intrusive body at least 5 miles across that forms the core of the Bear Lodge Mountains a short distance to the north (Darton and O'Harra, 1905). In the Bear Lodge Mountains, the main igneous body lies mainly in and below the Pahasapa limestone; it would seem, therefore, that igneous rocks might be expected to occur at about the same stratigraphic position at depth in the Miller Creek

and Houston Creek domes. A well on the Miller Creek dome drilled in 1959 penetrated 142 feet of the Pahasapa limestone without tapping igneous rock, but the depth was insufficient to show that igneous rocks are absent.

MINERAL DEPOSITS

URANIUM

Uranium was discovered in the northern part of the Nefsy Divide quadrangle in 1952. From 1952 to 1959 several small prospects have been developed and ore has been mined from open cuts. Production in 1958 totaled about 20 tons of ore having an average content of 0.15 percent U_3O_8. The mines are at the north end of Sunny Divide in and adjacent to the SW¼ sec. 21, T. 52 N., R. 65 W., and the uranium is in the basal part of the Lakota formation as shown on plate 2, locality 5. The lower part of the Lakota in this area is light-gray friable mostly fine-grained sandstone mottled yellow and red. The basal 5 to 10 feet of sandstone contains a few lenses of dark-gray claystone, pellets and pebbles of claystone and siltstone, scattered fragments of woody material, a few discontinuous coaly seams, and lenses of coarse grains and granules of quartz and chert. The uranium minerals, carnotite and tyuyamunite, are disseminated in the carbonaceous zone in discontinuous pod-shaped ore bodies. Trenching and drilling have not revealed appreciable reserves.

Bergendahl and others (1961) have described several relatively large uranium deposits about one-fourth mile west of the quadrangle in sec. 26, T. 52 N., R. 66 W. (pl. 2, loc. 48), at the Carlile mine, in a sandstone bed stratigraphically higher in the Lakota formation than the occurrences just described. About 10,000 tons of ore having an average content of 0.31 percent U_3O_8 were produced in this area from 1952, when mining began, to 1958 (C. A. Razor, written communication, 1959). The ore is associated with locally abundant carbonaceous mineral in a bed of fine grained to coarse grained sandstone. Prospecting in the Nefsy Divide quadrangle at the same horizon of the Carlile deposits has been unsuccessful, perhaps because carbonaceous material, which provides a suitable chemical environment for uranium precipitation, is uncommon in the upper part of the Lakota formation in this area.

The Fall River formation contains valuable uranium deposits in parts of the northern Black Hills (Robinson and Gott, 1958, p. 241–243), but none have been found in this formation in the Nefsy Divide quadrangle.

OIL AND GAS

Oil was discovered in the southern part of the Nefsy Divide quadrangle in June 1956. By January 1, 1960, 46 wells, including 19 producing wells, had been drilled in the quadrangle (table 2). Most of the production is from the Barton oil field, which comprises 11 producing wells in secs. 27 and 35, T. 50 N., R. 65 W.; and from the Tomcat Creek oil field having 5 producing wells in sec. 5, T. 49 N., R. 65 W. In addition, two wells have produced oil in secs. 9 and 10, T. 49 N., R. 65 W., about 1½ miles southeast of the Tomcat Creek field, and one well has produced oil in sec. 36, T. 50 N., R. 66 W., about 2½ miles northwest of the Tomcat Creek field.

The oil-bearing rocks in the Barton field are 2 to 5 feet thick and about 100 to 140 feet deep, and in the Tomcat Creek field they are 4 to 9 feet thick and about 400 to 440 feet deep. No sample logs were available to the writers, but from the depths recorded it seems likely that the oil is produced from sandstone beds in the basal part of the Fall River formation. Two wells in the Barton field initially produced 50 barrels of oil a day, but the initial production of most of the other wells in the quadrangle was one-half to about 20 barrels of oil a day. Five samples of oil from the Barton field range in A.P.I. gravity from 19.4 to 27.0, and one sample from the Tomcat Creek field has an A.P.I. gravity of 40.5.[1]

A decrease in porosity or a pinchout of the oil-bearing sandstone apparently provides the trap for the oil at all producing localities.

The low yields of most wells in the area, and the fairly large number of unsuccessful tests suggest that the Lakota formation and younger rocks do not contain large amounts of undiscovered oil in the Nefsy Divide quadrangle, although other small producing areas might be found by further drilling.

