Geology of the Inyan Kara Mountain Quadrangle, Crook and Weston Counties Wyoming

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

CONTRIBUTIONS TO GENERAL GEOLOGY

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GEOLOGY OF THE INYAN KARA MOUNTAIN QUADRANGLE, CROOK AND WESTON COUNTIES, WYOMING

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

ABSTRACT

The Inyan Kara Mountain quadrangle includes about 215 square miles on the west side of the Black Hills, in Crook and Weston Counties, Wyo. It is about 10 miles south of Sundance, 6 miles east of Upton, and 10 miles northeast of Newcastle, Wyo.

Exposed sedimentary rocks, exclusive of surficial deposits, are about 4,000 feet thick and range in age from Mississippian to Cretaceous. Sandstone, siltstone, and shale make up most of the sedimentary sequence; limestone, gypsum, bentonite, and coal are present in lesser quantities. The Pahasapa limestone of Mississippian age is the oldest formation exposed. It is overlain by the Minnelusa formation of Pennsylvanian and Permian age, followed in turn by the Opeche formation and Minnekahta limestone of Permian age, the Spearfish formation of Permian and Triassic age, the Gypsum Spring, Sundance, and Morrison formations of Jurassic age, and the Lakota, Fall River, Skull Creek, Newcastle, Mowry, Belle Fourche, Greenhorn, and lower part of the Carlile formations of Cretaceous age. A small plug of syenite porphyry that crosscuts all formations from the Pahasapa to the Spearfish crops out at Inyan Kara Mountain in the northern part of the quadrangle.

The sedimentary rocks have a fairly uniform dip of 1 to 3 degrees to the southwest. This simple monoclinal structure is interrupted by sharply folded domes at Inyan Kara and nearby Strawberry Mountains in the northern part of the quadrangle. The Inyan Kara Mountain dome is about 1½ miles across and has about 1,800 feet of structural closure in the outcropping Pahasapa limestone and younger rocks. A fault with a curving trace open to the northeast outlines the fold. Igneous and sedimentary rocks within the area circumscribed by the fault are upthrown as much as 600 feet. The Strawberry Mountain dome is about 1½ miles across and has about 450 feet of closure; the Minnelusa is the oldest formation exposed on the crest of the fold. Other less sharply folded anticlines or domes involve outcrops of the Opeche, Minnekahta, and Spearfish formations in the northeast corner of the quadrangle; the Sundance formation along Oil Creek in the southeastern part; and the Skull Creek, Newcastle, and Mowry formations near Turner Creek in the southeastern part.

Mineral resources include oil in the Newcastle, Mowry, and Belle Fourche formations at the Osage oil field, which extends about a mile into the southwestern part of the quadrangle; gypsum in the Gypsum Spring and Spearfish formations; small amounts of bituminous coal in the Lakota formation; bentonite in the Newcastle, Mowry, and Belle Fourche formations; and sand and gravel from stream terraces.

INTRODUCTION

LOCATION OF THE AREA

The Inyan Kara Mountain quadrangle includes about 215 square miles on the west side of the Black Hills in Crook and Weston Counties, Wyo. (fig. 1). The quadrangle is bounded by long 104°15′

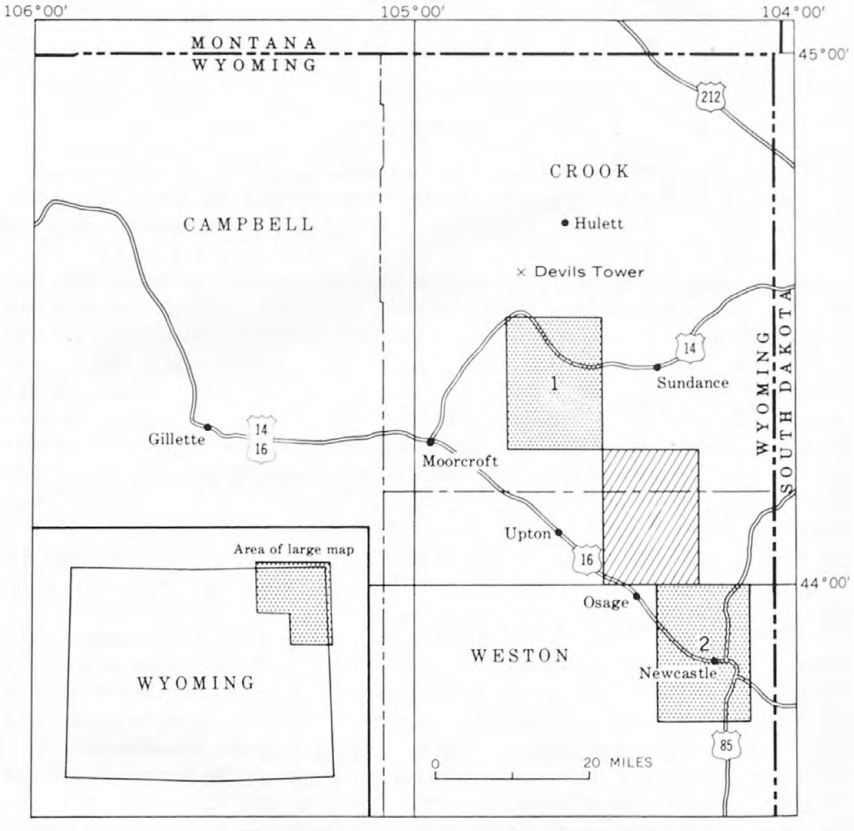

FIGURE 1.—Location of Inyan Kara Mountain quadrangle (crosshatched) and adjacent areas mapped by the Geological Survey, 1954–58. 1, Nefsy Divide quadrangle (Pillmore and Mapel, 1962); 2, Newcastle area (Mapel and Pillmore, in press).

and 104°30′ N., and lat 44°00′ and 44°15′ W. It is about 10 miles south of Sundance, 6 miles east of Upton, and 10 miles northeast of Newcastle, Wyo.

FIELDWORK AND ACKNOWLEDGMENTS

The quadrangle was mapped from 1956 to 1958 on behalf of the U.S. Atomic Energy Commission as part of a study of a larger area on the west and north sides of the Black Hills. Fieldwork during the summers of 1956 and 1957 consisted of measuring stratigraphic sections and locating geologic contacts on aerial photographs. This information provided control for geologic mapping done subsequently with a Kelsh plotter by C. L. Pillmore. The resulting map was checked and modified where necessary in the field during 1958. Use of the Kelsh plotter in geologic studies has been discussed by Pillmore (1957).

R. F. Schryver gave valuable help in the mapping in 1958. Reconnaissance stratigraphic studies and geologic mapping were done in the quadrangle by C. S. Robinson and P. K. Theobald at various times in 1954 and 1955. The field notes and maps prepared by these men were consulted during the present work and the use of this material is gratefully acknowledged. Unpublished maps and notes by W. W. Rubey and C. R. Longwell covering areas in the southwestern part of the quadrangle were also consulted in the initial stages of the work.

PREVIOUS WORK AND PUBLICATIONS

The Inyan Kara Mountain quadrangle is the southwestern part of the Sundance 30-minute quadrangle, which was mapped and described by Darton (1905) in a comprehensive early report. Small areas in the southwestern part of the Inyan Kara Mountain quadrangle were mapped by Longwell and Rubey (1923) in their study of the Pump Creek anticline and vicinity, and by Collier (1922), and Dobbin, Miller, and Walter (1935) in their studies of the Osage oil field. Other writers incidentally mention outcrops in or near the Inyan Kara Mountain quadrangle in discussions of the stratigraphy or structure of larger areas.

GEOGRAPHY

SURFACE FEATURES AND RELIEF

Steep, wooded ridges and narrow canyons occupy a broad band that crosses the quadrangle diagonally from northwest to southeast; elsewhere, the land surface is mostly gently rolling hills and broad

flats. Inyan Kara Mountain in the northeastern part of the quadrangle is a prominent isolated peak that rises abruptly more than 1,000 feet above the surrounding countryside and is a well-known landmark in the northern Black Hills. Strawberry Mountain, a rounded wooded hill about 4 miles southeast of Inyan Kara Mountain, is also a prominent topographic feature in the northeastern part of the quadrangle.

Inyan Kara and Mason Creeks and their tributaries drain the northern part of the quadrangle; Skull and Oil Creeks and their tributaries drain the southern part.

Altitudes range from about 4,100 feet in the southwest corner of the quadrangle to 6,368 feet at the top of Inyan Kara Mountain, giving a relief of slightly more than 2,000 feet.

CLIMATE AND VEGETATION

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

Vegetation on the more level tracts is mostly grass, sagebrush, and greasewood. Fir, pine, and aspen grow densely on many of the steeper slopes.

SETTLEMENT AND INDUSTRY

Permanent residents in the Inyan Kara Mountain quadrangle live mostly on ranches scattered along the main streams. Clay Spur, a small settlement on a siding of the Chicago, Burlington, and Quincy Railroad, is supported by a bentonite processing plant. Osage, a village of about 300 people, is about 4 miles southeast of Clay Spur and 2 miles south of the quadrangle boundary (fig.1).

U.S. Highway 16, which connects Newcastle, Osage, and Upton, crosses the southwest corner of the quadrangle; Wyoming Route 116, which connects Upton and Sundance, crosses the northwest corner; and Wyoming Route 585, which connects Sundance and Newcastle, crosses the northeast corner. These and other roads and trails provide ready access to nearly all parts of the area.

Wheat, hay, and some corn are grown on the more level tracts of land; the remainder of the area is devoted mostly to the grazing of livestock. Small amounts of oil are produced from shallow wells in the Osage oil field near Clay Spur, and bentonite is mined in the same area.

SEDIMENTARY ROCKS

Exposed sedimentary rocks, exclusive of surficial deposits, in the Inyan Kara Mountain quadrangle have a thickness of about 4,000 feet and include strata of Mississippian to Cretaceous age. These rocks overlie as much as 500 feet of unexposed sedimentary rocks of Mississippian, Ordovician, and Cambrian ages. The distribution of the exposed rocks is shown on the geologic map (pl. 1), and a brief description of both the exposed and the unexposed sedimentary rocks is given in table 1.

Sandstone, siltstone, shale, and limestone make up most of the exposed sedimentary sequence; gypsum, dolomite, bentonite, and coal are present in lesser amounts. The Pahasapa limestone of Mississippian age is the oldest exposed formation. It is overlain by the Minnelusa formation of Pennsylvanian and Permian age, followed by the Opeche formation and Minnekahta limestone of Permian age, the Spearfish formation of Permian and Triassic age, the Gypsum Spring, Sundance, and Morrison formations of Jurassic age, the Lakota, Fall River, Skull Creek, Newcastle, Mowry, Belle Fourche, Greenhorn, and lower part of the Carlile formations of Cretaceous age. All the formations are essentially concordant, although several disconformities can be recognized including those between the Pahasapa and Minnelusa formations, the Minnelusa and Opeche formations, the Spearfish and Gypsum Spring formations, the Gypsum Spring and Sundance formations, and the Lakota and Fall River formations. Stratigraphic sections of the Minnelusa to Fall River formations, inclusive, are shown graphically on plates 2 and 3.

Surficial terrace deposits of Tertiary and Quaternary age, and landslide material and alluvium of Quaternary age locally cover the older rocks.

Sedimentary rocks older than the Pahasapa limestone were not studied during the investigation. They have been described from outcrops or drill holes at nearby places in the Black Hills by several writers including Darton (1909, p. 12–20), Darton and Paige (1925, p. 5–7), Furnish, Barragy, and Miller (1936), Leatherock (1950), McCoy (1952, 1958a, 1958b), Ross (1957), and Carlson (1958).

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TABLE 1.—*Generalized stratigraphic section of sedimentary rocks in the Inyan Kara Mountain quadrangle.*

System and series	Group, formation, and member		Thickness (feet)	Lithology
Upper Cretaceous	Carlile shale (part)	Turner sandy member	150–175	Dark-gray shale and sandy shale; thin seams of light-gray sandstone; at the base a bed as much as 5 ft thick of light-gray sandstone that contains fish teeth and phosphatic nodules; marine fossils.
		Lower unnamed member	90	Grayish-black shale, locally calcareous at the base, a few silty partings; marine fossils.
	Greenhorn formation		270	Light- to dark-gray marl, dark-gray shale; and a few thin beds of limestone and bentonite; marine fossils.
	Belle Fourche shale		425	Grayish-black shale with siderite concretions; bentonite beds at the base and top.
Lower Cretaceous	Mowry shale		200	Hard siliceous shale that weathers light gray grading to soft dark-gray shale in the basal 10 to 20 ft; many thin bentonite beds including one at the top 2½ ft thick; marine fossils.
	Newcastle sandstone		50	Light-gray sandstone, brown and gray carbonaceous shale and siltstone; and gray bentonite.
	Skull Creek shale		180±	Grayish-black shale; thin siltstone seams locally; a few marine fossils.
	Inyan Kara group	Fall River formation	135–150	Brown-weathering sandstone, light- to dark-gray siltstone, and dark-gray shale; locally carbonaceous.
		Lakota formation	100–240	Light-gray sandstone and conglomeratic sandstone; variegated sandy claystone; local coal beds in lower part; nonmarine fossils.
Upper Jurassic	Morrison formation		110±	Greenish-gray and grayish-red claystone, gray marl; grayish-white sandstone; calcareous in the lower part; nonmarine fossils.
	Sundance formation	Redwater shale member	165	Greenish-gray shale, light-gray siltstone and sandstone; gray sandy limestone; glauconitic; marine fossils.
		Lak member	60–80	Pink and yellowish-gray siltstone and very fine grained friable sandstone; no fossils.
		Hulett sandstone member	60–70	Yellowish-gray ledge-forming sandstone; marine fossils.
		Stockade Beaver shale member	45–80	Greenish-gray shale; some light-gray sandstone at the top; marine fossils.
		Canyon Springs sandstone member	10–40	Friable light-gray, yellowish-gray, or pink, calcareous sandstone; local greenish-gray siltstone and light-gray oolitic limestone; marine fossils.
Middle Jurassic	Gypsum Spring formation		0–20	White gypsum, some red claystone locally; no fossils.
Triassic	Spearfish formation		450–650	Red siltstone, sandstone, and silty claystone; thick gypsum beds in the lower half; no fossils.
Permian	Minnekahta limestone		40	Light-gray thin-bedded limestone; marine fossils locally.
	Opeche formation		60–95	Red siltstone; no fossils.

