Geology of the Upton Quadrangle, Crook and Weston Counties, Wyoming

By WILLIAM J. MAPEL *and* CHARLES L. PILLMORE

CONTRIBUTIONS TO GENERAL GEOLOGY

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GEOLOGY OF THE UPTON QUADRANGLE, CROOK AND WESTON COUNTIES, WYOMING

By William J. Mapel and Charles L. Pillmore

ABSTRACT

The Upton 15-minute quadrangle includes about 215 square miles on the west side of the Black Hills in Crook and Weston Counties, Wyo.

Exposed sedimentary rocks, exclusive of surficial deposits, are about 5,900 feet thick and range in age from Late Jurassic to Late Cretaceous. Sandstone, siltstone, and shale make up most of the sedimentary sequence; limestone and bentonite are present locally. The Sundance Formation of Late Jurassic age is the oldest formation exposed. It is overlain by the Morrison Formation of Late Jurassic age, followed in turn by the Lakota, Fall River, Skull Creek, Newcastle, and Mowry Formations of Early Cretaceous age, and the Belle Fourche, Greenhorn, Carlile, Niobrara, Pierre, Fox Hills, and Lance Formations of Late Cretaceous age. The Morrison Lakota, and Lance Formations, which have an aggregate thickness of about 1,000 feet, are nonmarine; the remaining rocks are marine.

The main structural feature is the Black Hills monocline, which is a moderately steep fold that extends northwestward across the quadrangle in a slightly sinuous band 3–4 miles wide between much more gently dipping rocks to the northeast and southwest. Structural relief across the monocline is about 4,000 feet, the northeast side being uplifted relative to the southwest side. A few shallow folds, including the Thornton dome and the Pump Creek and Arch Creek anticlines, occur in the northern part of the quadrangle, and four minor faults cut rocks along the monocline.

Oil is produced from the Lakota Formation in the shallow Wind Creek oil field, and bentonite is mined from the Newcastle, Mowry, and Belle Fourche Formations.

INTRODUCTION

The Upton quadrangle includes about 215 square miles on the west side of the Black Hills in Crook and Weston Counties, Wyo. (fig. 1). It is bounded by long 104°30′ W. and 104°45′ W., and lat 44°00′ N. and 44°15′ N. The quadrangle is about 17 miles northwest of Newcastle, 10 miles east of Moorcroft, and 12 miles southwest of Sundance.

The quadrangle is in the southwestern part of the large area described by Darton (1909) in an early report on the northern part of the Black Hills. Small areas in the southeastern and southwestern

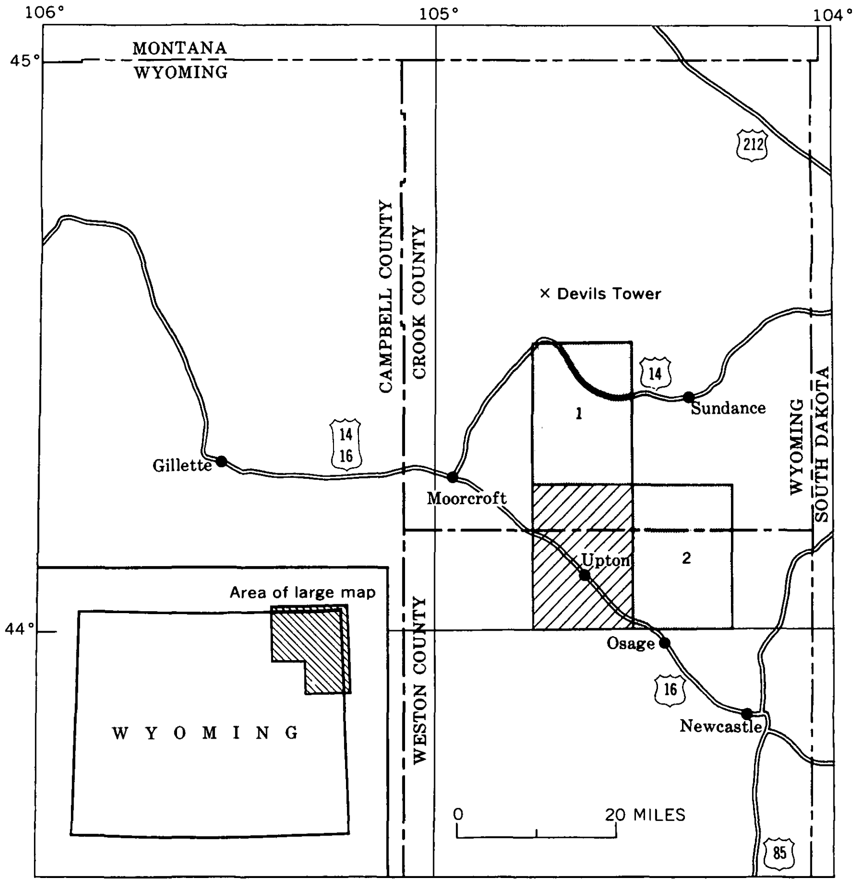

FIGURE 1.—Index map to Upton 15-minute quadrangle (crosshatched) and adjacent areas mapped by the U.S. Geological Survey in 1954–58. 1, Nefsy Divide 15-minute quadrangle (Pillmore and Mapel, 1963); 2, Inyan Kara Mountain 15-minute quadrangle (Mapel and Pillmore, 1963a).

parts of the quadrangle were mapped by Longwell and Rubey (1923) in their study of the Pump Creek anticline, and by Hancock (1920) in his study of Thornton dome and vicinity. J. C. Davis (1963, Geology of the Clay Spur bentonite district, Crook and Weston Counties, Wyoming: Univ. Wyoming M.S. thesis, Laramie, Wyo.) reviewed the history of bentonite mining near Upton, and discussed the geology of the bentonite deposits. Several other writers, notably Dobbin and Reeside (1929), Grace (1952), Haun (1958), Mapel and Gott (1959), Reeside and Cobban (1960), and Wulf (1962), described some aspects of the stratigraphy of outcropping rocks near Upton in studies of larger areas in the Black Hills and nearby regions.

Mapping for the present report was done mostly 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. Some additional mapping was done and several stratigraphic sections were measured during brief periods in the summers of 1959, 1960, and 1962.

Unpublished data by W. W. Rubey and C. R. Longwell covering their fieldwork in 1922–24 were consulted frequently during the initial stages of the work. J. R. Gill made available the results of his 1957 and 1958 studies of the lower part of the Pierre Shale along the west side of the Black Hills. R. F. Schryver helped map Lower Cretaceous rocks along Mason Creek in 1958. T. C. Nichols and L. G. Schultz made X-ray analyses, and Nichols and J. C. Thomas made physical tests on samples of bentonite.

GEOGRAPHY

Low hills, broad flats, and local areas of badlands constitute most of the land surface. A low ridge about 2 miles wide covered with pine trees trends diagonally northwestward across the middle of the quadrangle northeast of Upton; elsewhere the vegetation is mostly sagebrush and grasses native to the northern Great Plains.

Streams in the northern part of the quadrangle drain northward to the Belle Fourche River, and those in the southern part drain southeastward to the Cheyenne River. Mason Creek in the northeastern part of the quadrangle and Iron and Turner Creeks in the southeastern part are the only perennial streams.

Altitudes range from about 4,100 feet along Beaver Creek at the southeastern corner of the quadrangle to about 4,700 feet north of Mason Creek.

Upton, which had a population of about 1,200 in 1960, is near the center of the quadrangle. U.S. Highway 16 and the Chicago, Burlington & Quincy Railroad cross the quadrangle diagonally northwestward and pass through Upton. These and other roads and trails give easy access to the area.

The main industries are cattle and sheep raising, and bentonite mining. Two plants along the railroad northwest of Upton process bentonite for shipping. Some oil has been produced from the Wind Creek oil field, part of which is in the northwestern corner of the quadrangle. Some wheat and hay grow locally.

SEDIMENTARY ROCKS

Exposed sedimentary rocks in the Upton quadrangle, exclusive of surficial deposits, are about 5,900 feet thick and include strata of Late Jurassic and Cretaceous age. These rocks overlie as much as 2,800 feet of unexposed sedimentary rocks of Cambrian to Jurassic age. The distribution of the exposed rocks is shown on the geologic map (pl. 1), and a brief description of the exposed and unexposed rocks is given in table 1.

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

System	Series	Group, formation, and member		Thickness (feet)	Lithology
Cretaceous	Upper Cretaceous	Lance Formation		800+	Light-gray sandstone and dark-gray shale and sandy shale; nonmarine fossils.
		Fox Hills Sandstone		175	Light-gray and light yellowish-gray sandstone, dark-gray shale; marine fossils.
		Pierre Shale	Upper part	300	Dark-gray shale, sandy and silty near top; septarian limestone concretions that weather medium gray; marine fossils.
			Kara Bentonitic Member	90	Dark-gray bentonitic shale; some barite concretions and a few limestone concretions that weather medium gray; marine fossils.
			Middle part	900	Dark-gray shale, silty in lower part; dark-gray and grayish-red septarian limestone concretions; marine fossils.
			Mitten Black Shale Member	650	Upper part: grayish-black shale containing dark-gray and dark-red septarian limestone concretions. Lower part: dark-gray to brown hard platy shale; many bentonite beds in basal 30–40 ft in southeast part of quadrangle; marine fossils.
			Gammon Ferruginous Member	575–750	Medium- to dark-gray shale, thin sandstone and siltstone layers locally; many thin tabular dark-red siderite concretions; a few gray septarian limestone conretions in upper 50–100 ft; sparse marine fossils.
		Niobrara Formation		185–210	Marl and shale; weathers light gray and yellowish orange; several thin beds of bentonite; marine fossils.
		Carlile Shale	Sage Breaks Shale Member	290	Grayish-black shale; several beds of septarian limestone concretions that weather light gray; sparse marine fossils.
			Turner Sandy Member	185	Dark-gray shale and sandy shale; interlaminated and interbedded with light-gray siltstone and very fine grained sandstone; tan-weathering silty septarian limestone concretions; marine fossils.
			Pool Creek Shale Member	40–50	Dark-gray shale; a few silty partings; thin bentonite bed in lower part; marine fossils.
		Greenhorn Formation		75–170	In southeast part of quadrangle, dark-gray to brownish-gray calcareous and noncalcereous shale that contains thin seams of light-gray limestone and a few beds of gray septarian limestone concretions in the upper part; grades northwestward to dark-gray noncalcareous shale containing large light-gray septarian limestone concretions; marine fossils.
		Belle Fourche Shale		650–750	Grayish-black shale; dark-red siderite concretions in lower part; light-gray, tan, and yellowish-gray septarian limestone concretions in upper part; several thick bentonite beds; marine fossils in upper part.
		Mowry Shale		200–215	Siliceous light-gray shale grading to dark-gray shale in basal 15–20 ft; many bentonite beds; marine fossils.
		Newcastle Sandstone		20–50	Light-gray sandstone, brown and gray carbonaceous shale, and bentonite; marine and nonmarine fossils.

TABLE 1.—*Generalized stratigraphic section of rocks in the Upton quadrangle*—Con.

System		Series	Group, formation, and member		Thickness (feet)	Lithology
Cretaceous		Lower Cretaceous	Skull Creek Shale		185–210	Grayish-black shale; local siltstone parting sparse marine fossils.
			Inyan Kara Group	Fall River Formation	130	Brown-weathering sandstone, light- to dark-gray siltstone, and dark-gray shale; locally carbonaceous.
				Lakota Formation	100–125	Light-gray sandstone and conglomeratic sandstone; variegated sandy claystone; nonmarine fossils.
Jurassic		Upper Jurassic	Morrison Formation		80–100	Greenish-gray and grayish-red claystone and marl, some grayish-white sandstone; nonmarine fossils.
			Sundance Formation		370	Greenish-gray shale, light-gray and light yellowish-gray sandstone, pink and tan siltstone, and light-gray glauconitic limestone; divided from top to bottom into the Redwater Shale, Lak, Hulett Sandstone, Stockade Beaver Shale, and Canyon Springs Sandstone Members.
		Middle Jurassic	Gypsum Spring Formation		10±	Massive white gypsum and red claystone. May be absent locally.
Triassic			Spearfish Formation		550	Red siltstone, sandstone, and claystone; thick gypsum beds in the lower part.
Permian			Minnekahta Limestone		40	Light-gray limestone.
			Opeche Shale		100	Red siltstone.
			Minnelusa Formation		800–850	Light-gray and red sandstone, gray limestone and dolomite, red shale; gypsum and anhydrite locally.
Carboniferous	Pennsylvanian					
	Mississippian	Lower Mississippian	Pahasapa Limestone		500	Light-gray locally dolomitic limestone.
			Englewood Limestone		50	Pinkish-gray limestone.
Ordovician		Upper Ordovician	Whitewood Dolomite		50±	Light-gray to tan dolomite. May be absent in southern part of the quadrangle.
		Middle Ordovician	Winnipeg Formation		50±	Light yellowish-gray to greenish-gray siltstone and greenish-gray shale. May be absent in southern part of the quadrangle.
Cambrian		Upper Cambrian and Lower Ordovician	Deadwood Formation		300±	Mostly brown sandstone; some greenish-gray siltstone and shale, and gray limestone.
Precambrian						Metamorphic and igneous rocks.