The Miller Creek dome was drilled to the Pahasapa limestone in 1959 (pl. 1, section A–A') without encountering commercial amounts of oil or gas, although a show of oil was discovered in the Minnelusa formation. The Houston Creek dome, which lies a short distance southeast of the Miller Creek dome and is a possible trap for oil and gas, has not been drilled. The Minnelusa formation, which contains oil in many parts of the Powder River Basin, is present at moderate depth in this fold.

[1] Information from records on file at the office of the U.S. Geol. Survey, Federal Center, Denver, Colo.

TABLE 2.—*Wells drilled for oil and gas, Nefsy Divide quadrangle*

[Wells listed to Jan. 1, 1960]

Location in sec.	Company and farm	Year completed	Total depth (ft.)	Oldest rocks reached	Initial production (bbls per day)	Oil-bearing formation
	T. 52 N., R. 64 W.					
NE¼NE¼SW¼ 33	Murphy Corp., Snook No. 1	1959	1, 954	Pahasapa	Oil show	Minnelusa.
	T. 50 N., R. 65 W.					
CNE¼NW¼ 26	E. F. Carnell, Govt. No. 1	1958	2, 073	Minnelusa		
N½NE¼NW¼ 26	E. F. Carnell, Barton No. 2	1958	1, 870	do	Oil show	Minnelusa.
SE¼SE¼SW¼ 27	Moffatt-Myers Dev. Co., Barton Bros. No. 3–W.	1951	158	Lakota		
CNE¼NW¼ 27	Fred Moffatt, Barton No. 1	1949	470	Sundance		
SE¼NW¼SE¼ 27	Glenwood Oil Co., Barton Bros. No. 1	1956	225	Morrison	4	Fall River.
NW¼SW¼SE¼ 27	No. 2	1956	82	Fall River	1½	Do.
SE¼SW¼SW¼ 27	Ben Fleming, Barton Bros. No. 1	1956	231	Lakota		
CSW¼SW¼ 28	Montana Chemical and Mining Corp., Barton No. 1.	1957	280	do		
NW¼NW¼SW¼ 34	Montgomery, Goforth, Pfeiffer, and Potter, Barton Bros. No. 1.	1956	299	Morrison(?)	Oil show	Lakota(?).
NE¼SE¼NE¼ 34	Northern Plains Exploration Co., Barton Bros. No. 1.	1956	270	do		
NE¼NW¼NE¼ 34	Western States Oil Co., Barton Bros. No. 1.	1956	160	Lakota		
NW¼NW¼NE¼ 34	Lewis and Wolff, Barton No. 2	1949	175	do		
NE¼SE¼SE¼ 34	Fleming and Willis, Barton-State No. 1	1956	190	do	Oil show	Lakota(?).
NE¼NW¼NW¼ 35	Glenwood Oil Co., Barton Bros. No. 3	1956	148	do	3	Fall River.
SE¼NW¼NW¼ 35	No. 4–A	1956	135	do	50	Do.
SW¼NW¼NW¼ 35	No. 6	1956	158	do	3	Do.
NE¼SW¼NW¼ 35	No. 7	1956	102	Fall River	3	Do.
NE¼NW¼NW¼ 35	No. 8	1957	109	do	1	Do.
SE¼NW¼NW¼ 35	No. 9	1957	120	do	4	Do.
SE¼NW¼NW¼ 35	No. 10	1957	1, 670	Minnelusa		
NE¼SW¼NW¼ 35	Fleming and Willis, Barton Bros. No. 1	1956	119	Fall River	50	Do.
NW¼SE¼NW¼ 35	No. 2	1956	134	Lakota	6	Do.