TABLE 1.—*Generalized stratigraphic section of sedimentary rocks in the Inyan Kara Mountain quadrangle*—Continued

System and series		Group, formation, and member	Thickness (feet)	Lithology
Carboniferous	Pennsylvanian	Minnelusa formation	700–800	Light-gray and red sandstone, gray limestone and dolomite; red shale; local gypsum and anhydrite; marine fossils.
	Mississippian	Pahasapa limestone	500–600	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	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 shale and siltstone, and gray limestone; marine fossils.
Precambrian				Metamorphic and igneous rocks

Currently accepted ages of Jurassic and Cretaceous formations in the Inyan Kara Mountain quadrangle in terms of European stages are given by the chart below.

Ages of Jurassic and Cretaceous formations in Inyan Kara Mountains quadrangle in terms of European stages

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

MISSISSIPPIAN SYSTEM

PAHASAPA LIMESTONE

The Pahasapa limestone forms high jagged ledges and cliffs at the southwest end of Inyan Kara Mountain and crops out in a few ledges on steep talus-covered slopes on the north side. The Pahasapa is truncated by syenite porphyry that makes up the core of Inyan Kara Mountain, but most of the Pahasapa seems to be present at the southwest end of the mountain. The formation is light-gray limestone and dolomitic limestone, and in areas near the quadrangle, it is about 600 feet thick (Darton, 1905, p. 2; Andrichuk, 1955, fig. 5). Fossils reported from the formation are mostly corals and brachiopods and indicate Kinderhook and Osage age (Darton, 1909, p. 21–22; Gries, 1952, p. 71).

PENNSYLVANIAN AND PERMIAN SYSTEMS

MINNELUSA FORMATION

The Minnelusa formation is exposed on the north side of Inyan Kara Mountain, and the top of the formation crops out in the center of the Strawberry Mountain dome and in a few canyons along the northeast edge of the quadrangle. The uppermost 20 to 50 feet of the formation at all these places is resistant light-gray to light yellowish-gray, fine-grained calcareous sandstone that make cavernous ledges and cliffs. The remainder of the formation could not be examined in detail because of poor exposures.

In areas adjacent to the Inyan Kara Mountain quadrangle, the Minnelusa ranges from 700 to about 800 feet in thickness and consists of interbedded light-gray to locally pink sandstone, gray sandy dolomite and limestone, some red shale and siltstone, and local beds of gypsum and anhydrite. The following description of cuttings from a well about 1½ miles south of the quadrangle shows the lithology of the formation in the subsurface near the southwestern part of the quadrangle.

Partial log of the Black Hills Power and Light Co. well 1-W, NW¼NW¼SE¼ sec. 10 T. 46 N., R. 63 W., Weston County, Wyo.

[Completed 1941, total depth 2,592 feet in the Pahasapa limestone. Description after C. C. Williams (in Whitcomb and others, 1958, p. 249–250)]

	Thickness (feet)
Opeche formation (part):	
Shale, red; contains some anhydrite	15
Shale, red and gray; contains scattered coarse sand grains	5
Minnelusa formation:	
Dolomite, pink; contains some red shale and coarse-grained sandstone. Depth to top of this unit, 1,730 ft.	10
Dolomite, pink	40
Sandstone, pink, medium rounded grains	35
Dolomite, pink	45

Partial log of the Black Hills Power and Light Co. well 1–W, NW¼NW¼SE¼ sec. 10, T. 46 N., R. 63 W., Weston County, Wyo.—Continued

	Thickness (feet)
Minnelusa formation—Continued	
Dolomite and sandstone, pink; some red shale	30
Dolomite, pink	10
Dolomite, pink; some red shale and sandstone	10
Dolomite, sandstone, and anhydrite	10
Sandstone, pink, hard	10
Dolomite, pink; some red shale, anhydrite, and pink sandstone	30
Sandstone, red; some red shale	30
Dolomite and pink sandstone	10
Dolomite, pink and gray	20
Anhydrite, gray dolomite, trace of sandstone	30
Sandstone, pink	10
Dolomite, gray, anhydrite, and red shale	30
Sandstone, red, shaly	10
Shale, red; some anhydrite	15
Sandstone, white; streaks of red shale	30
Dolomite, gray; contains some anhydrite	15
Sandstone	70
Shale, gray, sandy	10
Sandstone and dolomite	25
Dolomite, gray; contains anhydrite and a few thin sandy streaks	45
Shale, red and gray; a few thin streaks of dolomite	30
Dolomite, gray; streaks of red sandy shale	20
Shale, red, and sandstone	30
Shale, red, and dolomite	40
Limestone; streaks of red shale	90
Shale, red; streaks of dolomite	20
Thickness of the Minnelusa formation	810
Pahasapa limestone (part):	
Limestone, dolomitic, porous and cavernous in part (drilling bit dropped without circulation or weight from 2,580 ft. to 2,952 ft). Base of unit is bottom of the hole, depth 2,952 ft.	52

Descriptions of the Minnelusa formation at various places on the west side of the Black Hills are given by Darton (1909, p. 22-24), Brady (1931, 1958), and Foster (1958).

The upper 250 to 300 feet of the formation in the vicinity of the Inyan Kara Mountain quadrangle has been assigned to the Permian system on the basis of correlations with the Hartville formation south of the Black Hills (Foster, 1958, p. 39-40); the lower part of the Minnelusa formation is considered to be Pennsylvanian in age.

PERMIAN SYSTEM

OPECHE FORMATION

The Opeche formation is about 60 to 95 feet thick in the Inyan Kara Mountain quadrangle, where it consists almost entirely of nonresistant poorly bedded red siltstone and silty claystone that includes a few seams and nodules of gypsum locally in the middle part. The contact with the underlying Minnelusa formation is sharp and probably represents a disconformity (Gries, 1952, p. 71; Burk and Thomas, 1956,

p. 10). No fossils have been reported from the Opeche in the Black Hills; its age assignment is based on its stratigraphic position between adjacent formations of Permian age. Equivalent beds in the Casper area of east-central Wyoming are placed by Burk and Thomas (1956, p. 8-10) in the basal part of their Goose Egg formation.

MINNEKAHTA LIMESTONE

The Minnekahta limestone crops out in the northeastern part of the quadrangle on broad dip slopes and steep hogbacks that are almost bare of vegetation. The formation is about 40 feet thick and consists of light-gray finely crystalline limestone and pinkish- or purplish-gray dolomitic limestone that has slightly undulating to contorted laminae. Stylolites are common. The limestone beds generally weather to blocky slabs 1 inch to 1 foot thick. Red shaly partings commonly occur in the basal 5 feet.

A sample of limestone collected about 3 feet below the top of the formation in the SW¼ sec. 9, T. 49 N., R. 62 W. (locality 40, pls. 1 and 2), was analyzed for calcium and magnesium with the following results (J. A. Thomas, analyst):

Ca (*percent*)	Mg (*percent*)	*Residue* (*percent*)	*Calculated* $CaCO_3$ (*percent*)
39.0	Trace	2.5	97.5

Darton and Paige (1925, p. 9) report analyses of 4 samples of dolomitic limestone from the Minnekahta, from various places in the Black Hills, in which the magnesia content (MgO) ranges from 0.41 to 19.85 percent.

Fossils from the Minnekahta include a few pelecypods (Darton, 1909, p. 27; Darton and Paige, 1925, p. 9-10) and a fossil fish (Hussakof, 1916) that suggest a Permian age. The Minnekahta formation has been identified in the Casper area of east-central Wyoming, where it makes up part of the Goose Egg formation of Burk and Thomas (1956).

PERMIAN AND TRIASSIC SYSTEMS

SPEARFISH FORMATION

The Spearfish formation is exposed on rolling hills and in local badlands in a band 2 to 3 miles wide in the northeastern part of the quadrangle. The formation is about 450 feet thick at its outcrop in the east-central part of T. 48 N., R. 62 W., but it generally thickens westward and is nearly 600 feet thick in a well a few miles to the northwest, in sec. 12, T. 49 N., R. 64 W., and it is probably between 550 and 650 feet thick at most places in the subsurface in the western part of the quadrangle.

The Spearfish is divided on the geologic map (pl. 1) into two parts of about equal thickness. The lower part consists of thin-bedded red siltstone and silty claystone interbedded with white gypsum in beds locally more than 10 feet thick. The stratigraphically highest persistent gypsum bed marks the top of the lower part of the formation. The upper part of the formation is mostly red silty claystone, siltstone, and silty sandstone. Gypsum also occurs in this part of the formation, but mostly as secondary deposits that fill narrow fractures within the top few feet.

Sandstone and siltstone in the Spearfish are crudely thin bedded, commonly cross laminated, and locally ripple marked. Microscopic examination of samples from gypsum beds in the lower part of the formation in the SW¼ sec. 9, T. 49 N., R. 62 W. (locality 40, pls. 1 and 2) show the rock to be mostly granular to fibrous gypsum crystals intergrown with some calcite and, in one bed, with some dolomite. Chemical analyses and the calculated mineralogic composition of the gypsum samples from this locality are given in table 4.

The lower gypsiferous part of the Spearfish formation is equivalent to 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 is considered early Triassic in age (Oriel *in* McKee and others, 1959, p. 9 and table 1). Fossils have not been reported from the Spearfish formation in the Black Hills.

JURASSIC SYSTEM

MIDDLE JURASSIC SERIES

GYPSUM SPRING FORMATION

The Gypsum Spring formation generally ranges in thickness from 5 to 15 feet in the northern part of the quadrangle, and from 15 to 20 feet in the southern part. It is locally absent near Strawberry Mountain in the SE¼ sec. 3, T. 48 N., R. 62 W., and at places near State Route 116 in sec. 10 and the W½ sec. 11, T. 49 N., R. 63 W. Changes in thickness probably are principally due to varying amounts of erosion prior to deposition of the overlying Sundance formation.

The formation consists at most places of a single bed of white fairly pure gypsum that resists erosion and commonly makes a prominent massive white ledge. At places in the northern part of the quadrangle, the formation contains in addition to the gypsum bed an overlying sequence as much as 5 feet thick of red and green claystone. Chemical analyses and calculated mineralogic compositions of 2 samples of gypsum from the formation are listed in table 4.

Regional relations of the Gypsum Spring formation, summarized by Imlay (1947, p. 240–243) and Oriel (McKee and others, 1959, p. 20), indicate that the formation is Middle Jurassic in age and that it rests unconformably on the Triassic Spearfish formation.

UPPER JURASSIC SERIES

SUNDANCE FORMATION

The Sundance formation is about 370 feet thick. It crops out in an irregular band, 2 to 4 miles wide, which crosses the central part of the quadrangle diagonally from northwest to southeast. The formation includes in ascending order the Canyon Springs sandstone, Stockade Beaver shale, Hulett sandstone, Lak, and Redwater shale members as defined by Imlay (1947).

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

Some details of lithology of the Sundance formation are shown graphically on plate 2 and are stated in the following measured section:

Part of the Sundance and underlying formations west of Oil Creek in the S½ sec. 35, T. 48 N., R. 62 W., Weston County, Wyo.

[Locality 38, pls. 1 and 2]

	Feet
Sundance formation (part):	
Redwater shale member (part):	
16. Poorly exposed; mostly dark-greenish-gray shale; top of the unit is the top of the exposure	5
15. Sandstone, light-gray, very fine grained, calcareous, glauconitic, friable; some interlaminated greenish-gray shale; nonresistant	20
14. Shale, greenish-gray; much interlaminated light-gray very fine grained calcareous sandstone	14
13. Sandstone, light-gray, very fine grained, calcareous, very glauconitic; nonresistant	3
Partial thickness, Redwater shale member	42
Lak member:	
12. Siltstone, sandy; and silty very fine grained sandstone; pink to pale reddish brown in upper part, banded pink and light gray in lower 20 ft.; massive in upper part, becoming crudely thin bedded at the base; slightly calcareous locally; nonresistant	80

Part of the Sundance and underlying formations west of Oil Creek in the S½ sec. 35, T. 48 N., R. 62 W., Weston County, Wyo.—Continued

	Feet
Sundance formation—Continued:	
Hulett sandstone member:	
11. Sandstone, light-yellowish-gray, fine to very fine grained, calcareous; ripple marked at the top and base, locally cross laminated; forms a massive cliff	30
10. Sandstone, light-yellowish-gray, very fine grained, calcareous, cross-laminated; many thin laminae of green siltstone; nonresistant	6
9. Sandstone, light-yellowish-gray, very fine grained, calcareous, cross-laminated; forms a resistant ledge	3
8. Shale, greenish-gray; interbedded and interlaminated light-gray siltstone and very fine grained sandstone; nonresistant	6
7. Sandstone, light-gray to light-yellowish-gray, fine- to very fine grained; calcareous, cross laminated; in blocky beds ½ to 1 ft thick; forms ledges	10
Thickness, Hulett sandstone member	55
Stockade Beaver shale member:	
6. Siltstone, light-greenish-gray; interlaminated light-gray very fine grained sandstone; calcareous; grades into unit below	8
5. Shale, dark greenish-gray, noncalcareous; a few silty laminae in the top 6 to 8 ft	36
Thickness, Stockade Beaver shale member	44
Canyon Springs sandstone member:	
4. Sandstone, light greenish gray at the base becoming light yellowish gray at the top, very fine grained, calcareous, massive, friable, nonresistant	23
3. Siltstone, greenish-gray, very calcareous, thin-bedded, fossiliferous	6
Thickness, Canyon Springs sandstone member	29
Partial thickness, Sundance formation	250
Unconformity.	
Gypsum Spring formation:	
2. Gypsum, white, granular; makes a single massive overhanging ledge	18
Unconformity.	
Spearfish formation (part):	
1. Siltstone, dark-red, locally sandy, crudely thin-bedded; a few discontinuous seams of gypsum as much as ½ in. thick in fractures in the upper 20 ft.; nonresistant	50+

Canyon Springs sandstone member.—The Canyon Springs sandstone member of the Sundance formation was named by Imlay (1947, p. 247–248) for exposures on a butte in the center of sec. 23, T. 48

N., R. 62 W. The member ranges in thickness from 10 to about 40 feet in the Inyan Kara Mountain quadrangle. It consists mostly of very fined grained friable calcareous sandstone that generally is nonresistant and makes few good outcrops. The sandstone is mostly light yellowish gray, but locally it is pink or is banded or mottled pink and yellow. The basal part of the member generally includes a few inches to several feet of greenish-gray calcareous siltstone. At one place (locality 39, pls. 1 and 2), a ledge-forming bed 5 feet thick of fossiliferous oolitic sandy limestone caps the member. The Canyon Springs sandstone member rests unconformably on a smooth, even surface cut on the underlying Gypsum Spring formation or, where the Gypsum Spring is absent, on the Spearfish formation.