Shale, siltstone, and sandstone make up nearly all of the sedimentary sequence; limestone and bentonite are present locally. The upper part of the Sundance Formation of Late Jurassic age is the oldest formation exposed. It is overlain by the Morrison Formation of Late Jurassic age, followed in turn by the Lakota, Fall River, Skull Creek, Newcastle, and Mowry Formations of Early Cretaceous age, and the

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Belle Fourche, Greenhorn, Carlile, Niobrara, Pierre, Fox Hills, and Lance Formations of Late Cretaceous age. The Morrison, Lakota, and Lance Formations, which have an aggregate thickness of about 1,000 feet in the quadrangle, are nonmarine; the remaining rocks are marine.

Surficial deposits of Quaternary or Recent age cover the older rocks locally and include terrace gravel, landslide material, slope wash, and alluvium.

Sedimentary rocks older than the upper part of the Sundance Formation have been penetrated by drilling at a few places in and near the quadrangle, and they are exposed nearby to the northeast. No study was made of these subsurface rocks; information about them can be found in other published reports including those by Darton (1909), Andrichuk (1955), Foster (1958), Privrasky and others (1958), McCoy (1958a, b), and Robinson and others (1964).

UPPER JURASSIC SERIES

SUNDANCE FORMATION

The oldest rocks exposed in the Upton quadrangle belong to the uppermost part of the Redwater Shale Member, which is the youngest member of the Sundance Formation. They crop out in the bottom of Dark Canyon and in one of its tributaries in sec. 11, T. 49 N., R. 64 W., and they consist of gray siltstone and greenish-gray silty shale about 30–40 feet thick capped by a bed about 5 feet thick of yellowish-gray very fine grained to silty thin-bedded calcareous sandstone. The Sundance Formation is exposed extensively in the adjacent Inyan Kara Mountain quadrangle to the east where it has a total thickness of about 370 feet, including the Redwater Shale Member which is about 165 feet thick (Mapel and Pillmore, 1963a).

Imlay (1947, p. 260–264) reported fossils of Late Jurassic age in the Redwater Shale Member of the Sundance Formation in the Black Hills.

MORRISON FORMATION

The Morrison Formation is exposed locally in Dark, Philpott, and Baker Canyons in the northeastern corner of the quadrangle. The Morrison is about 80 feet thick on the north side of Dark Canyon near the middle of sec. 11, T. 49 N., R. 64 W., and is from 80 to about 100 feet thick outside the quadrangle nearby.

The lower 60–70 feet of the Morrison Formation consists mostly of calcareous greenish-gray locally silty and sandy claystone that weathers to alternate pale-green and grayish-red bands. Interbedded with the claystone are thin beds and nodules of gray argillaceous limestone. Overlying these rocks is noncalcareous green and gray claystone that makes up the rest of the formation. In Dark Canyon and nearby to the north and east, a bed 6 feet thick of calcareous grayish-white very fine grained cross-laminated sandstone forms local ledges about 25 feet above the base of the formation. The Morrison grades downward into the underlying Sundance Formation.

The stratigraphic section on page J8 shows the lithology of the Morrison Formation and lower part of the overlying Lakota Formation in Dark Canyon.

Fossils found in the calcareous lower part of the Morrison Formation include abundant ostracodes and charophytes, a few nonmarine mollusks, and some fragments of dinosaur bones. Fossils have not been reported from the noncalcareous upper part. The age of the formation is generally regarded as Late Jurassic (Kimmeridgian and early Portlandian of Europe) (Peck, 1957, p. 8; Sohn, 1958, p. 122).

LOWER CRETACEOUS SERIES

LAKOTA FORMATION

The Lakota Formation consists of interfingering deposits of paludal and fluvial sandstone, siltsone, and claystone exposed on the floors and lower slopes of valleys tributary to Mason Creek in the northeastern corner of the quadrangle. The Lakota and the overlying Fall River Formation make up the Inyan Kara Group of Waagé (1959). Generally the Lakota supports a fairly dense growth of pine trees which contrast with grassy slopes that are more characteristic of the underlying and overlying formations. No complete sections of the Lakota were measured in the Upton quadrangle; however, the formation is about 100 feet thick a mile east of the quadrangle in sec. 24, T. 49 N., R. 64 W., and about 125 feet thick half a mile north of the quadrangle in sec. 2 of the same township.

Two parts of roughly equal thickness make up the Lakota Formation. They are separated by a disconformity that can be traced across the northeastern corner of the quadrangle and for several miles to the north and east. The lower part of the formation consists mostly of tabular-bedded locally ledge-forming sandstone interbedded with some carbonaceous siltstone and shale. The upper part is characterized at the base by conglomeratic crossbedded cliff-forming sandstone, and in the upper few feet by claystone that commonly weathers to shades of purple, red, and yellow. Small ferruginous pellets about 1 mm long locally are abundant within a few feet of the top of the Lakota.

The contact between the Lakota formation and the underlying Morrison Formation is the base of the first sandstone or carbonaceous bed above the interbedded claystone and limestone beds of the Morrison. The contact is conformable.

Some details of lithology in the Lakota Formation are shown by the graphic sections (fig. 2), and by the following partial stratigraphic section:

Lakota (part) and Morrison Formations near the middle of sec. 11, T. 49 N., R. 64 W., Crook County, Wyo.

[Loc. 1, fig. 2]

	Feet
Top of ridge.	
Lakota Formation (part):	
15. Sandstone, very light gray, very fine grained, highly silicified; makes blocky ledge	6
14. Poorly exposed; appears to be mostly grayish-white to pale-green siltstone in bottom half grading upward to pale-green silty claystone in upper half	9
13. Sandstone, very light gray, mostly fine- to medium-grained; coarse grains and granules of chert and quartzite abundant in basal few feet; friable; crossbedded; forms cliff	23
Local unconformity.	
12. Sandstone, very light gray, irregularly stained yellow, very fine grained; much carbonaceous material in thin brown laminae; in thin tabular beds; cross laminated; forms ledges	10
11. Covered	8
10. Siltstone and silty claystone, medium-gray; a few very carbonaceous brown layers; nonresistant	22
9. Siltstone and silty claystone, medium-gray to brown, carbonaceous; a few thin beds of very light gray very fine grained sandstone; nonresistant	10
Partial thickness, Lakota Formation	88
Morrison Formation:	
8. Partly covered; noncalcareous green claystone in scattered exposures	13
7. Claystone, greenish-gray and grayish-red, calcareous, silty; several thin lenticular beds of nodular light-gray argillaceous limestone	33
6. Covered	2
5. Sandstone, grayish-white, very fine grained, very calcareous, cross-laminated; makes slabby ledges a few feet above the road	6
4. Siltstone, greenish-gray, sandy, calcareous, nonresistant	5
3. Covered	21
2. Limestone, grayish-white, silty	1
Thickness, Morrison Formation	81
Sundance Formation, Redwater Shale Member (part):	
1. Siltstone, yellow, calcareous; chips of glauconitic coquina in grassy slope about 20 ft below this bed	1

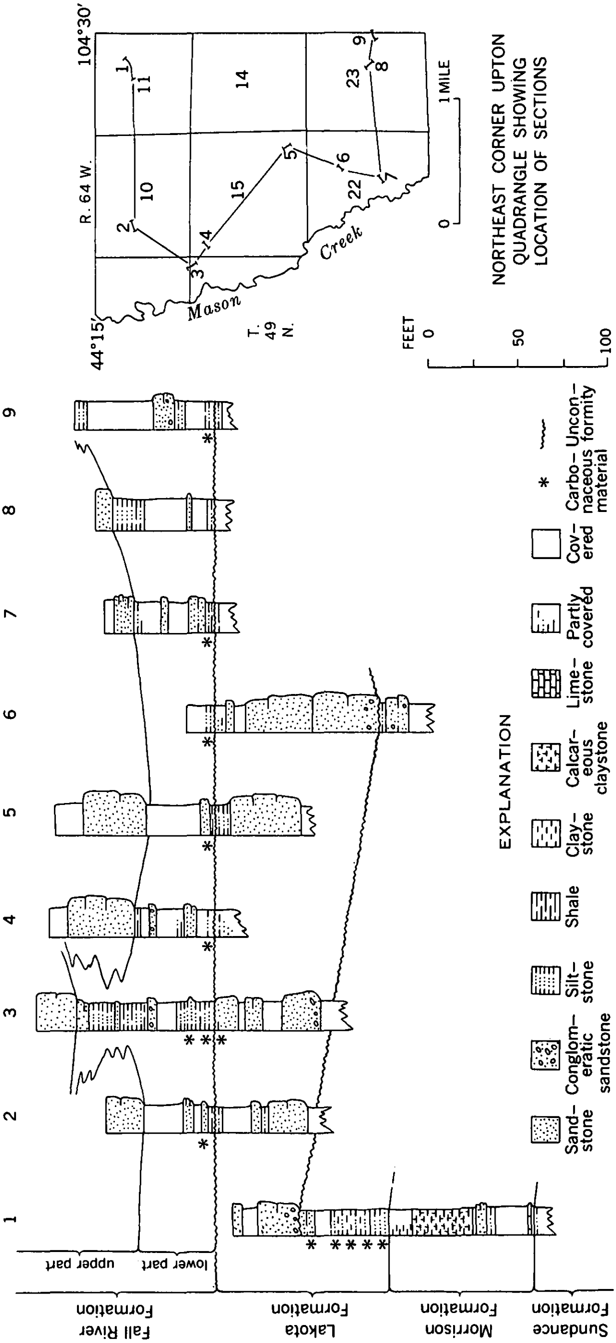

FIGURE 2.—Columnar sections of the Fall River, Lakota, and Morrison Formations, northeastern part of the Upton quadrangle.

Except for fragmentary plant remains, fossils were not found in the Lakota Formation in the Upton quadrangle; ostracodes from the lower part of the formation in the nearby Nefsy Divide quadrangle were regarded by Sohn (1958) as latest Jurassic or Early Cretaceous.

FALL RIVER FORMATION

The Fall River Formation underlies broad grassy benches and caps flat-topped, steep-sided divides on both sides of Mason Creek in T. 49 N., R. 64 W.; the upper part of the formation forms rugged ledges and cliffs along Pump Creek in the township to the south. The formation is about 130 feet thick where measured in outcrops along Highway 116 about 2 miles east of the quadrangle. It ranges from 125 to about 150 feet in thickness to the north (Bergendahl, Davis, and Izett, 1961, p. 629).

The Fall River Formation is divided into two parts on the geologic map (pl. 1). The lower part ranges in thickness from 45 to 80 feet and consists mostly of nonresistant thin-bedded light- to dark-gray siltstone interbedded with silty carbonaceous shale and a few beds of light-gray very fine grained sandstone. The siltstone and sandstone beds generally weather yellowish gray to tan. At several localities along Mason Creek, a thin blocky-weathering carbonaceous sandstone bed about 35 feet above the base of the Fall River contains coarse grains and granules of gray and brown chert in thin discontinuous seams. Carbonaceous siltstone and silty shale characterize the basal few feet of the formation and rest with a sharp, even contact on lighter colored siltstone or claystone of the underlying Lakota Formation. Regional stratigraphic relations indicate that the contact marks a widespread unconformity (Waagé, 1959, p. 13–14).

In parts of the Upton quadrangle and in the Inyan Kara Mountain quadrangle to the east (Mapel and Pillmore, 1963a), the thin-bedded sequence just described is overlain by two cliff-forming beds of friable light-gray mostly fine to very fine grained sandstone. The sandstone beds are generally 10–20 feet thick and are separated by 10–15 feet of thin-bedded sandstone and siltstone. The lower bed is the more conspicuous in outcrops in the Upton quadrangle. East of Mason Creek it forms the tops of most of the stream divides. The lower bed locally attains a thickness of at least 50 feet, and, where present in outcrops, its base marks the base of the upper part of the formation. The lower bed grades laterally into thin-bedded sandstone and siltstone near the north edge of the quadrangle in sec. 9, T. 49 N., R. 64 W., and locally at the east edge of the quadrangle in secs. 26 and 35 of the same township. In these areas where the lower bed is absent, the upper bed is thick and resistant, and its base is taken as the base of the upper part of the formation. The upper bed extends northward for several miles across the Nefsy Divide quadrangle and is continuous with the Keyhole Sandstone Member of the Fall River Formation of Davis and Izett (1958).