E½SW¼NW¼ 35	No. 3A	1957	136	do	Oil show	Do.
NW¼SW¼SE¼ 35	No. 3	1956	192	do	Oil show	Fall River(?).
NW¼SE¼NW¼ 35	No. 4	1957	120	Fall River	4	Fall River.
T. 50 N., R. 66 W.						
NW¼SW¼SE¼ 36	W. M. Jones, State No. 1	1959	577	Lakota	4	Fall River(?)
T. 49 N., R. 64 W.						
SE¼SE¼SW¼ 6	Bradley and McKay, No. 1	1956	233	Morrison		
T. 49 N., R. 65 W.						
SE¼SE¼NW¼ 3	Roden Drlg. Co., Barton No. 1	1957	370	Morrison		
SE¼SE¼SE¼ 4	Ben Fleming, Govt No. 1	1957	536	Sundance	Oil show	Lakota.
CSE¼SE¼ 5	Ben Fleming, Thompson No. 1	1957	447	Morrison	Oil show	Do.
CNE¼SW¼ 5	Ben Fleming, Thompson No. 2	1957	444	Lakota	Oil show	Do.
E½SE¼SE¼ 5	No. 3	1957	434	Morrison	Oil show	Do.
W½SE¼SE¼ 5	No. 4	1957	488	do	Oil show	Do.
NW¼NE¼SW¼ 5	True Oil Co., Walter Thompson No. 1	1959	454	do	23	Fall River(?).
NE¼NW¼SW¼ 5	No. 2	1959	480	Lakota	20	Do.
NE¼NE¼SW¼ 5	No. 3	1959	425	Lakota?	18	Do.
SW¼NE¼SW¼ 5	No. 4	1959	478	Lakota	20	Do.
SW¼SE¼NW¼ 5	True Oil Co., Bertrum Thompson No. 2	1959	482	Morrison	5	Do.
NW¼SE¼NE¼ 6	No. 1	1958	546	Lakota		
SE¼NE¼NE¼ 9	Ben Fleming, Govt. No. 1	1956	389	do	½	Do.
SW¼NW¼NW¼ 9	Caywood Drlg. Co., Barton-Caywood No. 1.	1957	398	do		
SW¼NW¼NW¼ 10	Glenwood Oil Co., Foster No. 1	1957	401	do	15	Do.
NE¼NW¼NW¼ 11	Glenwood Oil Co., Joe Ondriezak No. 1	1957	402	Morrison		
T. 49 N., R. 66 W.						
SE¼SW¼NW¼ 1	L. B. McWethy, L. Oost No. 1	1932				
SE¼SE¼SE¼ 2	True Oil Co., Ernest Wagner No. 1	1958	730	Lakota(?)		

BENTONITE

The Clay Spur bentonite bed at the top of the Mowry shale has been extensively strip mined along its outcrop in the southwest corner of the quadrangle. The strip mines are part of a nearly continuous belt of pits that extends from the vicinity of Osage northward for more than 30 miles. The bentonite is about 30 inches thick, and, according to Knechtel and Patterson (1955), is highly dilatant and gel forming, suitable for high-grade drilling clay and foundry-sand bonding material. The gel strength of the bentonite is greater in the weathered rock, thus, the bed is not mined where it lies beneath more than about 20 feet of overburden, which is about the depth of weathering.

The Newcastle sandstone, Mowry shale, and lower part of the Belle Fourche shale contain other, thinner bentonite beds, but these have not been mined in the quadrangle.

COAL

The lower part of the Lakota formation reportedly contains a coal bed of possible commercial value near the east edge of the quadrangle in sec. 10, T. 50 N., R. 64 W. Stone (1912, p. 22) states that a drift 50 feet long was opened in this bed in 1908–9, and he describes the deposit as follows:

> The roof of the coal bed is thin-bedded hard drab shale, and the floor is 5 inches of hard sandstone underlain by soft clay shale. Four feet of coal is found here in a bed divisible into three benches. The upper bench is 2 feet of splint with streaks of fine coal; the middle is from 10 to 12 inches of fine bright bituminous coal; and the lower is 1 foot of splint or bony coal with thin bands of shale.

He states that the coal is high in ash and cannot be classified as a high-grade domestic fuel. The coal was not seen in nearby outcrops of the Lakota formation and apparently underlies only a small area in the immediate vicinity of the old prospect.

Some coal has been mined from the lower part of the Lakota formation a few hundred feet east of the quadrangle on the high divide south of Houston Creek, secs. 23 and 24, T. 51 N., R. 64 W. The coal bed is reported to be as much as 4 feet thick and the coal is bituminous in rank (Stone, 1912, p. 21–22).

SAND AND GRAVEL

Sand and gravel have been dug from stream-terrace deposits along the Belle Fourche River for road-surfacing material. No information is available to indicate the value of the deposits for other uses.

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