Stockade Beaver shale member.—The Stockade Beaver shale member of the Sundance formation ranges in thickness from about 45 to 80 feet in the Inyan Kara Mountain quadrangle. It is thinnest where the underlying Canyon Springs sandstone member is thickest and is thickest where the Canyon Springs member is thin or absent. The member consists mostly of fissile greenish-gray noncalcareous to slightly calcareous shale but includes some interbedded and interlaminated light-gray calcareous siltstone and very fine grained sandstone in the top 10 to 20 feet. The contact with the underlying Canyon Springs sandstone member is generally fairly sharp.

Hulett sandstone member.—The Hulett sandstone member of the Sundance formation consists of 60 to 70 feet of light-gray to light yellowish-gray, fine-grained to very fine grained calcareous sandstone and a few interbeds of greenish-gray siltstone and silty shale at the base and top. It crops out in slabby to blocky beds a few inches to several feet thick, which are locally ripple marked and cross laminated. The sandstone is very friable and poorly exposed in the northwestern part of the quadrangle, but it is fairly well exposed elsewhere in ledges and cliffs, which are especially prominent on the high bluffs east of Oil Creek in Tps. 47 and 48 N., R. 62 W. The Hulett sandstone member grades downward through an interval of 5 to 15 feet into the underlying Stockade Beaver shale member of the Sundance formation.

Lak member.—The Lak member of the Sundance formation consists of 60 to 80 feet of dominantly pink very fine grained, massive to crudely thin-bedded sandstone and siltstone. The member is nonresistant and generally is poorly exposed except for scattered outcrops mostly in gullies and washouts. It grades within about 5 feet into the underlying Hulett sandstone member, from which it is distinguished by its contrasting color and lack of calcareous cement.

Redwater shale member.—The Redwater shale member of the Sundance formation is about 165 feet thick and consists of greenish-gray shale and sandy shale, and light-gray sandstone, siltstone, and limestone. It is mostly nonresistant and crops out in only a few scattered exposures on rolling grassy hills.

Most of the member is greenish-gray shale that contains interbedded and interlaminated light-gray calcareous siltstone and silty sandstone. A few coquinoid or oolitic limestone beds generally ½ to 1 foot thick form slabby ledges in the upper part of the member. Glauconite is abundant in the sandstone, siltstone, and limestone except for beds in the topmost 10 to 20 feet. The topmost bed of the Redwater shale member is a persistent calcareous yellow-weathering sandstone or sandy limestone, commonly 2 to 5 feet thick, that can be traced for many miles along the west side of the Black Hills. The contact of the Redwater shale member with the underlying Lak member is marked by an abrupt change from sandstone or siltstone that is light gray and highly glauconitic to sandstone or siltstone that is pink or yellowish gray and nonglauconitic.

MORRISON FORMATION

The Morrison formation generally ranges between 70 and 130 feet in thickness in the Inyan Kara Mountain quadrangle. It is especially well exposed in badlands on the crest of the divide between Inyan Kara and Mason Creeks in the south-central part of T. 49 N., R. 36 W., and it is fairly well exposed in the valley of Mason Creek and at places along the west side of Oil Creek.

The formation is divisible into two lithologically distinct parts at most places in the quadrangle. The lower part averages about 60 feet in thickness and consists mostly of greenish-gray and grayish-red calcareous silty claystone and marl. The basal 20 to 30 feet commonly 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 of gray argillaceous limestone, a few inches thick, are common throughout the lower part of the formation. The upper part of the Morrison is about 5 to 15 feet thick along Sheldon and Mason Creeks in the northwestern part of the quadrangle, and about 20 to 35 feet thick along Oil Creek in the southeastern part. It consists of noncalcareous claystone that is dark greenish gray in the lower part, grading upward at many places to dark brownish gray at the top.

The Morrison is gradational into the underlying Sundance formation. The contact at most places is the top of a persistent bed of yellow-weathering sandstone and generally can be picked within about 1 foot.

Along Oil Creek, claystone and marl in the Morrison formation grade laterally into a bed of sandstone as much as 150 feet thick, which constitutes the entire formation in an area about 2½ miles long and 1½ miles wide extending from the center of sec. 29, T. 47 N., R. 62 W., southeastward to the NW¼ sec. 3 of the next township to the south. The sandstone is mostly light gray, locally mottled shades of red, purple, and yellow, and is fine grained, well sorted, very friable, and massive. It is well exposed in rounded ledges and cliffs on the divide west of Oil Creek at locality 26 (pls. 1 and 3). In lithologic character and stratigraphic relations the bed resembles the Unkpapa sandstone, which replaces the Morrison formation locally at the south end of the Black Hills (Darton and Paige, 1925, p. 11). A bed at least 20 feet thick of friable light yellowish-gray sandstone crops out at the base of the Morrison formation southwest of Inyan Kara Mountain, in the SW¼ sec. 25, T. 49 N., R. 63 W. Outcrops of the Morrison are poor in this area and the extent of this thick sandstone could not be determined.

The following stratigraphic section is typical of the Morrison formation. Two additional sections, one of which includes the thick Morrison sandstone bed west of Oil Creek, are described with the Lakota formation on pages 23–25.

Morrison and parts of the Lakota and Sundance formations north of Mason Creek in the SW¼NW¼ sec. 34, T. 49 N., R. 63W., Crook County, Wyo.

	Feet
Lakota formation (part):	
16. Sandstone, light-gray to yellowish-gray, fine-grained, crossbedded; forms ledges	20
15. Covered	10
14. Sandstone, light-gray, fine-grained, locally carbonaceous; in irregular beds mostly about ½ ft. thick	4
13. Shale, brown, carbonaceous	1½
12. Sandstone, light-gray, fine-grained, friable, carbonaceous	2
11. Shale, brown, carbonaceous	2
10. Sandstone, brown, fine-grained, very clayey, carbonaceous	1
Partial thickness (rounded), Lakota formation	40
Morrison formation:	
9. Claystone, mostly olive gray grading to greenish gray in basal part; a bed 0.3 ft. thick of selenite at the base	11
8. Claystone, greenish gray with some grayish-red bands, calcareous; a few thin lenticular beds of light-gray argillaceous limestone; contains ostracodes at base and 15 ft. above base	35
7. Covered	11
6. Claystone, greenish-gray, calcareous; a lens of light-gray limestone at the top; ostracodes at base of unit	4

Morrison and parts of the Lakota and Sundance formations north of Mason Creek in the SW¼NW¼ sec. 34, T. 49 N., R. 63W., Crook County, Wyo.—Con.

	Feet
Morrison formation—Continued	
5. Mostly covered: a slabby ledge 1 ft. thick of light-yellowish-gray very fine grained calcareous sandstone at about the middle of the unit	6
4. Limestone, light-gray, in thin contorted beds; forms a slabby ledge	1
3. Shale, greenish-gray; some interlaminated light-gray very fine grained sandstone	2
Thickness, Morrison formation	70
Sundance formation (part):	
Redwater shale member (part):	
2. Sandstone, light-gray to yellow, fine- to very fine grained, very calcareous; a few partings of greenish-gray shale in the bottom 1 ft.	2½
1. Shale, greenish-gray, noncalcareous, slightly sandy	10
Partial thickness, Sundance formation	12½

Ostracodes and charophytes are common in the Morrison formation, and the formation also contains a few dinosaur bones, some fossil wood, and the fresh-water pelecypod *Unio nucalis* Meek and Hayden. Except for the wood, the fossils so far reported have been collected from the lower calcareous part of the formation, and their age is generally regarded as Kimmeridgian (Late Jurassic). (See Reeside *in* Yen, 1952, p. 22–26; Peck, 1957, p. 8; Sohn, 1958, p. 124.) Fossil wood found in the upper noncalcareous part of the formation has not been identified specifically.

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 were, in ascending order, the Lakota, Minnewaste, Fuson, and Fall River or Dakota formations. The Minnewaste is a local limestone bed at the southern end of the Black Hills, and where it is absent in other parts of the Black Hills there is much uncertainty and confusion in applying the other three names.

Two formations are recognized in the Inyan Kara group in this report. These are the Lakota and Fall River formations as redefined by Waagé (1959); they are separated by an unconformity of regional

extent. The names Minnewaste and Fuson are restricted by Waagé to members in the upper part of the Lakota formation in a small area in the southern Black Hills. The regional relations of the Inyan Kara group in the Black Hills and in nearby areas have been discussed by Waagé (1959).

LAKOTA FORMATION

The Lakota formation is about 50 feet thick in a small area near the center of the E½ sec. 32, T. 47 N., R. 62 W., at the south edge of the Inyan Kara Mountain quadrangle. Elsewhere the formation ranges in thickness from about 100 feet in the northwest corner of the quadrangle to as much as 240 feet in Black Canyon in the southern part.

The formation consists of complexly interfingering beds of sandstone, conglomeratic sandstone, claystone, and intermediate types of rock, which crop out 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. 3).

The Lakota formation is divided by a local unconformity into 2 units of contrasting lithology in the southeastern part of the quadrangle, and by a different unconformity into 2 different units in the northwestern part. Correlation of beds within the Lakota formation is shown on plate 3.

In the southeastern part of the quadrangle, along Oil Creek, Black Canyon, and Skull Creek, the lower one-third to one-half of the formation consists of as much as 100 feet of light-gray medium to very fine grained sandstone that locally contains beds of brown to dark-gray carbonaceous siltstone, brown claystone, and local seams of coal. Sandstone in this part of the formation is tabular bedded to inconspicuously crossbedded, friable, and generally fairly well sorted. The carbonaceous material is concentrated in two zones, one at or near the base of the formation and the other about 60 feet above the base. The remainder of the formation is sandstone and sandy claystone locally as much as 190 feet thick. The lower part of this upper sequence is generally cliff-forming, conspicuously crossbedded conglomeratic sandstone containing granules and small pebbles of chert and quartzite and fragments of sandstone and siltstone (fig. 2). The base of the conglomeratic sandstone is an unconformity, and other unconformities are common in the conglomeratic mass. The uppermost part of the formation is locally conglomeratic light-gray sandstone interbedded in varied proportions with gray, red, or purple sandy claystone. Polished rounded pebbles and cobbles of quartzite and chert are concentrated in thin zones in some of the sandy claystone beds in the upper part of the formation.

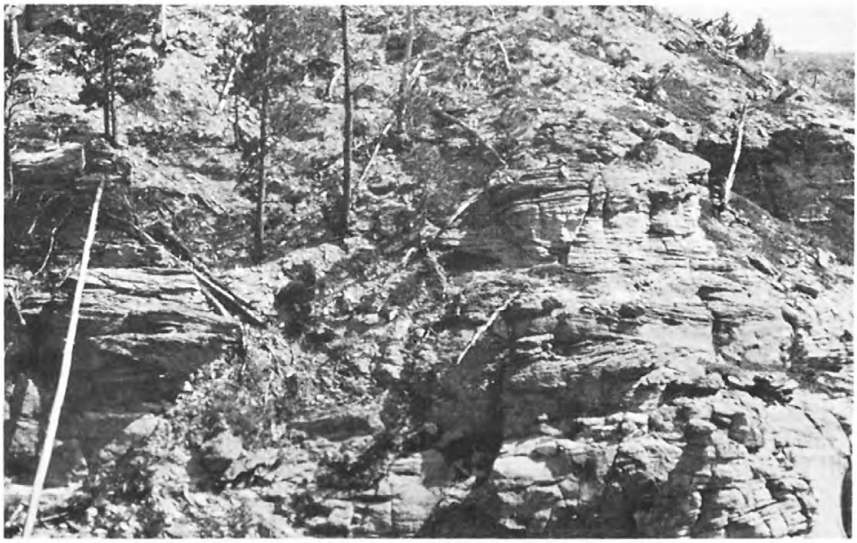

FIGURE 2.—Crossbedded sandstone in the upper part of the Lakota formation, Black Canyon, Inyan Kara Mountain quadrangle.

The unconformity that marks the base of the conglomeratic sandstone in the Lakota formation in the southern part of the quadrangle can be traced from the south edge of the quadrangle to a point about 2 miles northwest of the Skull Creek Community Hall. At locality 13 (pls. 1 and 3) the unconformity disappears in the lower part of the formation in an essentially conformable sequence of nonconglomeratic sandstone and brown sandy claystone. A sandstone bed near the top of the formation at locality 13 and in the hills north of the Skull Creek Community Hall can be traced from that area northward into the drainage area of Mason Creek, and an unconformity at the base of this sandstone bed divides the Lakota into two units in the northern part of the quadrangle. These two units are like the two units farther south in that the sandstone in the lower unit is nonconglomeratic, tends to be evenly bedded, and contains thin carbonaceous beds of sandstone, siltstone, and claystone; and sandstone in the upper unit is generally conglomeratic and conspicuously crossbedded.

In both the northern and southern parts of the quadrangle, siltstone and claystone in the topmost 5 to 10 feet of the Lakota formation generally contain numerous small ferruginous spherulitic pellets about 1 mm in diameter. Beds in this part of the formation commonly weather to patches of light-gray, pink, or yellow soil easily seen from a distance on grassy hillsides.

The dip directions of crossbeds in the upper part of the Lakota formation were determined at 29 localities in and near the quadrangle,

and the results are summarized on figure 3. Readings on at least 10 sets of crossbeds were averaged in calculating the dip direction at each locality. Although dips in all directions were found, a preferred orientation to the northeast is shown by the group of crossbeds as a whole. The data are generally consistent with the interpretation that, in the Inyan Kara Mountain quadrangle, crossbedded sandstone in the Lakota was deposited by meandering streams flowing generally to the northeast.

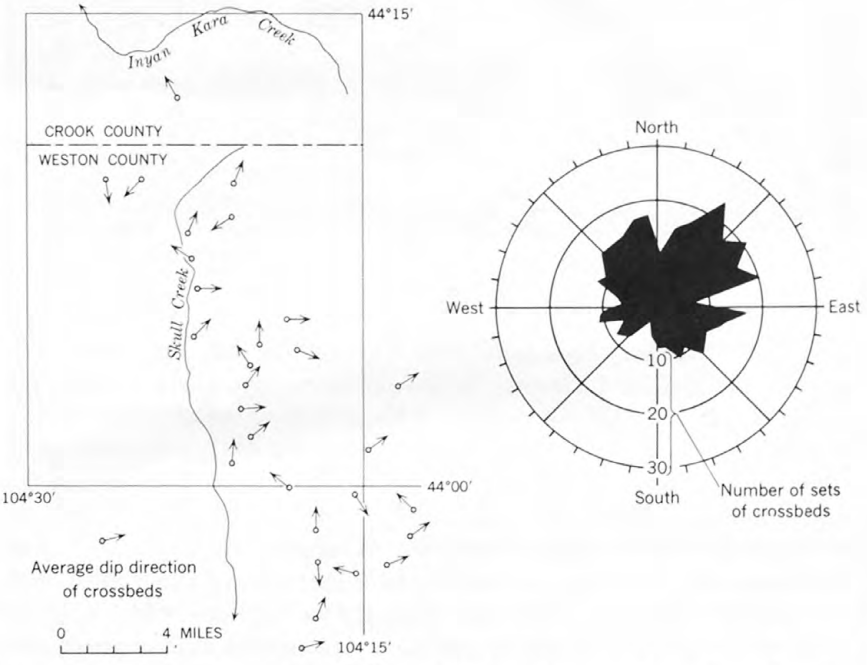

FIGURE 3.—Dip directions of crossbeds in the Lakota formation, Inyan Kara Mountain quadrangle and vicinity. Map and diagram summarize dip directions of 417 sets of crossbeds at 29 localities.