Thin slabby beds of sandstone interbedded with light- to dark-gray siltstone and shale constitute the upper part of the Fall River Formation above the cliff-forming units just described.

Both the upper and the lower parts of the Fall River contain abundant nodules and seams of siltstone 1 or 2 inches thick impregnated with dark-brown or reddish-brown iron oxides. Most of the thin siltstone beds in both parts of the formation are cross laminated and some are ripple marked. Other sedimentary features include the faint outlines of narrow vertical tubes alined normal to the bedding, and discontinuous sinuous grooves and other irregular markings on the bedding surfaces. These features record the activity of crawling and burrowing organisms at the time of deposition.

Some details of lithology in the Fall River Formation are shown by the graphic sections (fig. 2) and by the following partial stratigraphic section:

Parts of the Fall River and Lakota Formations, east of Mason Creek in SE¼SE¼ sec. 9 and adjacent part of the section to the south, T. 49 N., R. 64 W., Weston County, Wyo.

[Loc. 3, fig. 2]

	Feet
Top of ridge.	
Fall River Formation (part):	
Upper part:	
13. Sandstone, light yellowish-gray, mostly fine-grained to very fine grained; a few small fragments of light-gray siltstone at the base; locally slightly carbonaceous; contains a few small nodules and thin seams impregnated with dark-brown iron oxides; forms blocky ledges	24
Lower part:	
12. Sandstone, light-gray to light yellowish-gray, very fine grained; a few thin seams impregnated with dark-brown iron oxides; cross laminated, ripple marked; in beds mostly less than 1 in. thick; nonresistant	6
11. Shale and siltstone, interbedded and interlaminated; shale is dark gray to olive gray, silty; siltstone is dark to light gray, very thin bedded; a few thin seams impregnated with dark-brown iron oxides	18
10. Sandstone, very light gray, very fine grained, cross-laminated; forms ledge	½
9. Partly covered; mostly shale and siltstone as in unit 11 above	16
8. Sandstone, light-gray; weathers light yellowish gray; mostly fine-grained to very fine grained; thin layers in top one-half foot contain coarse grains and granules of chert; forms persistent blocky ledge	5
7. Covered	11
6. Siltstone, very light gray to light yellowish-gray; shaly at base	5½

Parts of the Fall River and Lakota Formations, east of Mason Creek in SE¼SE¼ sec. 9 and adjacent part of the section to the south, T. 49 N., R. 64 W., Weston County, Wyo.—Continued

	Feet
Fall River Formation (part)—Continued	
Lower part—Continued	
5. Sandstone, very light gray to light yellowish-gray, very fine grained, very carbonaceous locally; contains conspicuous vertical striations; in blocky beds about 1 foot thick; forms ledge	3
4. Shale, medium-gray, silty	5
3. Siltstone, light-gray; scattered fragments of carbonaceous material; cross laminated; forms blocky ledge	3½
2. Siltstone, light- to dark-gray, carbonaceous, locally coaly	3½
Partial thickness, Fall River Formation	101
Unconformity.	
Lakota Formation (part):	
1. Sandstone very light gray, fine-grained to very fine grained, irregularly bedded; locally forms cavernous ledge	10

Except for fragmentary plant remains, fossils are rare in the Fall River Formation, and none were found in the Upton quadrangle. The age of the formation, based on plant remains, is generally regarded as Early Cretaceous (Albian of Europe).

SKULL CREEK SHALE

The Skull Creek Shale is widely exposed on low rolling hills and in local badlands in the eastern part of the quadrangle. The formation consists mostly of grayish-black shale covered at most places by a thin dark soil that supports only a sparse growth of sagebrush and grass.

No complete sections of the formation were measured; however, the formation is at least 200 feet thick in a partial section in the NW¼ sec. 28, T. 48 N., R. 64 W. The formation has a total thickness of 210 feet near the west edge of sec. 1, T. 47 N., R. 66 W., as interpreted from the electric log of the Davis Oil Co. Federal-Materi well 1 (log corrected for estimated 30° dip of the beds), and it is 185–195 feet thick according to electric logs of wells drilled farther north in the southeastern part of T. 49 N., R. 66 W.

The Skull Creek grades downward into the Fall River Formation through an interval of 10–15 feet in which black shale is interbedded with light-gray and yellowish-gray siltstone. Above this transitional zone the Skull Creek consists of nonresistant grayish-black shale that contains a few tabular to ovoid silty red-weathering limestone cone-in-cone concretions. North of the Pump Creek anticline, a discontinuous bed of grayish-white siltstone about one-half foot thick makes a fairly prominent bench near the middle of the formation. Bedding

FIGURE 3.—Sandstone dike in the Skull Creek Shale, sec. 36, T. 49 N., R. 65 W.

surfaces of the siltstone are covered by fucoidal markings similar to those in the Fall River Formation.

The upper part of the Skull Creek Shale in and near sec. 36, T. 49 N., R. 65 W., contains numerous dikes of firmly cemented light-gray very fine grained sandstone (fig. 3). The dikes generally range in thickness from ½ to 1½ feet, dip nearly vertically, and extend laterally for distances of as much as one-quarter of a mile. The dikes are confined to the upper part of the Skull Creek within about 50 feet stratigraphically of the overlying Newcastle Sandstone; older parts of the Skull Creek that are exposed in the deeper stream valleys do not contain dikes. The principal dikes trend mainly north-south and east-west in a roughly rectilinear pattern, but a few trend northwest or northeast, and some curve slightly.

Fossils are uncommon in the Skull Creek Shale, although some Foraminifera were reported from the west side of the Black Hills by Crowley (1951, p. 83, 85), Skolnick (1958), and Eicher (1958).

NEWCASTLE SANDSTONE

The Newcastle Sandstone is well exposed at many places in a band of light-colored outcrops that extends diagonally northwestward across the central part of the quadrangle. Near the head of Tomcat

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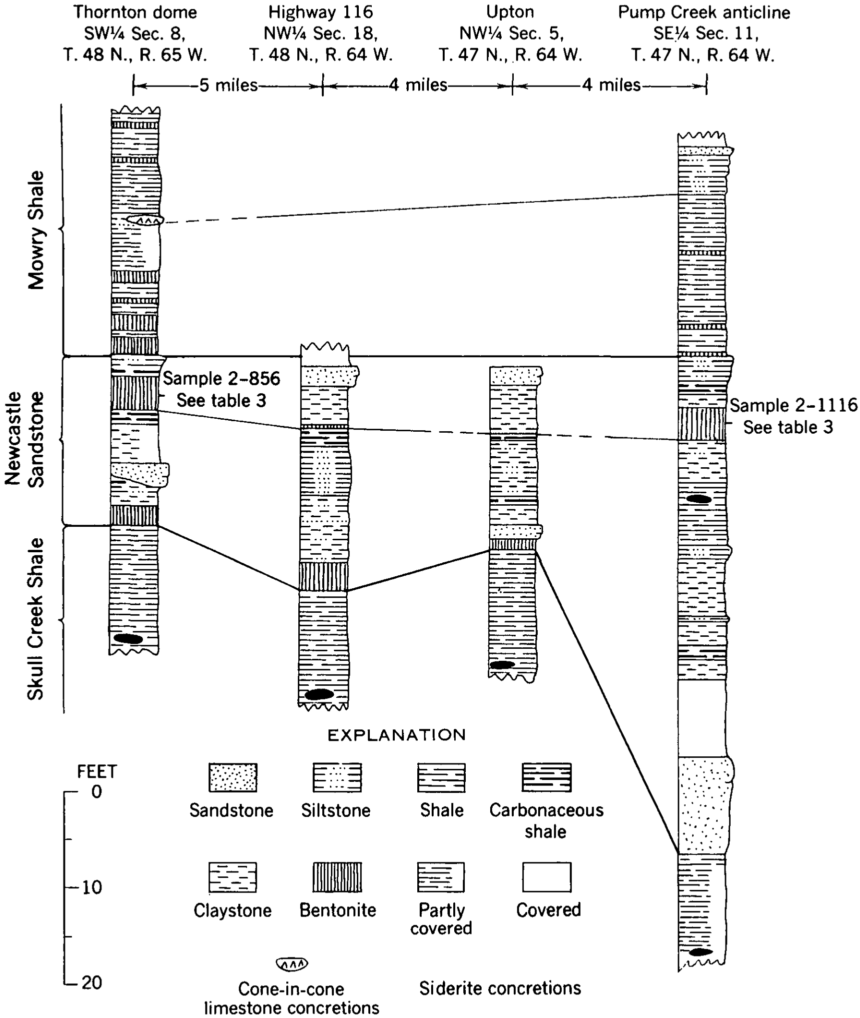

FIGURE 4.—Columnar sections of the Newcastle Sandstone and parts of adjacent formations in the Upton quadrangle.

Creek in the northern part of the quadrangle, sandstone in the formation is less resistant than usual or is missing; for several miles in this area, the formation makes no outcrop. Its position is marked by a a few patches of light-colored soil on smooth slopes or flats. The formation averages about 20 feet in thickness at most places; however, it thickens rather abruptly near Pump Creek, and in sec. 11, T. 47 N., R. 64 W., it reaches a thickness of 52 feet (fig. 4).

The Newcastle consists mostly of light- to medium-gray siltstone and silty bentonitic claystone. A resistant bed of grayish-white very fine grained sandstone 2–5 feet thick at about the top of the formation generally caps small buttes or forms broad dip slopes. Other discontinuous thin sandstone beds are present at a few places. Subordinate, but generally present, are thin beds of brown to black carbonaceous shale and one or more beds of bentonite; the bentonite has been mined locally. Figure 4 shows four sections of the Newcastle Sandstone in the quadrangle. Some details of lithology near Pump Creek where the formation is thickest are given in the following stratigraphic section:

Mowry Shale (part), Newcastle Sandstone and Skull Creek Shale (part) on the east flank of the Pump Creek anticline, SE¼ sec. 11, T. 47 N., R. 64 W., Weston County, Wyo.

	Feet
Mowry Shale (part):	
25. Sandstone, very light gray, very fine grained, calcareous, thin-bedded; weathers brown; forms slabby ledge	1. 0
24. Siltstone, very light gray, weathers brown; some interlaminated dark-gray silty shale; forms ledges	4. 0
23. Shale, black; some interlaminated light-gray siltstone	6. 0
22. Bentonite, light-gray	. 6
21. Shale, black	7. 0
20. Bentonite, light-gray	. 7
19. Shale, black	2. 3
18. Bentonite, light-gray, shaly at top	. 4
Partial thickness (rounded), Mowry Shale	22
Newcastle Sandstone:	
17. Siltstone, light-gray; interlaminated grayish-black shale; more shaly at bottom	2. 3
16. Shale, dark-brown to black, very carbonaceous, silty	1. 5
15. Claystone, light- to medium-gray, bentonitic	1. 3
14. Bentonite, light-gray, silty; grades into overlying unit	3. 6
13. Claystone, olive-gray and medium-gray, silty, bentonitic, slightly carbonaceous	4. 5
12. Shale, black; scattered dark-purplish-red siderite concretions	6. 5
11. Siltstone, very light gray, mostly nonresistant; discontinuous hard calcareous layers	1. 5
10. Claystone, medium-gray, bentonitic	1. 0
9. Shale, black, fissile	. 5
8. Claystone, olive-gray, bentonitic, locally silty	4. 5
7. Siltstone, light-gray, shaly	. 5
6. Claystone, medium-gray; silty at top	2. 5
5. Shale, dark-brown to black, very carbonaceous	1. 3
4. Claystone, medium-gray	2. 0
3. Covered	8. 0
2. Sandstone, very light gray, very fine grained; upper part hard and slabby; lower part friable and slightly carbonaceous	10. 0
Thickness (rounded), Newcastle Sandstone	52
Skull Creek Shale (part):	
1. Poorly exposed; black shale in scattered outcrops, fragments of dark-red siderite concretions in soil	15

The Newcastle is inconspicuous and not easily identified in electric logs of wells drilled in the western part of the quadrangle; in this area it apparently is thin and consists mostly of claystone or shale.

Fossils reported from the Newcastle Sandstone on the west side of the Black Hills include Foraminifera (Crowley, 1951, p. 85; Skolnick, 1958), some poorly preserved marine pelecypods (W. W. Rubey, written commun., 1954), a few dinosaur bones (Dobbin and Horn, 1949), and fragments of terrestrial plants. Baker (1962) proposed that the Newcastle was deposited on an alluvial plain, and Wulf (1962, p. 1394, 1412) regarded the Newcastle as a deltaic deposit laid down during a widespread regression of the Early Cretaceous sea. Other writers (Collier, 1922, p. 81–82; Grace, 1952, p. 20–22) suggested a shallow-water near-shore marine environment for most of the formation in the Black Hills.

MOWRY SHALE

The Mowry Shale forms a broad, low northeastward-facing escarpment that nearly bisects the quadrangle from northwest to southeast. A moderately dense growth of small pine trees distinguishes the outcrop belt from almost treeless slopes characteristic of areas underlain by the adjacent rocks. Slope wash covers the basal few feet of the Mowry at most places, but the rest of the formation generally is well exposed. The formation is about 215 feet thick in a section measured at Thornton dome in sec. 8, T. 48 N., R. 65 W.

Dark-gray to brownish-gray siliceous shale that weathers light silvery gray and forms thin brittle chips makes up most of the formation. Shale in the lower 15–20 feet is soft and weathers grayish-black. A thin bed of brown-weathering siltstone or very fine grained sandstone overlies the basal black shale in the eastern part of the quadrangle; brown-weathering silty cone-in-cone concretions occur at about the same stratigraphic position at Thornton dome in the western part of the quadrangle. (See graphic sections, fig. 4.)

Numerous bentonite beds mostly 0.1–1.5 feet thick crop out in the Mowry. At the top of the formation is a bed of bentonite called the Clay Spur Bentonite Bed (Rubey, 1931, p. 4) that commonly is about 2½ feet thick, but that is nearly 4½ feet thick north of Upton in sec. 12, T. 48 N., R. 65 W. At Thornton dome, bentonite beds in the Mowry have an aggregate thickness of 15.5 feet, or about 7 percent of the total rock in the formation.

Rubey (1929) discussed the composition and origin of the Mowry in detail. The following section illustrates the lithology of the formation.

Mowry Shale and parts of adjacent formations on the northeast side of Thornton dome, near center sec. 8, T. 48 N., R. 65 W. Weston County, Wyo.

	Feet
Top of exposure.	
Belle Fourche Shale (part):	
42. Shale, grayish-black; a bed 1.0 ft thick of light-gray bentonite 5 ft above the base; several beds of purplish-red siderite concretions	20
Mowry Shale:	
41. Bentonite (Clay Spur Bed), very light gray; forms tough popcorn-like crust where weathered	2.5
40. Covered	13±
39. Shale, dark-gray to dark brownish-gray; weathers silvery gray; forms hard brittle chips; contains fish scales and other fragmentary fish remains; dark-gray limestone concretion 20 ft long and 1½ ft thick in the lower part of this unit in stream gully nearby	30
38. Bentonite, light-gray	1.6
37. Shale, as in unit 39 above	7.0
36. Bentonite, light-gray	.2
35. Shale, dark brownish-gray	.6
34. Bentonite, light-gray	.9
33. Shale, as in unit 39 above	17
32. Bentonite, light-gray	.8
31. Shale, as in unit 39 above; exposed in scattered outcrops	44
30. Shale, as in unit 39 above	10
29. Bentonite, light-gray	.1
28. Shale, as in unit 39 above	20
27. Bentonite light-gray	.4
26. Shale, as in unit 39 above	2.0
25. Bentonite, light-gray	.1
24. Shale, as in unit 39 above	2.9
23. Bentonite, light-gray	.5
22. Shale, as in unit 39 above	5.8
21. Bentonite, light-gray	1.5
20. Shale, as in unit 39 above	8.5
19. Bentonite, light-gray	.2
18. Shale, as in unit 39 above	13.5
17. Covered	8.5
16. Shale, dark-gray; interlaminated light-gray bentonite	1.3
15. Bentonite, light-gray	.8
14. Shale, as in unit 39 above	3.0
13. Bentonite, light-gray	.4
12. Shale, as in unit 39 above	5.5
11. Poorly exposed; mostly grayish-black shale; brown-weathering cone-in-cone limestone concretions as much as 1 ft across at top	6.0
10. Bentonite, light-gray	1.3
9. Shale, black, soft	1.6
8. Bentonite, light-gray	.4
7. Shale, black, soft	1.1
6. Bentonite, light-gray; some dark-gray shale at top	1.8
5. Shale, black, hard	.5

Mowry Shale and parts of adjacent formations on the northeast side of Thornton dome, near center sec. 8, T. 48 N., R. 65 W. Weston County, Wyo.—Continued

	Feet
Mowry Shale—Continued	
4. Bentonite, light-gray; some dark-gray shale in upper part	2. 0
Thickness (rounded), Mowry Shale	215±
Newcastle Sandstone (part):	
3. Shale; mostly black in upper part: some light-tan silty laminae; local lens of siltstone half a foot thick at top; dark brown and very carbonaceous in lower part	1. 6
2. Bentonite, mostly light-gray; brownish gray in top one-half foot; forms tough popcornlike crust where weathered	3. 5
1. Shale, brownish-black, coaly	1. 5
Partial thickness (rounded), Newcastle Sandstone	6
Creek bottom.	

Reeside and Cobban (1960) summarized much of the available information on the regional stratigraphic relations of the Mowry and its fossils. Fossils other than fish remains are rare, but ammonites from a few localities in the Black Hills and nearby parts of Wyoming indicate the age is latest Early Cretaceous (late Albian of Europe) (Reeside and Cobban, 1960 p. 31).

UPPER CRETACEOUS SERIES

BELLE FOURCHE SHALE

The Belle Fourche Shale crops out on gentle slopes and flats in a band ½–3 miles wide between low ridges formed by the underlying Mowry Shale and the overlying Greenhorn Formation. The Belle Fourche–Greenhorn contact, which is drawn at the base of the main body of olive-gray or brown locally calcareous shale in the Greenhorn, occurs at successively higher stratigraphic horizons from east to west owing to lateral gradation of brown-weathering calcareous shale in the lower part of the Greenhorn Formation to black-weathering noncalcareous shale in the Belle Fourche Shale. Accordingly, the Belle Fourche, which is about 650 feet thick near Turner Creek in the southeastern part of the quadrangle, thickens at the expense of the Greenhorn to about 750 feet near Thornton dome in the west-central part of the quadrangle. The stratigraphic relations at the top of the Belle Fourche Shale are shown by the columnar sections (fig. 5).

The Belle Fourche is mostly grayish-black nonresistant shale interbedded with some light-colored bentonite. The basal 50–60 feet contains numerous very hard ovoid to tabular concretions of medium- to dark-gray slightly manganiferous siderite that weather dark purplish red and range in length from a few inches to about 3 feet. Fragments of these concretions commonly weather out so abundantly that the underlying slopes appear dark purplish red when seen from a distance.

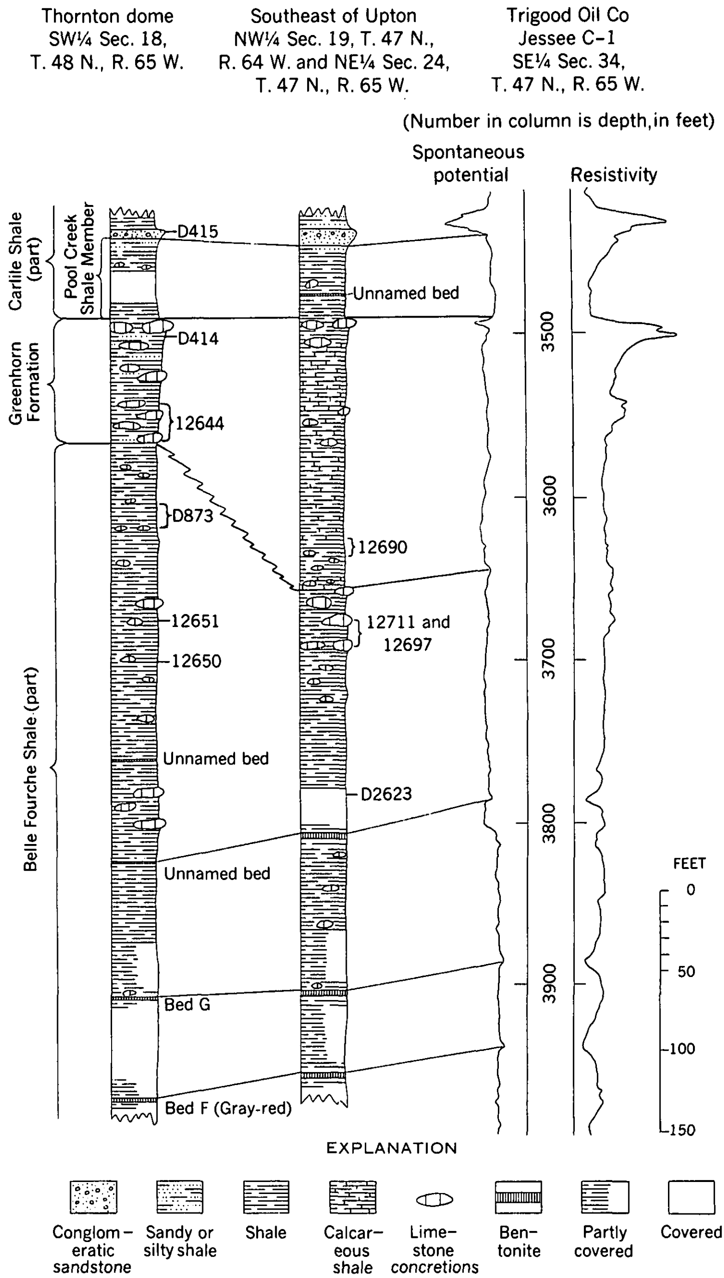

FIGURE 5.—Columnar sections and electric log of the upper part of the Belle Fourche Shale, Greenhorn Formation, and lower part of the Carlile Shale, Upton quadrangle. Jagged correlation line indicates laterally gradational beds. Numbers opposite the columns are locality numbers of fossil collections referred to in the text.

The next 200–250 feet of the formation is not well exposed in the quadrangle, but in nearby areas this part of the Belle Fourche is grayish-black shale containing a few scattered tabular silty ferruginous concretions in the upper few feet. The upper part of the formation, which is well exposed at many places on the ridge capped by the overlying Greenhorn Formation, consists of grayish-black shale 300–400 feet thick. This part contains yellow-weathering septarian limestone concretions generally 1 or 2 feet long but locally as much as 10 feet long. Small gray-weathering septarian limestone concretions and brown- and yellow-weathering cone-in-cone limestone concretions occur sparingly in the upper part of the formation.

Bentonite beds in the Belle Fourche Shale range in thickness from less than an inch to about 5 feet. The main beds include bentonite bed E about 25–35 feet above the base of the formation; bentonite bed F, also known as the gray-red bed, about 350 feet above the base; and bentonite bed G about 400 feet above the base. These beds are correlated with the bentonite beds assigned the same letters by Knechtel and Patterson (1956, 1962) at the north end of the Black Hills. Sharp decreases in resistivity mark the three beds on electric logs of drill holes, as shown on plate 1 and figure 5. Bentonite is more fully described in another part of this report.

The lithology of the Belle Fourche Shale is shown by the following two partial sections; the upper part of the formation southeast of Upton together with the overlying rocks is described on pages J23–J24.

Lower part of the Belle Fourche Shale, near center sec. 12, T. 48 N., R. 65 W., Weston County, Wyo.

	Feet
Top of hill.	
Belle Fourche Shale (part):	
10. Poorly exposed; mostly grayish-black shale; fragments of dark-red siderite concretions on slope	27
9. Bentonite (bed E), light greenish-gray to light-gray; sample 2–858 from lower part of bed is described in table 3	1.7
8. Siderite, dark-gray, very hard; weathers dark red	.2
7. Shale, grayish-black; contains scattered dark-gray siderite concretions that weather dark red; concretions mostly ½–2 ft long; stratigraphically lowest concretions about 4 ft above the base	23.5
6. Bentonite, light-gray	.1
5. Shale, grayish-black	5
4. Bentonite, light-gray	.4
3. Shale, grayish-black	2.5
Partial thickness (rounded), Belle Fourche Shale	60
Mowry Shale (part):	
2. Bentonite (Clay Spur Bed); light greenish gray in lower part grading upward to light gray; basal contact sharp; upper contact gradational within about 0.3 ft	4.4

Lower part of the Belle Fourche Shale, near center sec. 12, T. 48 N., R. 65 W., Weston County, Wyo.—Continued

	Feet
Mowry Shale (part)—Continued	
1. Shale, dark-gray; weathers medium gray; weathers to hard brittle fragments	5
Partial thickness (rounded), Mowry Shale	9

Greenhorn Formation and upper part of the Belle Fourche Shale near Thornton dome, SW ¼ sec. 18, T. 48 N., R. 65 W., Weston County, Wyo.