At most places the base of the Lakota formation is the stratigraphically lowest sandy or carbonaceous bed above the calcareous part of the Morrison formation. The Morrison formation locally consists entirely of sandstone west of Oil Creek, and in those places the Morrison-Lakota contact is the base of the lowest carbonaceous shale. The contact appears conformable.

The lithology of the Lakota formation is described in the four stratigraphic sections below. Two of the sections also include descriptions of the entire underlying Morrison formation.

Lakota and parts of the Fall River and Morrison formations west of Wyoming Route 116 near the center of sec. 24, T. 49 N., R. 64 W., Crook County, Wyo.

[Locality 9, pls. 1 and 3]

Top of the hill.

	Feet
Fall River formation (part):	
22. Covered	3
21. Sandstone, reddish-brown, very fine grained; locally cemented with iron oxides; forms a minor ledge	1
20. Mostly covered; some olive-gray shaly siltstone near the top	6
19. Siltstone, yellowish-gray; locally cemented with iron oxides	½
18. Shale, dark-gray, carbonaceous	6
17. Sandstone, light-gray, yellow-weathering, very fine grained, carbonaceous; forms a bench	1½
16. Siltstone, dark-gray, shaly, carbonaceous	2
Partial thickness, Fall River formation	20

Unconformity.

Lakota formation:	
15. Claystone, olive-gray, gray- and yellow-weathering, silty; contains numerous tiny ferruginous pellets	5
14. (Covered)	16
13. Sandstone, light-gray, yellow-stained, very fine grained; forms a line of slumped blocks	6
12. Covered	10
11. Claystone, brownish-gray, sandy; grades locally to clayey sandstone	20
10. Sandstone, light gray with some yellow-weathering bands, fine- to coarse-grained, poorly sorted, very friable, nonresistant	13
Local unconformity.	
9. Sandstone, very light gray, very fine grained, very friable, nonresistant	5
8. Claystone, olive-gray, silty; grades in basal part to gray siltstone; a stringer of brown carbonaceous shale about 3 ft. above the base; nonresistant	10
Section below offset about 100 yards to north side of the gully	
7. Sandstone, light-gray, stained pink and red, fine to very fine grained, friable, crossbedded; forms a ledge locally	9
6. Covered	2
5. Claystone, gray and brown, carbonaceous	9
Thickness, Lakota formation	105

Morrison formation (part):	
4. Mostly covered; some green noncalcareous claystone about the middle	12
3. Mostly covered; some green calcareous claystone in the upper half	14
2. Claystone, greenish-gray and reddish-purple, silty, calcareous	18
1. Marl, green	1
Partial thickness, Morrison formation	45

Base of the exposure.

Parts of the Fall River and Lakota formations one-half mile southwest of the Skull Creek Community Hall, NW¼NW¼ sec. 36, T. 48 N., R. 63 W., Weston County, Wyo.

[Locality 15, pls. 1 and 3]

Top of the ridge.

Fall River formation (part):	Feet
10. Sandstone, brown, stained red and orange, very fine grained, hard; locally quartzitic; forms blocky ledge	2
9. Partly covered; bottom 3 ft. black coaly shale	5
Partial thickness. Fall River formation	7

Unconformity.

Lakota formation (part):	
8. Mostly covered; olive-gray siltstone in the top 3 ft	37
7. Sandstone, very light gray, very fine grained, clayey, nonresistant	11
6. Claystone, mottled shades of gray, purple, and red, sandy	2
5. Covered	10
4. Sandstone, yellowish gray in the basal part becoming light gray at the top, friable, crossbedded, mostly fine to medium grained becoming very coarse grained and grading to granule sandstone in basal 5 to 10 ft.; forms a rounded cliff	70
Local unconformity.	
3. Siltstone, dark-gray, carbonaceous; locally cut into by channels at the base of the unit above	2
2. Mostly covered; some platy light-gray very fine grained sandstone at the base and top	12
1. Sandstone, light-gray to light-pinkish-gray, fine to very fine grained, friable; forms a massive ledge	15
Partial thickness, Lakota formation	159

Base of the exposure.

Lakota and Morrison formations on the west side of Oil Creek in the NE¼ sec. 21, T 47 N., R. 62 W., Weston County, Wyo.

Top of the hill.

Fall River formation (part):	Feet
26. Mostly covered; a few fragments of dark-gray carbonaceous shale in pits dug at the base of the unit; some yellowish-gray thin-bedded fine-grained sandstone about 15 ft. above the base, and a ledge-forming bed 2 to 3 ft. thick of yellowish-gray fine-grained sandstone locally cemented with brown iron oxides at the top of the unit	40

Unconformity.

Lakota and Morrison formations on the west side of Oil Creek in the NE¼ sec. 21, T. 47 N., R. 62 W., Weston County, Wyo.—Continued

	Feet
Lakota formation:	
25. Claystone, medium- to olive-gray, sandy; lenses as much as 10 ft. thick of light-gray silicified sandstone containing stringers of brown chert	37±
Section offset about 200 feet southeast on top of the unit below	
24. Sandstone, light-gray to light-purplish-gray, silicified; forms a hard blocky ledge	1
23. Claystone, light- to dark-gray, silty and sandy in the upper part	20
22. Sandstone, light-gray, fine- to coarse-grained; capped by a stringer of gray and white chert; forms a ledge	1
21. Claystone, olive-gray, mottled purple, sandy	4½
20. Sandstone, light-gray, mottled yellow, red, purple, and orange, poorly sorted, clayey to pebbly, massive, nonresistant	33
19. Sandstone, light-gray, locally mottled faintly pink, mostly fine to medium grained; includes a few beds of coarse-grained sandstone in the lower part and several seams and lenses of coarse-grained to pebbly sandstone in the upper part; reworked fragments of sandstone in the basal 3 ft.; conspicuously cross-bedded; forms a cliff	55
18. Sandstone, light-gray to light-yellowish-gray, fine-grained, massive to tabular-bedded in the lower part becoming faintly crossbedded in the upper part; a few lenticular beds 1 to 6 in. thick of carbonaceous siltstone about 5 ft. below the top; forms a cliff	21
17. Covered	3½
16. Mostly covered; scattered exposures of noncalcareous olive-gray claystone	11
15. Sandstone, light-gray to light-yellowish-gray, locally stained yellowish-orange, fine-grained; forms slabby ledges	6
14. Shale, dark-gray	2
13. Sandstone, light-gray, weathers light yellowish gray, fine-grained; in irregular beds as much as 6 in. thick, a few brown carbonaceous laminae; top 3 in. cemented with limonite	8
12. Mostly covered; some friable light-gray carbonaceous sandstone about the middle of the unit	6
Thickness, Lakota formation	209±
Morrison formation:	
11. Claystone, dark-brown, noncalcareous, silty	8
10. Claystone, dark-greenish-gray, noncalcareous	29
9. Claystone, dark-greenish-gray, calcareous	17
8. Claystone, banded greenish-gray and grayish-red, calcareous; a few thin beds of light-gray marl; a zone of limonite-cemented clay nodules mostly less than half an inch in diameter in a zone about 6 in. thick about 5 ft. above the base	34

Lakota and Morrison formations on the west side of Oil Creek in the NE¼ sec. 21, T. 47 N., R. 62 W., Weston County, Wyo.—Continued

Morrison formation—Continued	Feet
7. Sandstone, light-gray, very fine grained, calcareous, thin-bedded; a few partings of greenish-gray sandy claystone in the middle part; forms slabby ledges	11
6. Sandstone, light-gray, very fine grained, calcareous; many partings of greenish-gray sandy claystone and siltstone; nonresistant	9
5. Sandstone, light-gray, very fine grained, calcareous; a few partings of grayish-green sandy claystone; forms a ledge	7½
4. Covered	3½
3. Sandstone, light-gray, very fine grained, calcareous, friable, irregularly thin bedded; forms slabby ledges	12½
Thickness (rounded), Morrison formation	131
Sundance formation (part):	
Redwater shale member (part):	
2. Sandstone, grayish-yellow and light-gray (a few pink streaks), very fine grained, calcareous, friable	4
1. Mostly covered; some greenish-gray shale interbedded with very fine grained sandstone and siltstone in scattered outcrops; fragments of light-gray sandy fossiliferous limestone weathering out on the slope near the base	30
Partial thickness, Sundance formation	34

Lakota and Morrison formations on the west side of Oil Creek in the SW¼ sec. 28, T. 47 N., R. 62 W., Weston County, Wyo.

[Locality 26, pls. 1 and 3]

Fall River formation (part):	Feet
17. Shale, dark-gray, noncalcareous, slightly carbonaceous	3
Unconformity.	
Lakota formation:	
16. Claystone, light-gray, soft, plastic; sharp contact with the overlying unit	3
15. Mostly covered; at the top of the unit a bed 3 ft thick of light-gray fine-grained sandstone locally mottled yellow	50
14. Claystone, gray, plastic	6
Section below offset about 200 feet to the southeast on top of underlying unit	
13. Sandstone, light-gray to pale grayish-orange, mostly fine to medium grained; lenses of coarse-grained to granule sandstone in bottom half; crossbedded; forms a prominent cliff	70

Lakota and Morrison formations on the west side of Oil Creek in the SW¼ sec. 28, T. 47 N., R. 62 W., Weston County, Wyo.—Continued

Lakota Formation—Continued

Local unconformity of nearby areas at about this horizon.	Feet
12. Partly covered; mostly medium-gray claystone, some thin beds of yellowish-gray fine-grained sandstone; contact with overlying unit not exposed	12
11. Claystone, medium-gray, silty and sandy; some interbedded grayish-yellow fine-grained sandstone in the upper half	8
10. Sandstone, light-gray, fine-grained, firmly cemented, carbonaceous, lenticular; forms a blocky ledge	4½
9. Shale and sandstone, interbedded; claystone is dark gray, carbonaceous; sandstone is medium gray, very fine grained, carbonaceous, friable	12
8. Sandstone, medium-gray, very fine grained, carbonaceous, friable; a few partings of dark-gray shale	4½
7. Shale, dark-gray, carbonaceous; a few stringers of very fine grained carbonaceous sandstone	7
Thickness, Lakota formation	177

Morrison formation:

6. Sandstone, light-gray, fine to very fine-grained, friable, very well sorted, massive; forms rounded ledges	25
5. Sandstone, grayish-green mottled pale purple (some thin bands weather dark yellowish-orange), fine- to very fine grained, very friable, very well sorted, indistinctly thin-bedded to massive; gradational with overlying and underlying units; forms a slope	15
4. Sandstone, light-gray, weathers orange pink and grayish yellow, fine- to very fine-grained, very well sorted, massive, friable; forms a cliff	37
3. Sandstone, greenish-gray, very fine grained, clayey	2
2. Sandstone, light-gray, weathers light grayish yellow; fine- to very fine-grained, friable; a few fragments of green claystone in the lower part; variably calcareous; forms a slope; rests sharply on the underlying unit	75
Thickness, Morrison formation	154

Sundance formation (part):

Redwater shale member (part):

1. Shale, dark-greenish-gray, noncalcareous, interlaminated fine- to very fine grained calcareous light-gray sandstone; glauconitic locally	10

The Lakota formation is not abundantly fossiliferous although at various 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. 11) and a few fresh-water mollusks and dinosaur bones. These fossils indicate an Early Cretaceous (Aptian?) age for the formation.

FALL RIVER FORMATION

The Fall River formation is 135 to about 150 feet thick in the Inyan Kara Mountain quadrangle and consists of sandstone, siltstone, and shale exposed on broad divides and on dip slopes in a band 3 to 4 miles wide that crosses the quadrangle diagonally from northwest to southeast.

The formation is divided on the geologic map (pl. 1) into two parts. The lower part, which is 60 to 65 feet thick at most places, is mostly nonresistant and generally forms steep, grass-covered slopes above forested ledges and cliffs of the underlying Lakota formation. It consists of light- to dark-gray siltstone and silty shale interbedded and interlaminated with beds less than an inch to several feet thick of light-gray to light yellowish gray siltstone and very fine grained sandstone (fig. 4). Siltstone and shale in the basal 10 to 20 feet of the formation are mostly dark gray and contain abundant carbonaceous material. These beds rest unconformably on a nearly plane surface cut on underlying lighter colored, generally nonfissile beds of the Lakota. Firmly cemented beds of tan-weathering siltstone or very fine grained sandstone commonly make a pair of thin persistent ledges

FIGURE 4.—Thin-bedded sandstone and siltstone in the lower part of the Fall River formation, Inyan Kara Mountain quadrangle.

in the lower 40 feet of the formation. On the divide between Oil Creek and Black Canyon in the southwestern part of T. 47 N., R. 62 W., sandstone in this interval thickens to as much as 20 feet, becomes fine grained and friable, and locally forms a conspicuous ledge. Thin beds 1 or 2 inches thick, of coarse-grained to granule sandstone are found 40 to 50 feet above the base of the formation in the same area.

The upper part of the Fall River formation is about 70 to 80 feet thick, and has at its base one or more massive to inconspicuously cross-bedded very fine to fine-grained well-sorted friable sandstone beds that generally form tan-weathering ledges and cliffs at the crests of high divides. Two sandstone beds can be recognized in much of the area, each about 10 to 20 feet thick, separated by about 10 to 15 feet of thin-bedded sandstone and siltstone. The lower bed seems to pinch out to the north at about the quadrangle boundary; the upper bed can be traced northwestward beyond the quadrangle for several miles to the vicinity of Carlile, where it is called the Keyhole sandstone member of the Fall River formation (Davis and Izett, 1958). In most of the northern part of the quadrangle, the cliff-forming sandstone sequence rests fairly sharply on the underlying finer grained and thinner bedded part of the formation. Near the south edge of the quadrangle, however, sandstone in the upper part of the formation becomes thin bedded, interfingers locally with siltstone, and is not everywhere easily separated from siltstone and sandstone of the underlying part of the formation.

The uppermost part of the Fall River formation above the cliff-forming unit just described consists of 10 to 30 feet of nonresistant thin-bedded sandstone, siltstone, and shale that grades upward into black marine shale of the overlying Skull Creek formation.

Nodules and beds, 1 or 2 inches thick, of siltstone and sandstone impregnated with dark-brown iron oxides are common in both the lower and upper parts of the Fall River formation. Many siltstone and thin sandstone beds are cross laminated and ripple marked, and the bedding surfaces of many thin beds are covered by markings that resemble worm trails and burrows (fig. 5). These features, and the thin relatively even bedding of much of the formation suggest that the Fall River formation accumulated in quiet, shallow water, perhaps in broad estuaries or on tidal flats (Waagé, 1958, p. 75).

The two stratigraphic sections below show the lithology of the formation in the northern and the southern parts of the quadrangle, respectively. Variations in the formation at other places in the quadrangle are shown graphically on plate 3.

FIGURE 5.—Markings on the bedding surface of a sandstone slab from the Fall River formation.

Fall River formation along Mason Creek, SW¼ sec. 6, T. 48 N., R. 63 W., and the adjacent part of the section to the west, Weston County, Wyo.

[Locality 1, pls. 1 and 3]

	Feet
Skull Creek shale (part):	
18. Shale, black, fissile; silty seams in the basal 6 ft.; exposed in a road cut on the south side of State Highway 116	10
Fall River formation:	
Upper part:	
17. Shale, grayish-black; thin laminae of gray siltstone and a few lenses ¼ to 3 in. thick of light-gray very fine grained sandstone locally cemented with brown-weathering iron oxides	17
16. Shale, dark-brown, very carbonaceous	1
15. Sandstone, yellowish-gray, locally stained and mottled orange red, fine-grained, locally cross laminated; forms a massive rounded ledge	12
Section below offset to the north side of Route 116, NE¼SW¼ sec. 6	
14. Covered	10±
13. Poorly exposed; some dark-gray shale	6
12. Sandstone, light-gray to light-yellowish-gray, fine- to very fine grained, friable, cross-laminated, ripple-marked, in beds 1 in. to 2 ft thick; forms ledges	24

Fall River formation along Mason Creek, SW¼ sec. 6, T. 48 N., R. 63 W., and the adjacent part of the section to the west, Weston County, Wyo.—Continued

Fall River formation—Continued

Lower part:

	Feet
11. Sandstone, siltstone, and shale, interbedded and interlaminated; sandstone is light gray to light yellowish gray, fine to very fine grained, cross laminated; siltstone is light to dark gray, shaly; shale is dark gray; silty; a few seams cemented with brown-weathering iron oxides; nonresistant	26
10. Siltstone, dark-gray, shaly, nonresistant	8
9. Sandstone, light-gray, very fine grained, very thin bedded; some interlaminated dark-gray siltstone; nonresistant	3½
8. Sandstone, yellowish-gray, very fine grained, cemented at the base with brown-weathering iron oxides; is a single blocky bed that forms a minor bench	3½
7. Mostly covered; some dark-gray siltstone in the middle part	7½
6. Sandstone, grayish-yellow, very fine grained, carbonaceous; forms a blocky ledge	2
5. Siltstone, medium gray, shaly	1
4. Sandstone, as in unit 6 above	1½
3. Shale, dark-gray, very carbonaceous, silty	4
2. Siltstone, dark-gray, carbonaceous	4
Thickness (rounded), Fall River formation	130±

Unconformity.

Lakota formation (part):

1. Claystone, medium gray to olive gray, (mottled and streaked yellow), silty; numerous tiny ferruginous pellets	4

Part of the Fall River formation exposed in a scar left by a landslide on the west side of West Plum Creek, SW¼ sec. 2, T. 46 N., R. 62 W., Weston County, Wyo.

[Locality 28, pl. 3; one-half mile south of the quadrangle]

Top of the ridge.

Fall River formation (part):

Upper part (part):

	Feet
11. Partly covered; slabby ledges of light-yellowish-gray fine-grained sandstone	10
10. Sandstone, light-gray to light-yellowish-gray, tan-weathering, fine-grained, friable, in blocky beds as much as 6 ft thick; a few lenticular partings as much as 2 ft thick of light-gray shaly siltstone; forms ledges and cliff	40

Lower part:

9. Sandstone, very light gray, very fine grained to silty, in beds mostly less than 6 in. thick, cross-laminated; forms local ledges	5
8. Siltstone, dark-gray weathering to purplish-gray; scattered carbonized plant fragments, fissile, nonresistant	5
7. Sandstone, light-gray, very fine grained, cross-laminated, in beds mostly 1 to 6 in. thick; a few interbeds of light- to dark-gray siltstone; bottom 5 ft contains discontinuous thin seams of medium- to coarse-grained sandstone locally containing granules; forms local ledges	11½

Part of the Fall River formation exposed in a scar left by a landslide on the west side of West Plum Creek, SW¼ sec. 2, T. 46 N., R. 62 W., Weston County, Wyo.—Continued

	Feet
Fall River formation (part)—Continued	
Lower part—Continued	
6. Siltstone, light-gray, carbonaceous; shaly dark-gray partings and laminae; a few thin seams cemented with dark-brown iron oxides; nonresistant	9
5. Sandstone, very light gray, very fine grained to silty, locally carbonaceous; forms slabby ledges	6½
4. Siltstone, as in unit 6 above	26
3. Siltstone, dark-gray, shaly, locally carbonaceous	6
Partial thickness, Fall River formation	119
Unconformity.	
Lakota formation (part):	
2. Claystone, medium-gray (mottled red in upper part); silty to sandy becoming more sandy at base; nonresistant	10
1. Sandstone, light-gray to very light yellowish-gray, mostly medium to fine grained, crossbedded, friable; contains lenses and seams of coarse to very coarse grained sandstone in the lower part; forms massive cliffs	21
Partial thickness, Lakota formation	31

The age of the Fall River is generally regarded as Early Cretaceous (Albian).

SKULL CREEK SHALE

The Skull Creek shale crops out in low hills and local badlands in the southwestern part of the quadrangle. The formation, which is about 180 feet thick, consists mostly of grayish-black flaky shale that contains scattered red-weathering siderite concretions and, in the upper part, a few yellow-weathering cone-in-cone limestone concretions. A few discontinuous beds as much as a foot thick of laminated grayish-white siltstone crop out locally near the middle of the formation, but none could be traced for more than a few hundred yards. The siltstone beds commonly have markings on their bedding surfaces that suggest worm trails, similar to siltstone beds in the underlying Fall River formation. The Skull Creek grades downward into the Fall River formation, and the contact, which is picked at the top of a transitional zone of interbedded siltstone, shale, and sandstone, can usually be determined within about 5 feet stratigraphically.

The Skull Creek shale contains Foraminifera (Skolnick, 1958, p. 280–284; Eicher, 1958, p. 81) and a few marine mollusks; its age is Albian (Cobban, 1951, p. 2197).

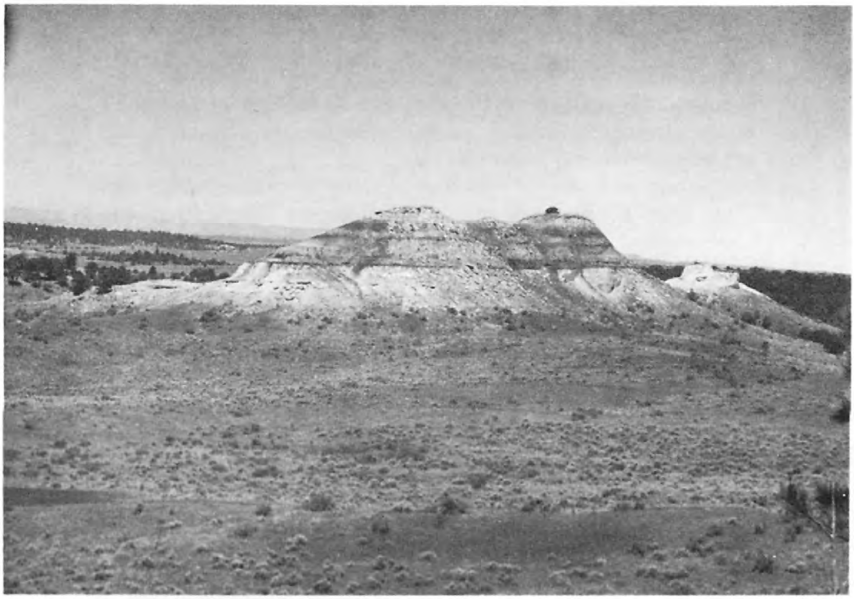

FIGURE 6.—Banded outcrop of the Newcastle sandstone on a butte in the southwestern part of the Inyan Kara Mountain quadrangle. Skull Creek shale forms dark-colored flats in the foreground.

NEWCASTLE SANDSTONE

The Newcastle sandstone is about 50 feet thick in the Inyan Kara Mountain quadrangle and consists of sandstone, siltstone, shale, claystone, and bentonite exposed in an irregular band west of outcrops of the underlying Skull Creek shale. A thin bed of resistant sandstone near the top of the formation forms broad dip slopes and caps a few small outlying buttes (fig. 6); the remainder of the formation is mostly nonresistant and forms local badlands.

The following stratigraphic section shows the lithology of the formation.

Newcastle sandstone in the SE¼ sec. 27, T. 47 N., R. 63 W., Weston County, Wyo.

		Feet
Mowry shale (part):		
16.	Shale, dark-gray, weathers medium gray, hard, brittle; contains fish scales	10
15.	Siltstone, light-gray; dark-gray shaly laminae; contains fish scales; forms a minor ledge	1
14.	Shale, grayish-black, soft, silty in the top 1 ft; contains a bed 0.3 ft thick of light-gray bentonite 3 ft above the base	16
	Partial thickness, Mowry shale	27

Newcastle sandstone in the SE¼ sec. 27, T. 47 N., R. 63 W., Weston County, Wyo.—Continued

Newcastle sandstone:		Feet
13.	Siltstone, medium- to light-gray, thin-bedded, nonresistant	2
12.	Shale, grayish-black, silty at the top	3½
11.	Shale, medium-gray, silty	2½
10.	Sandstone, light-gray, very fine grained to silty, slightly carbonaceous, a few partings of gray shale; forms local slabby ledges and caps outlying buttes	2
9.	Shale, medium-gray, bentonitic, silty	1
8.	Bentonite, light-greenish-gray, silty, slightly swelling	2
7.	Shale, dark-gray, carbonaceous at the top and base, silty in the middle part; scattered dark purplish-gray sideritic concretions as much as 6 in. long	8½
6.	Siltstone, light-yellowish-gray; contains dark-gray shaly partings and a lenticular bed ½-ft thick of light-gray very fine grained sandstone at the base; nonresistant	4½
5.	Shale, medium-gray, carbonaceous in the lower part; contains laminae of light yellowish-gray siltstone	3
4.	Shale, very dark gray, very carbonaceous	2½
3.	Bentonite, light-gray, silty and sandy, slightly swelling	2½
2.	Siltstone, light-tan to light-gray, locally carbonaceous; thin partings of grayish-black shale in the bottom 2 to 3 ft; a few lenses mostly less than 2 in. thick of light-gray, very fine grained sandstone; forms tough gumbo soil	17
	Thickness, Newcastle sandstone	51
Skull Creek shale (part):		
1.	Shale, grayish-black, soft, fissile	10

The contact of the Newcastle sandstone with the underlying Skull Creek shale appears to be conformable.

MOWRY SHALE

The Mowry shale crops out near the southwest corner of the quadrangle on a low ridge made conspicuous by a generous growth of pine trees. The formation is about 200 feet thick and consists mostly of resistant siliceous shale that weathers silvery gray and breaks into brittle platy chips. The light-colored siliceous shale grades downward in the basal 15 to 20 feet of the formation into soft grayish-black shale that was called the Nefsy shale member by Collier (1922, p. 82). Interbedded with the shale throughout the formation are a few thin beds of siltstone and many thin beds of bentonite, mostly less than 1 foot thick but including a bentonite bed 2½ feet thick at the top of the formation. This bentonite, which is called the Clay Spur bentonite bed, or Commercial bed of local usage, can be traced for many miles along the west side and across the north end of the Black Hills.

Fish scales are abundant in the Mowry, but other fossils are rare. According to Cobban (1951, p. 2179), impressions of the ammonites *Metengonoceras* and *Gastroplites* have been found in the formation in the vicinity of Osage, and Reeside and Cobban (1960, p. 21–22) report *Neogastroplites americanus* and *N. cornutus* in the Mowry in other parts of the Black Hills.

UPPER CRETACEOUS SERIES

BELLE FOURCHE SHALE

The Belle Fourche shale is poorly exposed on gentle grassy slopes and flats along U.S. Highway 16 in the southwest corner of the quadrangle. In addition, a few small outliers of the formation are found on dip slopes of the underlying Mowry shale. The formation is about 425 feet thick and consists mostly of nonresistant grayish-black shale. Siderite concretions that weather dark red to purplish black are common, especially in the basal 50 feet of the formation. Several thin beds of bentonite crop out in the lower part of the Belle Fourche shale, including a bed about one-half foot thick that lies about 5 feet above the base of the formation, and a bed as much as 3 feet thick that lies 35 to 40 feet above the base of the formation. Bentonite beds at about the same stratigraphic positions in the northern part of the Black Hills have been called beds D and E, respectively, by Knechtel and Patterson (1955). About 40 feet stratigraphically below the top of the Belle Fourche shale is a persistent bentonite bed that has been traced for many miles along the west side of the Black Hills. This bentonite bed is called the gray-red bentonite by W. W. Rubey and M. N. Bramlette (Moore, 1949, p. 27) and bed F by Knechtel and Patterson (1955) in nearby areas to the north. Where examined about half a mile south of the quadrangle in sec. 5, T. 46 N., R. 63 W., the gray-red bed is light gray to light pinkish brown and is 2½ to 3 feet thick.

The contact of the Belle Fourche and underlying Mowry shales is placed arbitrarily at the top of the Clay Spur bentonite bed, which roughly marks the change from soft shale that weathers grayish black in the Belle Fourche shale to hard siliceous shale that weathers light gray in the Mowry.

GREENHORN FORMATION

Outcrops of the Greenhorn formation occupy an area of less than a square mile in the extreme southwest corner of the quadrangle. The formation is about 270 feet thick. It consists of alternate calcareous and noncalcareous brown to dark-gray shale, a few thin beds of light-gray to tan sandy limestone and light-gray bentonite, and scattered yellowish-gray and light-gray limestone concretions. The top

of the formation is a ridge-forming sequence, about 25 feet thick, of interbedded light-gray thin-bedded limestone and light- to dark-gray marl. Marine fossils are fairly abundant, especially in the limestone beds at the top of the formation.