	Feet
Carlile Shale (part):	
Pool Creek Shale Member (part):	
14. Shale, dark-gray; a few laminae of light-gray siltstone	10
Greenhorn Formation:	
13. Shale, dark-gray; weathers medium gray and brownish gray; silty and sandy becoming more silty in upper half; lower part contains several beds of septarian limestone concretions as much as 6 ft long that weather light gray and have orange and yellow calcite veins; upper half contains at least five beds of tabular gray limestone concretions 1–3 ft thick and as much as 20 ft long. Sandy lenses 10 ft below top contain *Inoceramus fragilis* Hall and Meek, *Ptychodus whipplei* Marcou, and *Squalicorax falcatus* (Agassiz) (USGS loc. D414, fossils collected by W. J. Mapel and identified by W. A. Cobban). Concretions in lower part contain *Inoceramus fragilis* Hall and Meek, *Inoceramus* sp., *Astarte* n. sp., *Callista orbiculata* (Hall and Meek), *Lunatia* n. sp. aff. *L. concinna* Hall and Meek, and *Fasciolaria* sp. (USGS loc. 12644, fossils collected by W. W. Rubey and identified by J. B. Reeside, Jr.)	75
Belle Fourche Shale (part):	
12. Shale, light- and dark-gray in alternate bands, noncalcareous; scattered limestone concretions that weather light gray; at base, a bed of closely spaced limestone concretions mostly about 1 ft long; concretions in lower part contain *Inoceramus* sp. and *Callista orbiculata* (Hall and Meek) (USGS loc. D873, fossils collected by C. S. Robinson and identified by W. A. Cobban)	55
11. Shale, grayish-black, noncalcareous; scattered septarian limestone concretions that weather light gray, light yellowish gray, and brownish red; concretions mostly 1–2 ft long. Concretions about 50 ft below top contain *Anomis*? sp., *Callista orbiculata* (Hall and Meek), *Corbula nemstophora* Meek, *Turnus* n. sp., *Natica* (*Amauropsis*?) n. sp., "*Puzosia*" n. sp., *Acanthoceras* n. sp., *Metoicoceras whitei* Hyatt, and ammonite n. gen. n. sp. B (USGS loc. 12651, fossils collected by W. W. Rubey and identified by J. B. Reeside, Jr.). Concretions about 80 ft below top contain *Arca*? sp., *Inoceramus fragilis* Hall and Meek, *Astarte* n. sp., *Callista orbiculata* (Hall and Meek), *Natica* (*Amauropsis*?) n. sp., *Helicoceras* n. sp., *Turrilites* n. sp., "*Puzosia*" n. sp., *Acanthoceras* n. sp., *Mannites* n. sp., *Metoicoceras whitei* Hyatt, ammonite n. gen. n. sp. A, and molluscan borings in wood (USGS loc. 12650, fossils collected by W. W. Rubey and identified by J. B. Reeside, Jr.)	125

Greenhorn Formation and upper part of the Belle Fourche Shale near Thornton dome, SW ¼ sec. 18, T. 48 N., R. 65 W., Weston County, Wyo.—Continued

	Feet
Belle Fourche Shale (part)—Continued	
10. Bentonite, very light gray, slightly swelling	1.0
9. Shale, grayish-black, noncalcareous	16
8. Shale, dark-gray; weathers olive gray; calcareous in part; contains conspicuous beds of septarian limestone concretions that weather yellowish gray, have veins of yellow calcite, and are 1–2 ft thick and as much as 10 ft long	25
7. Shale, grayish-black, noncalcareous; scattered septarian limestone concretions that weather light gray and contain veins of yellow and orange calcite	20
6. Bentonite, very light gray, slightly swelling	1.2
5. Shale, grayish-black, noncalcareous	50
4. Partly covered; mostly grayish-black shale	34
3. Bentonite (bed G), pale-yellow, swelling; tabular gray- to yellow-weathering limestone concretions at the top	2.5
2. Mostly covered; some dark-gray shale in scattered exposures	65
1. Bentonite (bed F); light gray at top, pale grayish red at bottom; swelling; aragonite or fibrous calcite fragments on the surface	2.0
Partial thickness (rounded), Belle Fourche Shale	395
Base of the exposure.	

In addition to the fossils listed in the preceding stratigraphic section, a poorly preserved fragment of a very large ammonite identified by W. A. Cobban as either *Dunveganoceras albertense* (Warren) or *D. conditum* Haas was found about 175 feet stratigraphically above bentonite bed F in the NW ¼ sec. 19, R. 47 N., R. 64 W. (USGS loc. D2623). W. W. Rubey (Robinson and others, 1964) found *Pteria* aff. *P. nebrascana* (Evans and Shumard)?, *Inoceramus fragilis* Hall and Meek, *Astarte* n. sp., *Callista orbiculata* (Hall and Meek), and unidentified ammonite fragments near the top of the formation in the same vicinity (USGS locs. 12711 and 12697; fossils identified by J. B. Reeside, Jr.). Figure 5 shows the relative stratigraphic position of these collections. Nace (1941) reported bones of the ichthyosaur *Myopterygius petersoni* Nace from a locality he gave as 3 feet above the base of the formation near Upton in the SW¼ sec. 25, T. 48 N., R. 65 W.

The age of the Belle Fourche is considered earliest Late Cretaceous (Cenomanian of Europe) (Cobban, 1951, p. 2197).

GREENHORN FORMATION

The Greenhorn Formation forms the crest and upper slopes of a low northeastward-facing escarpment that extends northwestward across the quadrangle parallel to the outcrops of overlying and underlying formations. The Greenhorn ranges in thickness from about 75 feet near Thornton dome in the west-central part of the quadrangle to about 170 feet 8 miles southeast in sec. 19, T. 47 N., R. 64 W. The southeastward thickening is the result of a change in lithologic facies as already described in the discussion of the Belle Fourche Shale and as shown in figure 5.

In the southern part of the quadrangle, where the Greenhorn is thickest, the formation consists mostly of dark-gray calcareous shale but contains some interbeds of noncalcareous shale, a few thin discontinuous seams of fossiliferous brown sandy limestone, and, near the top, conspicuous beds of septarian limestone concretions as much as 5 feet across that weather light gray and contain veins of orange and brown calcite. The shale weathers mostly olive gray to brownish gray whereas shale in the underlying and overlying formations weathers grayish black.

Shale in the Greenhorn becomes less calcareous westward; northwest of Upton the Greenhorn consists of dark-gray noncalcareous shale that weathers olive gray, is locally slightly silty or sandy, and contains several beds of large gray septarian limestone concretions.

A description of the Greenhorn Formation southeast of Upton follows; the lithology of the formation near Thornton dome is described on page J21.

Carlile Shale (part), Greenhorn Formation, and Belle Fourche Shale (part) southeast of Upton, NW 1/4 sec. 19, T. 47 N., R. 64 W., Weston County, Wyo.

	Feet
Carlile Shale (part):	
Turner Sandy Member (part):	
13. Sandstone, very light gray; upper part weathers brown; mostly fine-grained to very fine grained; top 1–2 ft is coarser grained, contains many black grains, and locally numerous fish teeth and phosphatic nodules; calcareous; thin bedded; forms slabby ledges	8
Pool Creek Shale Member:	
12. Shale, dark-gray, noncalcareous; contains silty laminae which become more numerous in upper part; near middle, widely scattered silty limestone concretions that weather tan and are about 1 ft across	30
11. Bentonite, very light gray, slightly swelling; abundant fragments of calcite on surface	0.4
10. Shale, dark-gray, noncalcareous	13
Thickness (rounded), Pool Creek Shale Member	43
Partial thickness (rounded), Carlile Shale	51
Greenhorn Formation:	
9. Shale, dark-gray; calcareous in lower part, noncalcareous in upper part; at top is conspicuous bed of septarian limestone concretions that weather light gray and contain veins of orange and brown calcite	27

Carlile Shale (part), Greenhorn Formation, and Belle Fourche Shale (part) southeast of Upton, NW ¼ sec. 19, T. 47 N., R. 64 W., Weston County, Wyo. —Con.

	Feet
Greenhorn Formation—Continued	
8. Marl, dark-gray; weathers light gray; numerous thin beds of fossiliferous white-weathering limestone	29
7. Shale, dark-gray; weathers olive gray; scattered septarian limestone concretions, mostly 2–5 ft across, that weather light gray and contain veins of orange calcite	23
6. Shale, dark-gray, weathers olive gray, calcareous; forms deep gumbo soil	66
5. Shale, dark-gray, noncalcareous; lower half contains several very thin beds of brown-weathering limestone; a few yellow- to tan-weathering limestone concretions about 1 ft across	26
Thickness, Greenhorn Formation	171
Belle Fourche Shale (part):	
4. Shale, dark-gray, noncalcareous; at base and near top, conspicuous beds of closely spaced septarian limestone concretions that weather yellow, have veins of yellow calcite, and are as much as 5 ft thick and 20 ft long; a few scattered gray-weathering septarian limestone concretions that have veins of yellow calcite	40
3. Shale, grayish-black, noncalcareous; a few thin beds of cone-in-cone limestone concretions and scattered gray-weathering septarian limestone concretions containing veins of yellow calcite	90
2. Mostly covered; seems to be mostly dark-gray shale; near top, a poorly preserved fragment of cephalopod identified by W. A. Cobban as either *Dunveganoceras albertense* (Warren) or *Dunveganoceras conditum* Haas (USGS loc. D2623)	28
1. Bentonite (unnamed bed), pale yellowish-gray, slightly swelling. This bed is about 95 ft stratigraphically above bentonite bed G	2. 4
Partial thickness (rounded), Belle Fourche Shale	160

Base of the exposure.

W. W. Rubey (Robinson and others, 1964) found *Inoceramus fragilis* Hall and Meek, *Astarte* n. sp., *Metoicoceras whitei* Hyatt, and unidentified fish remains in the vicinity of the foregoing stratigraphic section at about the top of unit 5 or the base of unit 6 (USGS loc. 12690). Additional fossils from the Greenhorn are listed in the stratigraphic section, pages J21–J22, and the fossil localities are shown on figure 5.

CARLILE SHALE

The Carlile Shale consists of dark-gray shale interbedded in the lower part with minor amounts of siltstone and sandstone. The formation is 500–525 feet thick and includes, from oldest to youngest, the Pool Creek Shale Member, Turner Sandy Member, and Sage Breaks Shale Member. A sandstone bed at the base of the Turner Sandy Member generally forms a low ridge; the remainder of the formation is nonresistant.

POOL CREEK SHALE MEMBER

The Pool Creek Shale Member of the Carlile Shale, which is described in stratigraphic sections on pages J23–J24 and J26, is 40–50 feet thick and consists mostly of dark-gray noncalcareous shale. Laminae of light-gray siltstone occur in the upper half of the member and become more abundant near the top. A few septarian limestone concretions that weather light gray to tan and commonly are ½–1 foot long crop out near the middle of the member. The contact between the Pool Creek Shale Member of the Carlile Shale and the Greenhorn Formation is placed at the top of the uppermost zone of light-gray septarian limestone concretions in the Greenhorn.

The lower part of the Pool Creek Shale Member thickens southeastward beyond the quadrangle at the expense of the underlying Greenhorn Formation. A thin seam of bentonite 0.4 foot thick that is 13 feet above the base of the member in the southern part of the quadrangle in sec. 19, T. 47 N., R. 64 W., is 45 feet above the base of the member near Osage in sec. 20, T. 46 N., R. 63 W. (Robinson and others, 1964), and about 60 feet above the base of the member near Newcastle in sec. 31, T. 45 N., R. 61 W. (Mapel and Pillmore, 1963b).

Fossils collected from concretions near the middle of the member near Osage, about 5 miles southeast of the quadrangle, include *Inoceramus fragilis* Hall and Meek, *Scaphites larvaeformas* Meek and Hayden, and *Collignoniceras woolgari* (Mantell) (Robinson and others, 1964).

TURNER SANDY MEMBER

The Turner Sandy Member of the Carlile Shale is about 185 feet thick in outcrops near Thornton dome, and its thickness is about the same, as interpreted from the electric logs of drill holes, in other parts of the quadrangle. The member consists mostly of dark-gray shale interlaminated with very light gray siltstone and some thin beds of very fine grained light-gray sandstone that weathers brown. At the base of the member is a distinctive ledge-forming bed 2–6 feet thick of fine- to medium-grained calcareous sandstone that contains many granules and small pebbles of dark-gray and black chert and abundant fish teeth. A discontinuous bed 1 or 2 inches thick of chert-granule conglomerate also occurs about 120 feet above the base of the member in the southeastern part of the quadrangle in T. 47 N., R. 64 W. The remainder of the member is characterized by beds of tabular silty limestone concretions that weather yellow or yellowish gray and have veins of yellow calcite.

The following stratigraphic section shows the lithology of the Turner Sandy Member and underlying Pool Creek Shale Member of the Carlile Shale:

728–197 O—64——4

Turner Sandy Member and Pool Creek Shale Member of the Carlile Shale near Thornton dome, SW¼ sec. 18, T. 48 N., R. 65 W., Weston County, Wyo.