The stratigraphic section below, which was measured 3 miles south of the quadrangle, gives some lithologic details.

Greenhorn and parts of adjacent formations near Osage in the SW¼ sec. 17, T. 46 N., R. 63 W., Weston County, Wyo.

[Fossils identified by W. A. Cobban (written communication, 1955)]

	Feet
Carlile shale (part):	
Lower unnamed member (part):	
21. Poorly exposed; mostly dark-gray calcareous shale	10
Greenhorn formation:	
20. Limestone, medium-gray; weathers light gray to light brownish gray; locally sandy, in beds 1 in. to 2 ft. thick separated by dark-gray marl in beds 1 in. to 3 ft thick; forms a prominent hogback; yields abundant *Inoceramus labiatus* (Schlotheim) and *Ostrea* sp. (USGS loc. D 410)	23
19. Marl, dark-gray, weathers dark to light gray, fissile	8.5
18. Limestone, medium-gray, weathers light-gray, slightly sandy	.5
17. Marl, dark-gray, weathers brownish gray to light gray, fissile; a few thin discontinuous beds of gray sandy limestone that yield *Inoceramus prefragilis* Stephenson (USGS loc. D 409); a few scattered medium-gray limestone concretions	30
16. Bentonite, light-gray, nonswelling	.5
15. Shale, dark-gray, weathers grayish- brown, mostly calcareous with some some noncalcareous bands; a few discontinuous beds 1 to 2 in. thick of gray sandy limestone that contain fish remains; scattered light-gray sandy limestone concretions; about 35 ft above the base a prominent bed of tabular medium- to yellowish-gray sandy limestone concretions 1 to 2 ft thick and 3 to 8 ft long	110
14. Shale, grayish-black, noncalcareous, flaky	22
13. Shale, dark-gray, weathers grayish brown, calcareous; contains local dikes about 1 in. thick and several feet long of white coarsely crystalline calcite	35
12. Limestone, light-gray to light yellowish-gray, coarsely crystalline, fossiliferous, lenticular	.5
11. Poorly exposed; seems to be mostly grayish-brown calcareous shale	5
10. Bentonite, light-gray, swelling	.7
9. Shale, dark-gray to grayish-brown, calcareous	8
8. Limestone, as in unit 12 above	.3
7. Shale, grayish-black, noncalcareous, flaky	16
6. Shale, dark-gray to grayish-brown, calcareous	10
5. Limestone, dark-gray, silty, discontinuous	.5
Thickness (rounded), Greenhorn formation	270

Greenhorn and parts of adjacent formations near Osage in the SW¼ sec. 17, T. 46 N., R. 63 W., Weston County, Wyo.—Continued

	Feet
Belle Fourche shale (part):	
4. Shale, grayish-black, noncalcareous, flaky; scattered red-weathering silty siderite concretions	38
3. Bentonite (gray-red bed), very light gray at the top and base, light brown to pinkish brown in the middle, swelling; chips of yellowish-gray aragonite weathering from the upper part	2.3
2. Limestone, light-gray, very fossiliferous, discontinuous	.1
1. Shale grayish-black, noncalcareous, flaky	10
Partial thickness (rounded), Belle Fourche shale	50

CARLILE SHALE

The Carlile shale is about 500 feet thick near the Inyan Kara Mountain quadrangle and consists in ascending order of a lower unnamed member, the Turner sandy member, and the Sage Breaks member. Only the lower unnamed member and the basal part of the Turner sandy member are present in the quadrangle, and these units are present only in the southwest corner.

The lower unnamed member is about 90 feet thick and is mostly dark-gray shale that is variably calcareous in its basal part and contains a few laminae of silty shale and siltstone. The Turner sandy member overlies these beds and has at its base a persistent light-gray ledge-forming sandstone bed 3 to about 5 feet thick that contains locally abundant fish teeth and many dark grains and generally a few granules and pebbles of phosphatic material and chert. The basal sandstone and a few feet of overlying dark-gray shale and sandy shale are all that are preserved of the Turner sandy member in the quadrangle.

A section of the lower part of the Carlile shale that is well exposed about 3 miles south of the Inyan Kara Mountain quadrangle is described below.

Part of the Carlile shale near Osage, NW¼ sec. 20, T. 46 N., R. 63 W., Weston County, Wyo.

	Feet
Carlile shale (part):	
Turner sandy member (part):	
10. Sandstone, light-gray, very fine grained, calcareous, very thin bedded; interlaminated dark-gray silty shale; contains brown-weathering calcareous sandstone concretions as much as 5 ft thick and 20 ft long that form prominent lenticular ledges	17
9. Shale, dark-gray, noncalcareous, silty; some interbedded light-gray very fine grained sandstone; grades into the units above and below	36

Part of the Carlile shale near Osage, NW¼ sec. 20, T. 46 N., R. 63 W., Weston County, Wyo.—Continued

	Feet
Carlile shale (part)—Continued	
Turner sandy member (part)—Continued	
8. Sandstone, very light gray, mostly fine grained; many grains and locally some granules of gray and black phosphatic material and chert; in beds 1 in. to 1 ft thick separated by partings of dark-gray shale; calcareous; forms slabby ledges; unit contains *Scaphites corvensis* Cobban, *Prionocyclus wyomingensis* Meek, *Hypsodon lowii* (Stewart) Cockerell, *Ptychodus* sp., *Isurus?* sp., *Corax* sp. (USGS locs. 11200 and 11214, fossils collected by W. W. Rubey and identified by J. B. Reeside, Jr., written communication from W. A. Cobban, 1956)	5.5
Partial thickness (rounded), Turner sandy member	59
Lower unnamed member:	
7. Shale, dark-gray, silty; laminae of light-gray siltstone	40
6. Bentonite, light-gray, nonswelling	.3
5. Shale, dark-gray, silty	5
4. Bentonite, light-gray, nonswelling	.9
3. Shale, dark-gray, silty, slightly calcareous in bottom 5 ft; 2 beds of gray-weathering silty limestone concretions about the middle of the unit that contain *Inoceramus fragilis* Hall and Meek, *Scaphites larvaeformis* Meek and Hayden, *Collignoniceras woollgari* (Mantell), *Tragodesmoceras* sp., and *Pecten* sp. (USGS loc. D411, fossils identified by W. A. Cobban, written communication, 1955); concretions at about the same horizon nearby contain, in addition, "*Puzosia*" n. sp. (USGS loc. 11199, collected by W. W. Rubey, identified by J. B. Reeside, Jr., written communication to W. W. Rubey, 1925)	15
2. Poorly exposed; seems to be mostly light-gray to tan calcareous shale	30
Thickness (rounded), lower unnamed member	91
Partial thickness (rounded), Carlile shale	150
Greenhorn formation (part):	
1. Limestone, light-gray; interbedded light- to dark-gray marl; forms a ridge	10

TERTIARY AND QUATERNARY SYSTEMS

TERRACE AND PEDIMENT GRAVEL

Poorly consolidated stream-laid deposits of silt, sand, and gravel cover small areas at various heights above the present streams. The highest and oldest gravel, tentatively classified as Tertiary in age, is about 250 to 275 feet above the present streams; it includes a deposit on the divide north of Mason Creek in the northwest part of

the quadrangle and 3 smaller deposits along Pine Ridge to the southeast. Lower and younger gravel of probable Quaternary age occurs at elevations of 40 to about 150 feet above the present streams along Inyan Kara Creek and on the north side of Inyan Kara Mountain in the northeastern part of the quadrangle, west of Sheldon Creek in the northwestern part, and west of Skull Creek in the southern part.

The age assigned to the deposits, as well as their correlation, is based on the physiographic relations. Darton (1909, p. 59, pl. 4) regarded the high deposit on the divide north of Mason Creek as Tertiary in age and correlated it with the Oligocene White River formation. Alden (1932, pl. 1) classified high gravel in the vicinity of the quadrangle as stream-terrace and alluvial-fan deposits of Oligocene or Miocene age. The younger and lower gravel deposits are mostly stream-terrace deposits probably laid down during interglacial stages of the Pleistocene, as were other widespread terrace deposits in nearby parts of the northern Great Plains (Alden, 1932, pl. 1). Gravel just north of Inyan Kara Mountain covers a dissected pediment surface and is a pediment deposit.

The high gravel deposit on the divide north of Mason Creek (pl. 1) is at least 15 feet thick and consists of light-brown to light-gray calcareous siltstone interbedded with sand and gravel. Granules and pebbles of siltstone and sandstone, cemented with dark-brown iron oxides, constitute at least 90 percent of the larger fragments, and chert and quartzite compose most of the remainder.

Gravel deposits of the same composition as the one described above but at a lower altitude cap nearly level surfaces at the south end of the same divide. One of these deposits is well exposed and at least 20 feet thick in a pit in the NE¼ SE¼ sec. 1, T. 48 N., R. 64 W.

Gravel deposits make a narrow discontinuous band for more than 4 miles along the crest of the divide west of Skull Creek at the south edge of the quadrangle. The deposits are 5 to 10 feet thick and contain granules and pebbles, commonly ½ to 6 inches long, of quartzite, some chert, and sandstone and siltstone cemented with iron oxides. Most of these materials probably were derived from the Fall River and Lakota formations.

A gravel deposit several hundred yards long is at least 12 feet thick at about the center of sec. 23, T. 49 N., R. 62 W., east of Inyan Kara Creek. The deposit consists of a layer at the base about 6 feet thick made up mostly of pebbles and cobbles of limestone, overlain by about 6 feet of light-tan sandstone and siltstone and a few irregular lenses of coarser material. Gravel consisting largely of limestone fragments covers the Spearfish and Minnekahta formations at several other places in the vicinity.

On the north side of Inyan Kara Mountain, remnants of a sloping gravel-strewn plain form the crests of several low, even-topped divides that extend with decreasing gradients from the foot of the steeper mountain slopes northward for distances of more than a mile. The surface of the plain merges at its upper edge with dip slopes formed by the Minnekahta limestone. Gravel deposits that cap the divides are less than 5 feet thick and consist mostly of subrounded to subangular pebbles and cobbles of limestone and igneous rock derived from formations that comprise the higher parts of Inyan Kara Mountain.

QUATERNARY SYSTEM

LANDSLIDE MATERIAL

Landslides cover areas ranging in size from less than an acre to several square miles in the Inyan Kara Mountain quadrangle. Displaced material in most of the slides is shale and sandstone from the Redwater shale member of the Sundance formation and the overlying Morrison formation. Commonly, large blocks of sandstone from the Lakota formation also are displaced. The largest area of landslides is in the southeast corner of the quadrangle, on both sides of the divide that separates Oil and West Plum Creeks. Other large slides cover the sides of Mount Tom in T. 48 N., R. 62 W., and are found at various places south of Inyan Kara Creek in T. 49 N., Rs. 62 and 63 W.

Landslide material intermingled with talus composed of limestone and igneous rock are shown together on the geologic map (pl. 1) in a band that skirts Inyan Kara Mountain on the west and south.

ALLUVIUM

Alluvium consisting of silt, sand, and local lenses of gravel borders most of the large streams in the quadrangle, although at many places the deposits are too narrow to be shown on the geologic map (pl. 1).

Alluvium along Sheldon Creek, a short tributary of Mason Creek in the southwestern part of T. 49 N., R. 63 W., was deposited by a much larger stream at a time when the headwaters of the present Inyan Kara Creek probably connected with Mason Creek through the broad, open valley occupied by the deposit. Inyan Kara Creek has since been diverted northwestward and subsequent erosion has left the old stream channel and its alluvium about 20 feet higher than the present level of Inyan Kara Creek at the upper end of the deposit in sec. 17, T. 49 N., R. 63 W.

IGNEOUS ROCKS

Igneous rock crops out prominently in the quadrangle in a large intrusive body that makes up the core of Inyan Kara Mountain. The area of outcrop is roughly circular in plan and about a mile in diam-

FIGURE 7.—Aerial view of Inyan Kara Mountain looking northeastward. Mp, Pahasapa limestone; Ts, syenite porphyry.

eter. Within this area, the igneous mass stands in bold, nearly vertical cliffs and jagged peaks that rise several hundred feet above the nearby countryside (fig. 7).

The rock is syenite porphyry and is light to medium gray with abundant very light gray feldspar phenocrysts mostly less than 1 cm in longest dimension. Smith (*in* Darton, 1905, p. 5) describes the composition and texture of the rock as follows:

> Oligoclase forms the principal phenocrysts, but there is a minor amount of orthoclase which often appears as a border about the oligoclase. Augite and aegirite-augite are the chief ferromagnesian minerals. They are associated with a little brown hornblende showing partial resorption.
>
> The groundmass of the Inyan Kara porphyry varies in texture from microgranular to trachytic, the latter being more common near the borders of the mass. * * *
>
> At three points on the rim of the * * * [igneous mass], situated respectively south, east, and northeast of the main peak of the mountain, an exceptionally alkalic facies of prophyry is found. This is almost free from ferromagnesian minerals and consists essentially of alkali feldspar with a small proportion of magnetite and a little interstitial quartz. It contains a few scattered orthoclase and anorthoclase phenocrysts, comparable in size to those of the common facies of this porphyry, and is characterized by an abundant generation of anorthoclase crystals intermediate in size between these large crystals and the laths and grains of the groundmass, and averaging about 0.15 mm in length.

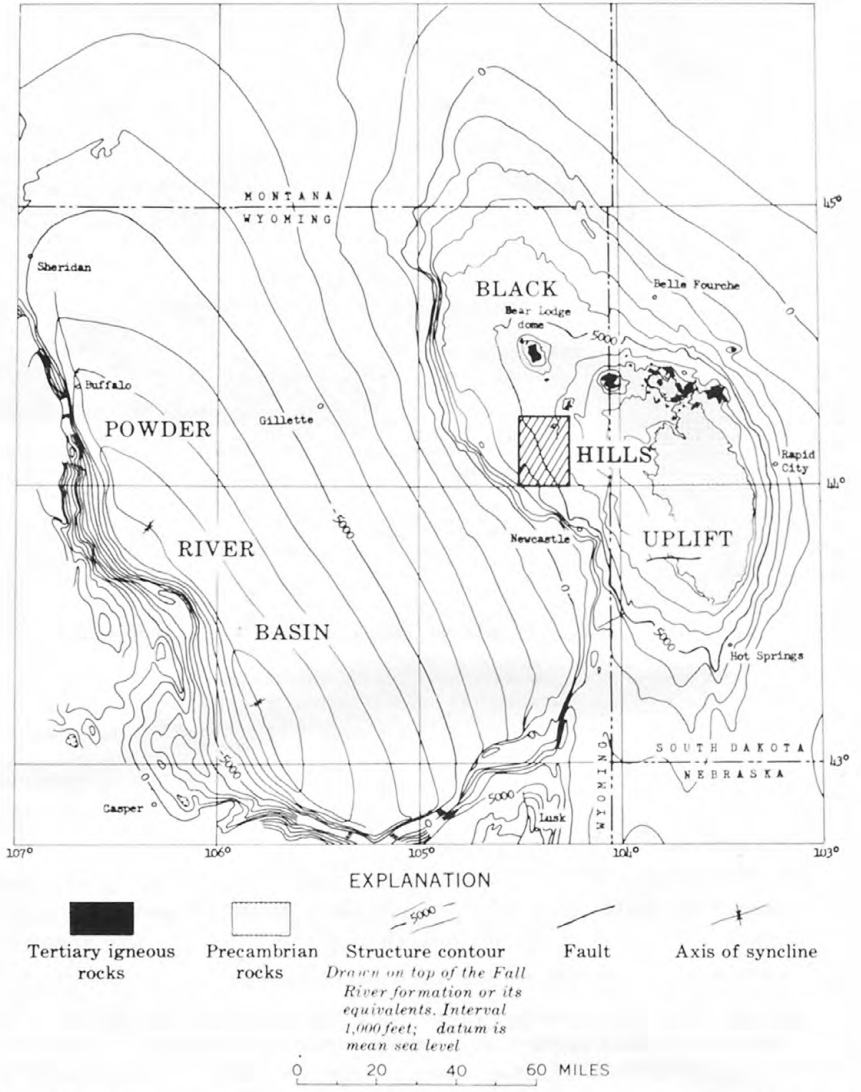

FIGURE 8.—Location of the Inyan Kara Mountain quadrangle (crosshatched) in relation to major structural features of northeastern Wyoming and adjacent areas. Data from Pierce, Girard, and Zapp (1952), Noble (1952, p. 32), and Dobbin and Erdmann (1955).

Sandstone of the Minnelusa formation is silicified and hardened in a zone 10 feet thick at the contact with the porphyry in the center of sec. 19, T. 49 N., R. 62 W. No other alteration was noticed.

STRUCTURE

The Inyan Kara Mountain 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 brought to the surface by the uplift in the mapped area dip generally southwestward 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 8 shows the configuration of these large structural features and the relation of the Inyan Kara Mountain quadrangle to them.

Structural details in the Inyan Kara Mountain quadrangle are shown on plate 1 by cross sections and by structure contours drawn at vertical intervals of 50 feet on the top of the Lakota formation in the southwestern part of the quadrangle and on the top of the Gypsum Spring formation or, where the Gypsum Spring is absent, on the top of the Spearfish formation in the northeastern part. The regional dip is 1°–3° SW., except in the extreme southwestern part of the quadrangle where the dip of the Greenhorn formation and Carlile shale steepens to about 7°. The rather uniform dip is disrupted by 3 small domes or anticlines in the northern part of the quadrangle and by 2 in the southern part. Faulting accompanies folding at Inyan Kara Mountain and Strawberry Mountain in the northern part of the quadrangle; 4 minor faults were mapped (pl. 1) in T. 49 N., R. 63 W., and one near Clay Spur in T. 47 N., R. 63 W. The faults seem to be mainly vertical.

Inyan Kara Mountain dome and related faults.—Inyan Kara Mountain is a sharply folded dome about 1½ miles across intruded by a large mass of igneous rock. The fold has a structural closure of about 1,800 feet and it is outlined, except for the northeast side, by the trace of a curving fault that almost encircles the mountain. Outcropping sedimentary rocks involved in the steepest folding include all formations from the Pahasapa to the Sundance. Dips ranging from 30°–90° were measured in the Minnekahta limestone on the north side of the dome, and the Pahasapa limestone is vertical to overturned in a large outcrop on the southwest side.

The intrusive body at Inyan Kara Mountain crops out slightly southwest of the crest of the dome. The igneous mass crosscuts all formations from the Spearfish to the lower part of the Pahasapa limestone. Smith (*in* Darton, 1905, p. 8) describes the igneous body as a laccolith, or generally concordant sill-like mass thickened in the middle; however, the part of the igneous body exposed at the surface would seem better described as a small plug. A possible configuration of the intrusive at depth is shown by structure section *A*–*A′* on plate 1.

The fault that nearly surrounds Inyan Kara Mountain has an inferred surface trace in the shape of a horseshoe open to the northeast. Igneous and sharply folded sedimentary rocks within the horseshoe-shaped area on the upthrown side of the fault are in contact with

relatively undeformed sedimentary rocks on the downthrown side. The displacement along the fault seems to be about 600 feet in the SE¼ sec. 24, T. 49 N., R. 63 W., where the Spearfish formation on the upthrown side is brought against the upper part of the Sundance and the Morrison formation. The displacement may be about the same for several hundred yards farther south where the Pahasapa limestone is exposed at the surface on the upthrown side. The fault dies out at both ends in the lower part of the Sundance formation.

Strawberry Mountain dome and related faults.—Strawberry Mountain, in the northeastern part of the quadrangle, is a sharply folded dome outlined by tree-covered dip slopes mostly on the Minnekahta limestone. The dome is slightly elongated in a northeast direction and is about 1½ miles long. It has a closure of about 450 feet. The Minnelusa formation crops out in the central and southwestern parts of the dome and is the oldest formation exposed.

A northeastward-trending fault with a maximum vertical displacement of about 50 feet, upthrown on the east, cuts obliquely across steeply dipping outcrops of the Spearfish, Minnekahta, Opeche, and Minnelusa formations on the east flank of Strawberry Mountain; in sec. 1, T. 48 N., R. 62 W., a short branching fault offsets the outcrop of the Minnekahta limestone.

Unnamed anticline northeast of Inyan Kara Mountain.—A westward-plunging anticline with a sinuous crestal trace extends westward into the northeast corner of the quadrangle. The anticline terminates in a low, broad dome, about 1½ miles long with a little more than 50 feet of closure, in the north half of T. 49 N., R. 62 W. The Minnekahta limestone forms the surface of the fold nearly everywhere, except for a few patches of the overlying Spearfish formation and—at the west and east ends of the fold—small outcrops of the underlying Opeche formation.

Oil Creek dome and nearby folds.—Stratigraphic and structural details of the Oil Creek dome are illustrated on figure 9. The dome is in the southeastern part of the quadrangle in the valley of Oil Creek, where the sedimentary rocks are bent upward into a low dome nearly bisected by the creek. The Stockade Beaver shale member of the Sundance formation comprises the oldest rocks exposed; younger members of the Sundance are successively exposed outward on the flanks of the dome. The fold is about 1 mile across and has a closure of 50 to 75 feet.

As shown by the structure section on figure 9, the Fall River formation progressively truncates older rocks toward the center of the dome beneath a local angular unconformity. This relation indicates that some folding occurred at the site of the dome before deposition of the Fall River formation. After deposition of the Fall River, folding

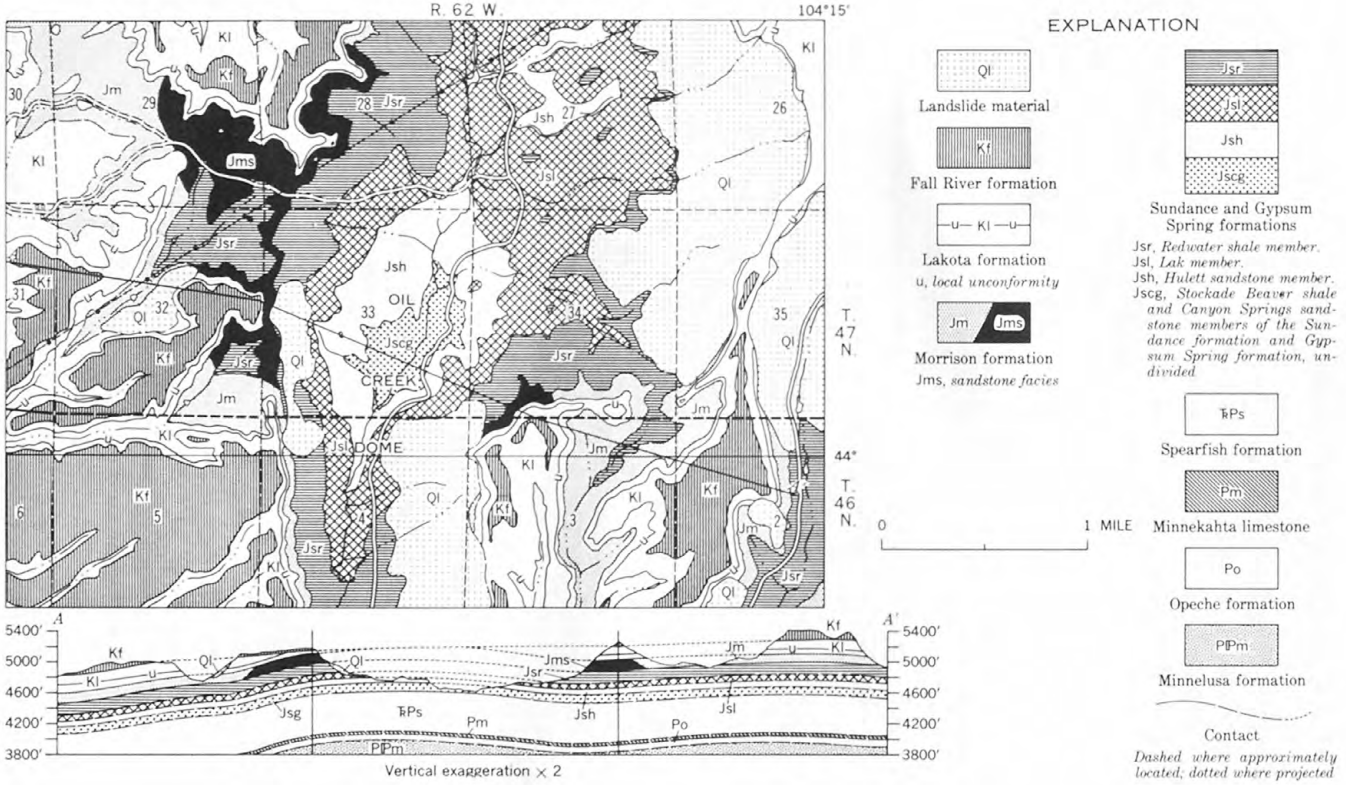

FIGURE 9.—Map and section of the Oil Creek dome and vicinity, Weston County, Wyo.

continued at or near the site of the dome, as shown by a northwest-trending shallow syncline and adjoining anticline in the Fall River and older formations adjacent to the northwest part of the dome.

Folds near Clay Spur.—A northwestward-trending broad low anticline about 2 miles long exposes the Skull Creek shale along Iron Creek north of Clay Spur in the southwest corner of the quadrangle. Dips in the Newcastle sandstone on the flanks of the fold are about 1°, and the fold has less than 50 feet of closure.

A broad structural saddle northwest of the anticline just described separates it from a larger and more prominent northward-trending fold known as the Pump Creek anticline, which has its axis outside the quadrangle in Tps. 47 and 48 N., R. 64 W. (Longwell and Rubey, 1923; Dobbin, Kramer, and Horn, 1957). The Pump Creek anticline is bordered by the Pump Creek syncline, an asymmetrical southward-plunging fold whose axis extends for about 5 miles along the west edge of the quadrangle. The Skull Creek shale, which is the surface formation in the trough of the syncline, dips as much as 14° on the steep west flank and 2° to 3° on the more gentle east flank of the fold.

Other faults.—A northeastward-trending fault can be followed for about 2 miles in secs. 10 and 16, T. 49 N., R. 63 W., where it cuts the Spearfish, Gypsum Spring, and Sundance formations. The fault has a maximum displacement of about 100 feet, upthrown on the east. A shorter nearby fault in secs. 14 and 22 of the same township has about the same displacement and trend. It also cuts the Spearfish, Gypsum Spring, and Sundance formations and is upthrown on the east. Two other faults in T. 49 N., R. 63 W., can be traced for a few hundred feet in the Lakota formation, but they seem to have less than 20 feet displacement.

A fault southeast of Clay Spur cuts across outcrops of the Mowry and Belle Fourche shales and has a maximum displacement of about 30 feet, upthrown on the west. This fault can be traced for about a mile.

Relation of folds and faults to igneous intrusives.—Folding and faulting at Inyan Kara Mountain seem clearly to have resulted from upward forces exerted during emplacement of the large igneous body that invades the fold. Other folds in the quadrangle are not so obviously related to intrusive activity; however, some of them may have igneous cores at moderate depth (Darton, 1909, p. 73).

The unnamed dome northeast of Inyan Kara Mountain is adjacent to a large irregularly shaped intrusive mass that crops out about 2 miles northeast of the mapped area and forms a group of hills known

as Black Buttes. According to Darton (1905, p. 10), who mapped the area, all formations from the Minnekahta to the Deadwood are brought to the surface and intruded by igneous rocks at Black Buttes. It seems reasonable to suppose that the small dome south of the Buttes may have resulted from an underground extension of this large intrusive complex.

The Strawberry Mountain dome is close to the centers of igneous activity at Inyan Kara Mountain and Black Buttes and it is similar in size and shape to domes intruded by igneous rocks at both those places. It seems likely, therefore, that the Strawberry Mountain dome, also, was formed by an underlying intrusive that is not yet exposed by erosion.

Age of folding.—Structural and stratigraphic relations at the Oil Creek dome indicate that during or after deposition of the Lakota formation, and before deposition of the Fall River formation, local folding was sufficiently intense to produce a dome about 1½ miles in diameter having about 150 feet of closure. Subsequent tilting to the west has reduced the closure to about 50 to 75 feet. But the principal folding of sedimentary rocks in the Black Hills, including the rocks in the Inyan Kara Mountain quadrangle, occurred much later, probably in latest Cretaceous or in early Tertiary time (Darton, 1905, p. 11).

MINERAL DEPOSITS

OIL AND GAS

More than 100 wells have been drilled for oil and gas in the Inyan Kara Mountain quadrangle to 1959. Most of these were drilled at the north end of the Osage oil field, which extends into the southwest corner of the quadrangle in and near sec. 31, T. 47 N., R. 63 W. Other wells, all unsuccessful in finding commercial quantities of oil or gas, are scattered at various other places in the western part of the quadrangle. A description of selected wells in the quadrangle is given in table 2.

Osage oil field.—The Osage oil field has been described by Collier (1922), Dobbin and others (1935), and Espach and Nichols (1941, p. 73–75). The field was discovered in 1919; from then until 1958 it produced about 7 million barrels of oil (Strickland, 1958, p. 136). About 7,000 acres is considered productive for the field as a whole, most of which lies south of the Inyan Kara Mountain quadrangle in T. 46 N., Rs. 63 and 64 W. The oil is on a structural terrace and is trapped in fractures in the Belle Fourche and the basal part of the

Mowry shales and in porous zones in the Newcastle sandstone. Most of the wells in the Inyan Kara Mountain quadrangle initially produced less than 15 barrels of oil per day from shale at depths of less than 200 feet. None of the wells were producing in 1959.