Carlile Shale (part):	
Sage Breaks Shale Member (part):	*Feet*
9. Shale, grayish-black; a few septarian limestone concretions that weather light gray and have veins of dark-brown and white calcite	20
Turner Sandy Member:	
8. Mostly covered. Dark-gray shale in scattered exposures; a few chips of yellowish-gray sandy limestone in float	80±
7. Shale, dark-gray; laminae and a few thin slabby beds of yellowish-gray very fine grained sandstone; scattered silty limestone concretions that weather yellowish gray; about 20 ft above base, a bed of silty limestone concretions that weather dark red	75
6. Shale, dark-gray, a few laminae of yellowish-gray very fine grained sandstone	28
5. Sandstone, very light gray, mostly fine- to medium-grained; granules and small pebbles of gray chert and black phosphatic material; calcareous; crossbedded; forms slabby ledges; contains numerous fish teeth including *Ptychodus whipplei* Marcou, *Ptychodus* sp., *Isurus appendiculata* (Agassiz), and *Squalicorax falcatus* (Agassiz) (USGS loc. D415, fossils identified by W. A. Cobban)	4
Thickness, Turner Sandy Member	185±
Pool Creek Shale Member:	
4. Shale, dark-gray, noncalcareous; a few laminae of light-gray siltstone and very fine grained sandstone; becomes very sandy in upper 3 ft; scattered septarian limestone concretions that weather light gray, have veins of yellow calcite, and are about 1 ft across	20
3. Covered	20
2. Shale, dark-gray, noncalcareous	10
Thickness (rounded), Pool Creek Shale Member	50
Greenhorn Formation (part):	
1. Shale, dark-gray, silty and sandy; weathers medium gray; at top, tabular gray-weathering limestone concretions 1–3 ft thick and as much as 20 ft long; forms hogback	10

The zones of *Scaphites warreni* Meek and Hayden and *Scaphites corvensis* Cobban are represented in fossil collections from the Turner Sandy Member near Upton (Robinson and others, 1964). The following fossils, identified by W. A. Cobban, were found about 120 feet above the base of the member in the NW¼ SW¼ sec. 19, T. 47 N., R. 64 W. (USGS loc. D3799): *Inoceramus perplexus* Whitfield, *Veniella* cf. *V. goniophora* Meek, *Gyrodes conradi* Meek, *Baculites* cf. *B. besairiei* Collignon, *Scaphites* sp. and, *Prionocyclus wyomingensis* Meek.

SAGE BREAKS SHALE MEMBER

The Sage Breaks Shale Member of the Carlile Shale is about 290 feet thick in the Upton quadrangle and consists of grayish-black shale that contains several beds of distinctive septarian limestone concretions. The concretions, most of which range from 1 to 3 feet in length, are cut by veins of coarsely crystalline white and brown calcite. The concretions weather light gray in contrast to the yellow-weathering concretions typical of the underlying Turner Sandy Member. In sec. 29, T. 47 N., R. 64 W., where the member is moderately well exposed, shale in the upper 50 feet is mostly calcareous, and shale in the remaining lower part is noncalcareous. A description of the Sage Breaks Shale Member at this locality follows:

Sage Breaks Shale Member of the Carlile Shale southeast of Upton, SW¼ sec. 29, T. 47 N., R. 64 W., Weston County, Wyo.

	Feet
Niobrara Formation (part):	
8. Marl, shaly; weathers light gray to yellow	6
Carlile Shale (part):	
Sage Breaks Shale Member:	
7. Shale, black, noncalcareous; contains abundant fish scales	5
6. Shale, grayish-black, calcareous	48
5. Shale, grayish-black; black phosphatic nodules as much as one-half inch long weathering out from near the top	40
4. Shale, grayish-black; contains seven beds of septarian limestone concretions mostly 1–3 ft long that weather light gray and contain veins of coarsely crystalline white and brown calcite and some barite; conspicuous beds of concretions at top and base; forms low ridge	45
3. Shale, grayish-black; scattered concretions like those in unit 4 about 10 ft below top	45
2. Shale, grayish-black; conspicuous bed of closely spaced concretions like those in unit 4 at top	35
1. Covered; fragments of limestone concretions like those in unit 4 in soil; base about top of Turner Sandy Member of Carlile Shale	70±
Thickness, Sage Breaks Member, Carlile Shale	290±
Bottom of shallow gully.	

Fossils are rare in the Sage Breaks Shale Member on the west side of the Black Hills, and none was found in the Upton quadrangle.

NIOBRARA FORMATION

The Niobrara ranges from 185 to 210 feet in thickness and consists mostly of nonresistant calcareous shale and marl. It is well exposed on bare slopes and in gullies north of Beaver Creek in secs. 29, 32, and 33, T. 47 N., R. 64 W.; but farther to the northwest it forms the bottoms or lower slopes of shallow northwest-trending stream valleys and is mostly covered by slope wash and alluvium. Calcareous beds in the Niobrara weather light gray, yellow, or bright orange and are easily distinguished in outcrops from gray-weathering shales of the adjacent formations.

Several thin beds of bentonite less than half a foot thick occur at the top and near the base of the Niobrara Formation, and a few platy masses of coquina consisting mostly of fragments of *Ostrea* are found locally. The contact with the underlying Sage Breaks Member of the Carlile Shale is sharp but conformable.

The following stratigraphic section was measured about 6 miles southeast of Upton and shows the sequence of beds:

Niobrara and parts of adjacent formations southeast of Upton SW¼ sec. 29, T. 47 N., R. 64 W., Weston County, Wyo.

	Feet	Feet
Pierre Shale (part):		
Gammon Ferruginous Member (part):		
15. Shale, grayish-black; weathers medium gray noncalcareous except for a zone about 5 ft thick near middle		25
14. Shale, dark-gray; weathers medium gray and brownish gray, calcareous		125
Partial thickness Pierre Shale		150
Niobrara Formation:		
13. Bentonire and shale as follows:		
Bentonite, light-gray, nonswelling	0.3	
Shale, brown-weathering noncalcareous	1.0	
Bentonite, light-gray, nonswelling	.1	
Shale, brown, noncalcareous	.1	
Bentonite, light-gray, nonswelling	.2	
Shale, dark-gray, noncalcareous	.5	
Bentonite, light-gray, nonswelling	.2	
Shale, brownish-gray-weathering, calcareous	1.0	
Bentonite, yellowish-gray, nonswelling	.2	
Total		3.6
12. Shale, grayish-black, nonclacareous; abundant fish scales		3
11. Shale, tan-weathering, very calcareous		9
10. Bentonite, light-gray, nonswelling		.1
9. Shale and marl, tan-weathering, very calcareous		23
8. Shale, grayish-black, noncalcareous; bed 0.2 ft thick of light-gray bentonite near middle		1
7. Marl; weathers tan and orange; contains *Ostrea* concentrated in a few thin platy masses; thin beds of grayish-black noncalcareous shale in top 15 ft		163
6. Bentonite, light-gray, nonswelling		.1
5. Marl; weathers tan and orange		1
4. Bentonite, light-gray, nonswelling		.1
3. Marl; weathers tan and orange; sharp contact with underlying unit		6.5
Thickness (rounded), Niobrara Formation		210

Niobrara and parts of adjacent formations southeast of Upton SW¼ sec. 29, T. 47 N., R. 64 W., Weston County, Wyo.—Continued

	Feet
Carlile Shale (part):	
Sage Breaks Shale Member (part):	
2. Shale, grayish-black, noncalcareous; abundant fish scales	5
1. Shale, grayish-black, calcareous	10
Partial thickness, Sage Breaks Shale Member, Carlile Shale	15

Except for the masses of *Ostrea* already noted and for locally abundant fish scales and bones, identifiable fossils are rare in the Niobrara Formation, and none was found in the Upton quadrangle.

PIERRE SHALE

The Pierre Shale consists mostly of dark-gray shale that crops out on grass- and sagebrush-covered flats and low hills in a northwestward-trending band 1–2 miles wide in the southwestern part of the quadrangle. The formation is about 2,575 feet thick as interpreted from the electric logs of wells drilled in T. 47 N., Rs. 65 and 66 W.

The Pierre Shale has been divided into several members along the west side of the Black Hills (Rubey, 1931, p. 4; Robinson and others, 1959; Gill and Cobban, 1962.) Subdivisions recognized near Upton are, in ascending order, the Gammon Ferruginous Member at the base, the Mitten Black Shale Member, an unnamed middle part, the Kara Bentonitic Member, and an unnamed upper part. These five parts are distinguished by the different appearance of the shale on weathering, differences in the concretions in the several parts, and the presence or absence of silty beds or bentonite. The Gammon Ferruginous Member and the Kara Bentonitic Member are well exposed locally, and areas underlain by these members generally appear as conspicuous light-colored bands on aerial photographs. Soil and slope wash cover the other parts of the formation at most places.

GAMMON FERRUGINOUS MEMBER

The Gammon Ferruginous Member of the Pierre Shale has a maximum thickness in the quadrangle of about 755 feet in outcrops in sec. 32, T. 47 N., R. 64 W. Farther west it is 575 feet thick in the Trigood Oil Co. Jessee C–1 well in sec. 34, T. 47, N., R. 65 W.; and it is 650 feet thick in the Delta-Continental Oil Co. David Nolan 1 well in sec. 24, T. 47 N., R. 66 W., as interpreted from the electric logs of the two wells.

The Gammon consists mostly of dark- to medium-gray noncalcareous shale that weathers medium to light gray. Some of the shale is silty, and, locally, thin lenses of very fine grained glauconitic sandstone crop out near the middle of the member. Soil formed on the Gammon generally is thin and noticeably lighter in color than soils on the adjacent units. The member is characterized by many beds of closely spaced tabular ferruginous concretions that weather orange red to dark red and generally are from 1–6 inches thick and several yards long. Gray-weathering septarian limestone concretions mostly 1–2 feet long occur in the top 50–75 feet. This part of the Gammon forms the crest of a low ridge at many places. The basal 100 feet of the Gammon is calcareous gray shale that lacks ferruginous concretions and appears to grade downward into the underlying Niobrara Formation. The contact with the Niobrara is mapped at the top of a thin zone of bentonite beds that approximately mark the upper limit of yellow-weathering chalky shale in the Niobrara.

The following measured section shows some details of lithology in the Gammon Ferruginous Member south of Upton:

Gammon Ferruginous Member of the Pierre Shale southeast of Upton, SW¼ sec. 29, T. 47 N., R. 64 W., Weston County, Wyo.

	Feet
Pierre Shale (part):	
Mitten Black Shale Member (part):	
12. Bentonite; light gray at base, grades to pink in upper part; selenite crystals in middle part	4.0
Gammon Ferruginous Member:	
11. Poorly exposed; appears to be mostly dark-gray shale; weathers to light-gray clayey soil; contains several beds of septarian limestone concretions that weather light gray and contain veinlets of brown, orange, and yellow calcite; fragments of *Baculites* sp. in soil	40
10. Mostly covered; appears to be mostly dark-gray shale; weathers to light-gray soil containing many fragments of dark-red ferruginous concretions	310
9. Sandstone, light-gray, very fine grained to silty, calcareous, glauconitic; forms local ledge	2
8. Shale, dark-gray; weathers light to medium gray; noncalcareous; several beds of tabular ferruginous concretions	95
7. Sandstone, light-gray, very fine grained to silty, calcareous, glauconitic; lenticular; forms local ledge	3
6. Shale, dark-gray; weathers light to medium gray; noncalcareous; contains many concretionary layers of ferruginous limestone or siderite mostly 1–6 in. thick and 3–5 ft apart; concretionary layers weather medium to dark red; unit weathers to gumbo soil nearly bare of vegetation	180
5. Shale, dark-gray; weathers light to medium gray; noncalcareous except for a zone about 5 ft thick near middle	25
4. Shale, brownish-gray to dark-gray; weathers mostly medium gray but has a few tan bands; calcareous	95
Thickness, Gammon Ferruginous Member, Pierre Shale	750

Gammon Ferruginous Member of the Pierre Shale southeast of Upton, SW¼ sec. 29, T. 47 N., R. 64 W., Weston County, Wyo.—Continued

	Feet
Niobrara Formation (part):	
3. Shale, dark-gray and brownish-gray, mostly calcareous; contains 5 beds of bentonite, each 0.1–0.2 ft thick	3. 5
2. Shale, grayish-black, noncalcareous	3
1. Shale; weathers yellowish orange; very calcareous	9
Partial thickness (rounded), Niobrara Formation	15

In the preceding section, the two thin sandy beds in the upper part of the member (units 7 and 9) are approximately at the stratigraphic position of the Groat Sandstone Bed as described by Rubey (1931, p. 4) and by Robinson and others (1959, p. 106–107); however, neither of the beds appear to persist along the outcrop for more than a few hundred feet.

Fossils were not found in the Gammon Ferruginous Member except for a few indeterminate fragments of Baculites. In other parts of the Black Hills the Gammon contains the index fossil *Scaphites hippocrepis* (DeKay), which also occurs in the Eagle Sandstone and Telegraph Creek Formation of southern Montana.

MITTEN BLACK SHALE MEMBER

The Mitten Black Shale Member of the Pierre Shale consists of several hundred feet of dark-weathering shale that crops out in a line of low hills and ridges between the underlying Gammon Ferruginous Member and the overlying, somewhat less resistant, unnamed shale unit, the middle part. Exposures are too poor for accurate thickness measurements of the Mitten Black Shale Member; however, electric logs of drill holes indicate that the Mitten is about 650 feet thick in the subsurface in T. 47 N., R. 65 W., and adjacent areas.

In the southeastern part of the quadrangle, the basal part of the Mitten Black Shale Member contains a zone about 35 feet thick of interbedded bentonite and shale; this zone is exposed intermittently from the south edge of the quadrangle northwestward for about 5 miles to sec. 22, T. 47 N., R. 65 W. The bentonite beds appear to be absent farther to the northwest. Similarly in the subsurface bentonite beds at the base of the Mitten are shown by a sharp decrease in resistivity in the electric log of the Trigood Oil Co. Jessee C–1 well in sec. 34, T. 47 N., R. 65 W. (depth 2,185–2,200 ft), but no such indication of bentonite can be seen at this position on the electric log of the Delta-Continental Oil Co. David Nolan 1 well which is 5 miles away in sec. 24, T. 47 N., R. 66 W. Because of the poor exposures, it is not clear if the bentonite beds thin and grade into shale northwestward or if the bentonite zone is truncated beneath an unconformity in the lower part of the Mitten.

Overlying the bentonite zone is about 100 feet of dark-gray shale that weathers to thin brittle chips and contains much organic material including fish scales and bones. These beds are succeeded by 200–300 feet of dark brownish-gray shale that contains small red-weathering ferruginous concretions. The rest of the member is soft grayish-black shale containing many dark-gray septarian limestone concretions that weather dark reddish orange. *Baculites gilberti* Cobban and *Inoceramus subcompressus* Meek and Hayden are abundant in concretions in the upper part of the member in the SE¼ SW¼ sec. 24, T. 48 N., R. 66 W. (USGS loc. D3712); and *Baculites perplexus* Cobban and *Inoceramus subcompressus* are found in concretions at the top of the member in the SW¼ SW¼ sec. 30 of the township to the west (USGS loc. D3798). The fossils were identified by W. A. Cobban.

The bentonite sequence at the base of the Mitten and the overlying 100 feet or so of dark brittle-weathering shale connect southward with the Sharon Springs Member of the Pierre Shale as recognized in the southern and eastern parts of the Black Hills. The bentonite zone near Upton can be traced intermittently southward into the Pedro Bentonite Bed in the Osage-Newcastle area and from there to the southern end of the Black Hills where the zone includes the Ardmore Bentonite Bed of Spivey (1940) (J. R. Gill, oral communication, 1960). The bentonite zone at the base of the Mitten also crops out in northern Crook County, Wyo., and in adjacent parts of southern Montana and western South Dakota. In these areas, Knechtel and Patterson (1955; 1962, p. 990–992) refer to the sequence of interbedded bentonite and shale collectively as bentonite bed I.

MIDDLE PART

The middle part of the Pierre Shale is about 900 feet thick in the Upton quadrangle. It consists mostly of dark-gray shale, and it lies between the underlying Mitten Black Shale Member and the overlying Kara Bentonitic Shale Member of the Pierre. Few outcrops of the middle part of the Pierre were seen. Near Osage, however, the lower 200–300 feet is distinguished from the adjacent beds of the Pierre by being slightly silty or sandy; in areas along the west side of the Black Hills, south of the Upton quadrangle, these silty beds have been called the Red Bird Silty Member of the Pierre Shale (Gill and Cobban, 1962). Overlying the silty beds and making up the rest of the middle part of the Pierre is dark-gray shale containing gray-weathering limestone concretions and, in the upper part, some red-weathering limestone concretions.

KARA BENTONITIC MEMBER

The Kara Bentonitic Member of the Pierre Shale is a sequence of gray shale and gray bentonitic shale about 90 feet thick. Outcrops of the member typically weather to a band of light-gray gumbo soil on which little or no vegetation grows. The basal 20–30 feet of the member consists of gray shale that contains scattered gray-weathering limestone concretions. This unit grades upward into 40–60 feet of light-gray bentonitic shale and shaly bentonite that swells and flows on weathering. Abundant barite nodules 1 or 2 inches long weather out from the bentonitic sequence, and a few gray-weathering limestone concretions are also scattered throughout. The upper 25 feet of the member is much less bentonitic. The top of the member is the base of a prominent ridge-forming bed of gray-weathering septarian limestone concretions generally 3–4 feet long that characterize the overlying shale. *Baculites eliasi* Cobban is locally abundant in the Kara Bentonitic Member.

The following section, which was measured 6 miles west of the quadrangle, shows the lithology and fossil content of the Kara Bentonitic Member and the adjacent parts of the Pierre.

Kara Bentonitic Member, upper part, and middle part of Pierre Shale, 1½ miles south of Kara in the NW¼ sec. 2, T. 48 N., R. 67 W., Weston County, Wyo.

[Fossils indentified by W. A. Cobban]

	Feet
Fox Hills Sandstone (part):	
9. Sandstone and shale, interbedded; sandstone is very light gray; weathers light yellowish gray; is fine grained, and is in beds as much as 1 ft thick; thicker beds are calcareous and form slabby ledges; shale is dark gray, noncalcareous, slightly sandy; forms ridge	50+
Pierre Shale (part):	
Upper part:	
8. Shale, dark-gray; weathers medium gray; noncalcareous; lower half poorly exposed; upper half contains several beds of dark-gray limestone concretions that weather light gray and are from 1 to 4 ft long; some concretions are septarian with veins of orange and brown calcite; a few laminae of fine-grained sandstone in upper 20 ft. Concretions within upper 50 ft contain *Nucula cancellata* Meek and Hayden, *Yoldia evansi* (Meek and Hayden), *Idonearca shumardi* (Meek and Hayden), *Gervillia* sp., *Inoceramus balchi* Meek and Hayden, *Inoceramus* n. sp., *Pteria linguaeformis* (Evans and Shumard), *Pteria* (*Oxytoma*) *nebrascana* (Evans and Shumard), *Ostrea* sp., *Pecten* (*Synclyclonema*) *halli* Gabb, *Pecten nebrascensis* Meek and Hayden, *Anomia* sp., *Crenella elegantula* (Meek and Hayden), *Protocardia subquadrata* (Evans and Shumard), *Cuspidaria moreauensis* (Meek and Hayden), *Dentalium* sp., *Ellipsoscapha minor* (Meek and Hayden), *Baculites grandis* Hall and Meek, and *Discoscaphites* n. sp. (USGS locs. D407, D435, and D437). Concretions about 125 ft below top contain *Idonearca shumardi* (Meek and Hayden), *Inoceramus* sp., *Protocardia subquadrata* (Evans and Shumard), *Baculites* cf. *B. baculus* Meek and Hayden, and *Discoscaphites* n. sp. (USGS loc. D434)	230

Kara Bentonitic Member, upper part, and middle part of Pierre Shale, 1½ miles south of Kara in the NW¼ sec. 2, T. 48 N., R. 67 W., Weston County, Wyo.—Con.

	Feet
Pierre Shale (part)—Continued	
Upper part—Continued	
7. Shale, dark-gray; weathers medium gray; noncalcareous; upper and lower parts contain conspicuous beds of dark-gray limestone concretions that weather light gray; a few scattered limestone concretions in middle that weather light gray; concretions at base as much as 6 ft long. Concretions in basal 35 ft contain *Nucula cancellata* Meek and Hayden, *Yoldia evansi* (Meek and Hayden), *Inoceramus* (*Endocostea*) *typicus* (Whitfield), *Pteria* (*Oxytoma*) *nebrascana* (Evans and Shumard), *Lucina occidentalis* (Morton), *Dentalium* sp., *Baculites eliasi* Cobban, and *Acanthoscaphites* n. sp. (USGS locs. D406 and D433)	70
Thickness upper part	300
Kara Bentonitic Member:	
6. Shale, dark-gray, slightly silty, slightly bentonitic locally; weathers dark gray to dark olive gray; contains a few scattered limestone concretions like those in unit 7 above. Concretions contain *Inoceramus* n. sp., *Lucina subundata* Hall and Meek, *Protocardia subquadrata* (Evans and Shumard), *Baculites eliasi* Cobban, and *Acanthoscaphites* n. spp. (USGS locs. D405 and D432)	25
5. Bentonite and bentonitic shale; bentonite is yellowish gray, shale is dark gray; middle part more shaly than upper and lower parts and contains scattered dark-gray limestone concretions like those in unit 7; a few fragments of barite on slopes; unit forms bare slopes on which bentonite swells and flows. Concretions near middle contain *Inoceramus* cf. *I. subcircularis* Meek, *Inoceramus* n. sp., *Lucina subundata* Hall and Meek, *Baculites eliasi* Cobban, and *Acanthoscaphites* n. sp. (USGS locs. D404 and D431)	38
4. Shale, dark-gray; weathers dark olive gray; noncalcareous; slightly bentonitic locally; contains a few dark-gray limestone concretions that weather light gray and are 1–2 ft long	13
3. Shale, dark-gray, weathers dark olive gray, noncalcareous; contains a few scattered dark-gray limestone concretions that weather light gray and are about 1 ft long; a few nodules and small concretions as much as 1 ft long of calcite and fibrous barite; limestone concretions contain *Inoceramus* sp., *Lucina occidentalis* (Morton), and *Baculites eliasi* Cobban (USGS loc. D403)	17
Thickness Kara Bentonitic Member	93
Middle part (part):	
2. Shale, very dark gray; weathers dark gray to black; noncalcareous; contains several beds of dark-gray limestone concretions that weather dark red and are about 1–3 ft long; a few scattered limestone concretions that weather light gray	80

Kara Bentonitic Member, upper part, and middle part of Pierre Shale, 1½ miles south of Kara in the NW¼ sec. 2, T. 48 N. R. 67 W., Weston County, Wyo.—Con.

	Feet
Pierre Shale (part)—Continued	
Middle part (part)—Continued	
1. Shale, dark-gray; weathers medium gray; noncalcareous; contains a few dark-gray limestone concretions that weather light gray. Concretions near top contain *Micrabacia*? sp., *Nuculana bisulcata* (Meek and Hayden), *Idonearca shumardi* (Meek and Hayden), *Nemodon* sp., *Yoldia evansi* (Meek and Hayden), *Inoceramus* cf. *I. barabini* Morton, *Inoceramus* cf. *I. balchi* Meek and Hayden, *Pteria linguaeformis* (Evans and Shumard), *Pecten nebrascensis* Meek and Hayden, *Crenella elegantula* (Meek and Hayden), *Periploma* sp., *Cuspidaria* cf. *C. ventricosa* (Meek and Hayden), *Thetis*? *circularis* (Meek and Hayden), *Protocardia subquadrata* (Evans and Shumard), *Anomia* sp., *Ellipsoscapha occidentalis* (Meek and Hayden), *Anisomyon* sp., *Drepanochilus nebrascensis* (Evans and Shumard), *Baculites eliasi* Cobban, *Discoscaphites*? sp., and *Acanthoscaphites* n. sp. (USGS locs. D402 and D429)	20
Partial thickness, middle part	100
Partial thickness, Pierre Shale	493

Base of exposure on grassy slope.

UPPER PART

The upper part of the Pierre Shale is mostly dark-gray shale and is about 300 feet thick. The unit contains several beds of gray septarian limestone concretions that have veins of orange and brown calcite. A few laminae of light-gray very fine grained sandstone and siltstone are interbedded with the shale in the upper 20–50 feet. *Baculites eliasi* Cobban in the lower beds and *Baculites baculus* Meek and Hayden and *B. grandis* Hall and Meek in the upper beds characterize the upper part of the Pierre above the Kara Bentonitic Member near Upton. A section of the upper part of the Pierre showing the lithology and fossil content 6 miles west of the Upton quadrangle is given with a description of the underlying Kara Bentonitic Member in the foregoing stratigraphic section.

Gray limestone concretions in roadcuts near the top of the Pierre Shale in the SW¼ sec. 8, T. 47 N., R. 65 W., yielded the following fossils, identified by W. A. Cobban (USGS loc. D395): *Nucula cancellata* Meek and Hayden, *Yoldia evansi* (Meek and Hayden), *Idonearca shumardi* (Meek and Hayden), *Indoceramus barabini* Morton, *Anomia agrentaria* Morton, *Anomia* sp., *Ellipsoscapha occidentalis* (Meek and Hayden), *Baculites grandis* Hall and Meek, and *Discoscaphites* n. sp. Other fossils, collected by W. W. Rubey from near the top of the Pierre Shale in the NE¼ sec. 35, T. 47 N., R. 65 W., were listed by Robinson and others (1964).