TABLE 2.—*Selected wells drilled for oil and gas, Inyan Kara Mountain quadrangle*

Location (section)	Company and farm	Date completed	Total depth (feet)	Oldest formation reached	Initial production (BOPD [1])	Producing formation
T. 49 N., R. 63 W.						
C SE¼NW¼ 17	Ralph Gardner, Krieger, et al. 1.	1948	1,232	Minnelusa		[2]
T. 48 N., R. 63 W.						
C SE¼NE¼ 30	Moffatt-Meyers Dev. Co., Douglas 1-W.	1951	475	Sundance		[3]
T. 47 N., R. 63 W.						
NE¼SW¼SE¼ 3	Farley & Freeman, Thomas 1.	1954	2,500	Pahasapa		
NW¼NE¼NW¼ 19	Wyalta Holdings, Dawson-Bethpage-Mission 1.	1957	385	Fall River		Oil show, Newcastle.
SE¼SW¼SW¼ 19	Midwest Resources Co., Boatsman 1.	1957	225	Skull Creek		
NW¼NE¼SW¼ 20	Jake Charbonneau, Govt. 1.	1957	445	Fall River		
SW¼SW¼SW¼ 29	S. P. Todd, Govt. 1	1956	480	do		
SE¼SE¼SW¼ 30	B. C. Hewett, National Lead Co. 2.	1956	401	Skull Creek	5	Newcastle.
NE¼NW¼NW¼ 31	G. B. Bock, Bock 2-A	1938	228	Newcastle	96	Do.
SW¼SW¼NW¼ 33	Hollaway & Jones, Hollaway & Jones C-2.	1956	276	Mowry	1	Mowry.
S½NE¼SW¼ 36	Webster Oil Co., Bock 1.	1921	1,687	Minnelusa		[2]
T. 47 N., R. 64 W.						
SE¼SE¼SE¼ 11	Omaha Oil Syndicate, 1.	1930	437	Fall River		[4]
C NE¼NE¼ 26	Upton Trust Oil Co., Hockett Ranch 1.	1939	305	do		
E½NE¼NE¼ 36	T. L. Hopkins, Hopkins 1.	1937	225	Newcastle	[4]	Newcastle.

[1] Barrels of oil per day.
[2] Completed as a water well in the Minnelusa formation.
[3] Completed as a water well in the Lakota formation.
[4] Completed as a water well in the Fall River formation.

Oil from the Osage field is green to brownish green, ranges from 32° to 40° A.P.I. gravity, and contains about 0.1 percent sulfur. Analyses of the oil have been given by Espach and Nichols (1941, p. 160) and by Wenger and Reid (1958, p. 154).

Oil and gas possibilities.—Sandstone near the base of the Fall River formation contains small amounts of oil in the Barton oil field a few miles northwest of the quadrangle, and the Minnelusa formation con-

tains oil in several nearby fields on the west side of the Black Hills. Stratigraphic traps containing oil might be found in either of these formations in the quadrangle, although the location of such traps cannot be predicted accurately from the geologic information presently available. The Oil Creek dome in the southeastern part of the quadrangle is a possible trap for oil in the Minnelusa formation or older rocks. This fold had not been tested to 1960.

COAL

The lower part of the Lakota formation contains beds of carbonaceous shale and coal at several places in the quadrangle, most notably on the northeast side of the high divide facing Skull Creek, in sec. 31, T. 48 N., R. 62 W., where two now-abandoned prospects were worked during the early part of the century. Because talus from overlying sandstone cliffs generally covers the main coal zone, which lies about 60 feet above the base of the Lakota formation, few outcrops of coal were seen during the present investigation; however, some information is available on the thickness and quality of the coal from earlier reports (Darton, 1905, p. 12; Stone, 1912, p. 24–32).

The coal is bituminous in rank, as shown by the analyses (table 3), and some is cannel coal. The coal is interbedded with carbonaceous shale in persistent carbonaceous zones that extend over large areas; however, the coal beds themselves are lenticular and no individual bed has been traced for more than a few hundred yards. Correlation of the main coal zone is shown on the graphic sections (pl. 3).

The thickest coal reported in the quadrangle is located about 1½ miles southeast of the Skull Creek Community Hall in the SE¼ sec. 31, T. 48 N., R. 62 W. Stone (1912, p. 28, 29) measured the following three sections of the coal bed at this locality.

Holwell coal bank No. 1

[Measured at face of drift driven into hill 55 feet]

	Ft.	In.
Sandstone roof.		
Clay, drab, soft.		
Bone	1	2
Coal, bituminous, ashy and bright streaks	2	
Coal, bituminous, bright (fuel analysis 6746, table 3)		7
Coal, cannel (fuel analysis 6743, table 3)	1	6
Coal, bituminous, bright (fuel analysis 6746, table 3)	1	9
Coal, cannel	1	4
Coal, bony, shaly; burns well		8
Total	9	0
Sandstone.		

Holwell coal bank No. 2

[Measured in drift driven into hill 90 feet; about 500 feet west of the Holwell No. 1]

	Ft.	In.
Bone		6
Bone with streaks of bituminous coal	1	1
Coal, bright, bituminous		3
Coal, bony		8½
Coal, bright, bituminous		2½
Coal, dull, bituminous		5½
Coal, cannel		5
Coal, bony		1½
Coal, bright, bituminous		9
Coal, splint	1	
Bone		6
Total	6	0

Section 1,000 feet east of Holwell No. 1

	Ft.	In.
Clay, drab, and brown shale	1	
Coal, ashy, with bituminous streaks		10
Sandstone, white, soft, with streaks of carbon		5
Coal, bituminous, good quality	2	4
Total	4	7

Quartzite, gray mottled with white.

TABLE 3.—*Fuel analyses of coal samples*[1] *from the Lakota formation, Inyan Kara Mountain quadrangle*

[Laboratory No.: Number given on U.S. Bureau of Mines analytic reports and included in their record of analyses. Sample condition: A, as received; B, air-dried; C, moisture-free; D, moisture- and ash-free.]

Laboratory No.	Sample condition	Air-dry loss	Proximate				Ultimate					Heat value (Btu)
			Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	
6743	A	10.7	14.0	23.8	38.0	24.16	2.11	4.78	46.78	0.63	21.54	8,230
	B		3.6	26.7	42.6	27.06	2.36	4.02	52.38	.70	13.48	9,220
	C			27.7	44.2	28.08	2.45	3.75	54.38	.73	10.61	9,560
	D			38.5	61.5		3.41	5.21	75.61	1.01	14.76	13,300
6746	A	12.6	16.8	38.7	39.5	4.96	3.57	6.33	57.55	.63	26.96	10,620
	B		4.8	44.3	45.2	5.68	4.09	5.64	65.85	.72	18.02	12,150
	C			46.5	47.5	5.96	4.29	5.36	69.21	.76	14.42	12,770
	D			49.5	50.5		4.56	5.70	73.60	.81	15.33	13,580
10410	A	7.7	11.6	33.1	34.0	21.30	2.64	5.24	50.05	.78	19.99	9,020
	B		4.2	35.9	36.8	23.08	2.86	4.74	54.22	.84	14.26	9,770
	C			37.4	38.5	24.9	2.99	4.47	56.61	.88	10.96	10,200
	D			49.3	50.7		3.94	5.89	74.57	1.16	14.44	13,440

[1] From Stone, 1912, p. 54, 55. See sections of coal at Holwell coal bank No. 1 (p. 47) and at Miller mine (p. 48) for sample descriptions.

The following stratigraphic section shows the stratigraphic relations of the coal (unit 2) to the unconformity at the base of the upper conglomeratic part of the Lakota formation (base of unit 7). The section was measured at the easternmost of the two prospects in sec. 31, T. 48 N., R. 63 W. (pl. 1).

Part of the Lakota formation showing stratigraphic position of coal, SE¼ sec. 31, T. 48 N., R. 63 W., Weston County, Wyo.

Lakota formation (part):	Feet
7. Sandstone, light-yellowish-gray; basal 5 ft. mostly very coarse grained with seams of granule sandstone; becomes mostly medium grained in upper part; crossbedded; forms a cliff	20+
Local unconformity.	
6. Siltstone, light-gray, weathers greenish gray	1½
5. Claystone, medium-gray carbonaceous, silty in upper part	2½
4. Siltstone, light-gray	2
3. Claystone, medium-gray	2
2. Coal, black	6½
1. Sandstone, light-gray, fine- to very fine-grained, locally carbonaceous at top; forms blocky ledges	7+
Partial thickness, Lakota formation	41½

Stone (1912, p. 30) describes in the following section the coal in the bottom of Berry Canyon near the center of sec. 12, T. 47 N., R. 63 W., at about the same horizon as the coal bed shown by the section above.

Spencer prospect, south bank of ravine

	Ft.	In.
Shale, brown to black	4	
Coal, splint		9
Coal, splint, very ashy		3
Bone		11–14
Coal, bituminous, with pyrite nodules	2	2

A coal of comparable thickness to the bed reported above has been mined to a small extent in sec. 29, T. 49 N., R. 63 W., according to Stone (1912, p. 24) who gives the following section:

Coal bed in the Lakota formation at the Miller mine, sec. 29, T. 49 N., R. 63 W.

[Measured at head of drift 180 feet long. Fuel analysis 10410 (table 3), selected sample of fresh-mined cannel coal from this mine]

Roof, black sandy clay.	Ft.	In.
Shale, black with fine seams of pyrite		3
Coal, cannel, solid	1	8
Shale, black		9
Coal, cannel, solid		9
Coal, cannel and bone, in 2- to 4-in. bands	1	4
Coal, bituminous		4
Clay, black, shaly	3	
Total coal	4	3

Stone states (1912, p. 25) that the coal bed at this locality is too lenticular to have much value.

BENTONITE

The Clay Spur (or Commercial) bentonite bed, which lies at the top of the Mowry shale and crops out in the southwest corner of the quadrangle, supplies much of the high-quality bentonite used in the United States. The bed averages about 30 inches in thickness in the quadrangle, and it has been extensively mined by stripping along the outcrop. The gel strength of the bentonite is greatest in the weathered rock, and, consequently, the bed is mined only where it lies beneath less than about 20 feet of overburden (Knechtel and Patterson, 1955).

A bed of very light gray swelling bentonite that is about 35 to 40 feet stratigraphically above the base of the Belle Fourche shale has also been strip-mined in the vicinity of Clay Spur. This bentonite is 2.9 feet thick where measured in a pit three-fourths of a mile south of Clay Spur in the NW¼NW¼SW¼, sec. 31, T. 47 N., R. 63 W.

A bentonite bed about 2½ feet thick in the lower part of the Newcastle sandstone (unit 3 of the stratigraphic section on p. 32) has been mined at several places in the southwestern part of the quadrangle. Other, thinner bentonite beds crop out in the Newcastle, Mowry, and Belle Fourche formations, but have not been mined.

GYPSUM

Beds of gypsum that crop out in the lower half of the Spearfish formation are locally 10 feet thick, and a gypsum bed that makes up most or all of the Gypsum Spring formation is 5 to 15 feet thick for much of the distance along its outcrop. The gypsum may contain as much as 12 percent impurities, mostly calcium and magnesium carbonates, as shown by the analyses of 5 samples from the 2 formations given in table 4. The same 5 samples were analyzed spectrographically for 69 elements; in addition to calcium and magnesium, 10 elements were detected and are listed below (J. C. Hamilton, analyst).

Element	Abundance (percent) [1]				
	Gypsum Spring formation [2]		Spearfish formation [2]		
	271428	271429	271430	271431	271432
Sr	0.07	0.07	0.07	0.07	0.07
Si	.03	.015	.007	<.002	.07
Fe	.015	.003	<.001	<.001	.015
Al	.015	<.001	<.001	<.001	.03
Mn	.003	.0003	.0003	.0007	.007
V	.0015	.0015	.0015	.0015	.0015
Ba	.0007	.00015	.00015	.0007	.0007
Cr	.0003	.0003	.0003	.0007	.0003
Cu	.0007	.00015	.00015	<.0001	.00015
Ti	<.0002	<.0002	<.0002	<.0002	.0007

[1] Figures reported to the nearest whole number in the series 7, 3, 1.5, 0.7, 0.3, 0.15, etc., except for elements having concentrations below the amount that could be detected by the method of analyses.
[2] Geographic and stratigraphic position of samples shown in table 4.

TABLE 4.—*Chemical and calculated mineralogic composition of gypsum from the Gypsum Spring and Spearfish formations, Inyan Kara Mountain quadrangle* [1]

[Gypsum Spring formation sampled in the SW¼ sec. 12, T. 47 N., R. 62 W.; Spearfish formation sampled in the SW¼ sec. 9, T. 49 N., R. 62 W.]

A. Chemical composition (percent)

[E. J. Fennelly, G. T. Burrow, and I. C. Frost, analysts]

Sample No.	Stratigraphic position	CaO	MgO	SO_3	CO_2	H_2O at 105° C. [1]	Loss on ignition at 1000° C. [2]	Insoluble in 1:1 HCl
271428	Gypsum Spring formation, bottom part of 10-ft bed.	33.9	0.93	42.2	3.54	18.38	4.96	0.34
271429	Gypsum Spring formation, top part of 10-ft bed.	33.2	<.05	45.8	1.09	19.57	2.06	.25
271430	Spearfish formation, 3-ft bed 100 ft above base of fm.	32.9	<.05	46.4	.40	19.90	1.13	.80
271431	Spearfish formation, 11-ft bed 180 ft above base of fm.	33.2	<.05	46.4	.29	20.09	1.03	<.05
271432	Spearfish formation, 5-ft bed 235 ft above base of fm.	32.2	2.44	41.1	5.00	17.86	6.96	.94

B. Calculated mineralogic composition (percent)

Sample No.	Gypsum	Calcite	Magnesite [2]	Insoluble
271428	91	7	1	<½
271429	98	2	----------	<½
271430	99½	½	----------	<½
271431	>99½	½	----------	<½
271432	88	7	5	1

[1] Based on dried weight.
[2] Magnesium in the samples probably in the form of dolomite, but is reported as magnesite for ease in computation.

SAND AND GRAVEL

Sand and gravel have been dug for road-surfacing material from several small surficial gravel deposits in the northwest corner of the quadrangle; however, the deposits probably contain too many structurally weak sandstone and siltstone fragments to have much value for use as concrete aggregate or for other uses requiring uniform physical properties.

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