FOX HILLS SANDSTONE

The Fox Hills Sandstone forms a low grassy ridge that stands about 100 feet above adjacent outcrops of the less resistant Pierre Shale. The formation occupies a band a few hundred feet to about half a mile wide, and like the outcrop band of the underlying Pierre Shale, it trends northwestward. The Fox Hills is very poorly exposed, and no measurements were made of its thickness. According to Dobbin and Reeside (1929, p. 18–19), the formation is 125 to about 200 feet thick a few miles northwest of Upton. Barnett (1915, p. 104) reported a thickness of 186 feet in T. 48 N., R. 66 W., a short distance west of the Upton quadrangle.

Where exposed in areas near the Upton quadrangle, the Fox Hills is mostly light-gray to light yellowish-gray fine-grained to very fine grained friable sandstone interbedded at the base and in the upper part with gray sandy shale. Sandstone beds in the lower part of the formation contain distinctive brown-weathering sandstone concretions commonly 1 or 2 feet thick and several feet long. The basal part of the Fox Hills Sandstone is transitional with the underlying Pierre Shale through an interval of about 20–30 feet.

Fossils are scarce in the Fox Hills on the west side of the Black Hills; however, Dobbin and Reeside (1929, p. 18) reported *Halymenites major* Lesquereux (now called *Ophiomorpha major*) in a bed of white sandstone at the top of the formation about 7 miles northwest of Upton. They stated (p. 18) that marine fossils also were collected from the lower part of the Fox Hills Sandstone in the same vicinity.

W. W. Rubey (Robinson and others, 1964) found the following fossils near the top of the formation in the NE¼ sec. 12, T. 47 N., R. 66 W. (USGS loc. 11924; fossils identified by J. B. Reeside, Jr.): *Nucula* sp., *Yoldia evansi* (Meek and Hayden), *Veniella humilis* (Meek and Hayden), *Tellina scitula* Meek and Hayden, *Dentalium* sp., *Fusus newberryi* Meek and Hayden, *Ellipsoscapha subcylindrica* (Meek and Hayden), *Discoscaphites* sp., and fish vertebrae.

LANCE FORMATION

The Lance Formation occupies an area of grassy knolls and ridges of moderate relief in the southwestern corner of the quadrangle. The formation is poorly exposed except for a few concretionary sandstone ledges on some of the hillsides, and in small areas of badlands at the heads of a few gullies. A thickness of about 800 feet is assigned to the Lance within the quadrangle. This amount represents somewhat more than half of the formation; the rest crops out beyond the quadrangle to the southwest.

The Lance consists of lenticular beds of light-gray friable fine-grained sandstone interbedded with gray siltstone, mudstone, and claystone. Some of the beds are carbonaceous, and generally there are one or more thin beds of brown carbonaceous shale at the base of the formation. Calcite-cemented concretionary sandstone masses are common in the sandstone beds; some are almost spherical and 1 or 2 feet in diameter, and others are loglike masses several feet long. The contact of the Lance with the underlying Fox Hills is gradational and is placed at the transition from marine rocks in the Fox Hills to nonmarine rocks in the Lance.

Fossils are scarce in the Lance; however, Dobbin and Reeside (1929, p. 18) reported finding dinosaur bones within about 50 feet of the base of the formation a few miles northwest of Upton. The Lance is latest Cretaceous.

QUATERNARY SYSTEM

TERRACE DEPOSITS

Stream terrace deposits consisting of silt, sand, and gravel cap small buttes at four places between Arch and Mason Creeks in the northeastern corner of the quadrangle (secs. 8, 16, 21, and 22, T. 49 N., R. 64 W.). Terrace gravels also form a thin veneer on the tops of three small hills between Turner and Iron Creeks in the southeastern corner (sec. 26, T. 47 N., R. 64 W.). The deposits at all these places lie about 180 feet above the nearby main streams. In all the deposits the gravels consist mostly of chert and fragments of sandstone and siltstone cemented with iron oxides. The coarsest fragments are mostly 1 or 2 inches long. The base of the deposits is not exposed, but it is estimated that the maximum thickness is less than 10 feet in the northern deposits, and probably less than 5 feet in the southern deposits.

In other parts of the Black Hills, terraces at about the same level relative to the modern drainage as the ones in the Upton quadrangle have been assigned a Quaternary age on the basis of the regional physiographic relations (Alden, 1932; Knechtel and Patterson, 1962, p. 933).

LANDSLIDE MATERIAL

Landslide material covers an area about half a mile long and several hundred feet wide along the face of a ridge capped by the Lakota Formation in sec. 11, T. 49 N., R. 64 W. The slide consists of parts of the Lakota and underlying Morrison Formations, which have moved downward over the Redwater Shale Member of the Sundance Formation.

SLOPE WASH

Deposits of slope wash consisting of locally derived silt and clay that have accumulated on hillsides and in the bottoms of broad valleys are extensive enough to be shown on the geologic map (pl. 1) at two places. One place is near the headwaters of Tomcat Creek in T. 49 N., R. 65 W., and the other is near the junction of Pine and Spring

Creeks in T. 47 N., R. 64 W. At both places the deposits cover about a square mile and consist of detritus from the lower part of the Mowry Shale that has washed down over the Newcastle Sandstone and part of the Skull Creek Shale. The thickness of the slope wash is probably no more than a few feet.

ALLUVIUM

Alluvium consisting mostly of fine-grained sand, silt, and clay borders the large streams in the quadrangle. The most extensive deposits, and the only ones mapped (pl. 1), form nearly level tracts a few hundred feet wide in the valleys of Beaver Creek and its tributaries in the southern part of the quadrangle and in the valleys of Mason and Little Piney Creeks in the northern part. Beaver Creek occupies a narrow trench cut as much as 10 feet below the top of the bordering alluvium; thickness of the alluvium is unknown. The channels of Mason and Little Piney Creeks are less deeply intrenched in the alluvial deposits.

STRUCTURE

The Upton quadrangle is on the west side 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 exposed on the west side of the Black Hills dip southwestward into the Powder River Basin, a structural depression that occupies at least 15,000 square miles in Wyoming and Montana.

Structural details in the Upton quadrangle are shown on plate 1 by a cross section and by structure contours drawn at intervals of 100 feet on the top of the Fall River Formation. The main structural feature is the steep Black Hills monocline, which extends northwestward in a band 3–4 miles wide and separates much more gently dipping rocks in areas to the northeast and southwest. A few shallow folds occur in the northeastern part of the quadrangle, and four minor faults were mapped along the monocline.

The structural relief within the quadrangle is nearly 6,000 feet, the structurally highest point being in the northeastern part and the lowest point in the southwestern part.

The uplift of the Black Hills and the folding that resulted in the structural configuration shown on plate 1 is generally regarded as of early Tertiary age.

FOLDS

Black Hills monocline.—The Black Hills monocline is a sharp flexure that marks the east edge of the Powder River Basin, or the west edge of the Black Hills uplift. It extends from the vicinity of Newcastle northwestward across Weston and Crook Counties to the Wyoming-Montana boundary, a distance of about 60 miles.

In the Upton quadrangle the monocline is a well-defined fold 3–4 miles wide that has a slightly sinuous trace along which rocks on the northeast are sharply elevated nearly 4,000 feet relative to the same rocks on the southwest. The upturned edges of formations, ranging from the upper part of the Belle Fourche Shale to the Fox Hills Sandstone, crop out along the flank of the monocline. Beds in the Pierre Shale locally dip about 30° in the steepest part of the fold. Younger rocks on the southwest side of the monocline flatten abruptly away from the fold, and older rocks on the northeast side flatten slightly less abruptly.

Thornton dome and nearby folds.—Thornton dome is a sharply folded, elongated dome about 3 miles long and 1½ miles wide on the crest of the Black Hills monocline 4 miles northwest of Upton. The axis of the dome trends northwest parallel to the strike of the monocline in this vicinity. The Skull Creek Shale makes a hill in the center of the fold; the Mowry Shale, which dips 10°–15° away from the crest, forms a low ridge that clearly outlines the structure. The southwest flank of the dome merges with the Black Hills monocline, but elsewhere dips at the edge of the dome flatten abruptly in the basal part of the Belle Fourche Shale. The structural closure is about 400 feet.

A narrow structural terrace in the Mowry Shale extends from the southeast end of Thornton dome for about 4 miles to the vicinity of Upton; there the terrace terminates in a poorly defined southeastward-plunging anticline and a parallel syncline. The amplitude of the folding near Upton appears to be less than 50 feet.

Small sharply folded domes similar in size and configuration to Thornton dome occur rather commonly in the northern part of the Black Hills (Darton, 1909, p. 66–73). Igneous rocks intrude some of these folds and clearly have caused the doming. An igneous intrusion at moderate depth seems a likely explanation for the folding at Thornton dome; however, a hole drilled on the crest of the dome reached a depth of 2,505 feet in the lower part of the Minnelusa Formation without entering igneous rocks. The intrusive body, if one is present, is below this level.

Pump Creek anticline.—The Pump Creek anticline is an asymmetrical southward-plunging anticline that can be traced for about 6 miles along the east edge of the quadrangle. The Fall River Formation comes to the surface at the crest of the fold and is dissected by Pump Creek, which flows nearly along the axis. The Fall River, Skull Creek, and Newcastle Formations dip 10°–12° on the steep east flank of the anticline; the Skull Creek Shale dips an average of about 2° southwestward on the gentle west flank. The anticline appears to have slight structural closure near its north end; the amount could not be determined exactly, but it probably is no more than 25 feet. The Pump Creek anticline and the bordering syncline to the east, which lies mostly in the adjoining Inyan Kara Mountain quadrangle, fade out northward in an area of nearly horizontal dips in the Skull Creek Shale.

Arch Creek anticline.—The Arch Creek anticline is a broad indefinite fold about 2 miles long near the head of Arch Creek in the northeastern part of the quadrangle. The upper part of the Fall River Formation forms the surface at the crest of the anticline, and the south end of the fold is partly outlined by the curving trace of the contact between the Fall River and the overlying Skull Creek. Dips are 1°–2° on the flanks. The structurally highest part of the anticline probably coincides with a low ridge in the Fall River Formation at the corner common to secs. 28, 29, 32, and 33, T. 49 N., R. 64 W. At this point the fold may have a closure in the surface rocks of as much as 25 feet.

Local unmapped folds.—Local folds having amplitudes of several feet can be seen in bentonite pits at the top of the Mowry and in the basal part of the Belle Fourche. Dips of 4° or 5° counter to the regional dip were measured locally in pits dug into bentonite bed E in the valley of Iron Creek southeast of Upton. These minor structural features are locally significant in controlling the depth to bentonite for purposes of strip mining; however, none of the folds could be traced in less well exposed strata beyond the walls of the pits, and none is shown on the structure-contour map (pl. 1).

Knechtel and Patterson (1962, p. 979) suggested that undulations in the bottom of the Clay Spur Bentonite Bed in the northern Black Hills, similar in scale to some of the gentle folds noticed in the Upton quadrangle, might be giant ripple marks, and therefore nondeformational.

FAULTS

Northeastward-trending faults offset beds in the upper part of the Belle Fourche Shale at four places along the Black Hills monocline. Two of the faults are south of Upton in sec. 10, T. 47 N., R. 65 W., and the other two are near Turner Creek in secs. 26 and 35 of the township to the east. None of the faults appears to extend for more than half a mile. Displacements along the faults are 20–30 feet where they cut bentonite bed F in the Belle Fourche Shale. All the faults are upthrown on the northwest. The attitudes of the fault planes could not be determined, but presumably all the faults dip steeply.

MINERAL DEPOSITS

OIL AND GAS

Prospecting for oil and gas has been done intermittently in the Upton quadrangle since the early 1920's. By August 1962, about 80 wells scattered rather uniformly had been drilled. This effort resulted in the 1958 discovery of the small Wind Creek oil field northwest of Upton in sec. 23, T. 49 N., R. 66 W. Shows of oil are reported from several wells in other parts of the quadrangle.

Several fields near the quadrangle produce oil and this has led to the continuing interest in oil and gas exploration in the area. The Osage oil field, discovered in 1919, is within 2 miles east of the quadrangle; the large and prolific Fiddler Creek field, discovered in 1948, is about 3 miles south of the quadrangle; the small Thornton and Wakeman Flats fields, discovered in 1915 and 1919, respectively, are 3–4 miles west of the quadrangle; and the small Tomcat Creek and Barton fields, discovered in 1956 and 1957, are 1–2 miles north of the quadrangle. The Wyoming Geological Association (1957, 1961) summarized the geology and production history of these and other fields near Upton.

The Newcastle Sandstone is the most prolific oil reservoir so far discovered in the region near Upton. Oil in this formation occurs in stratigraphic traps formed by sandstone lenses and changes in porosity of the sandstone beds. Some oil in the Osage field comes from fractures in the Mowry and Belle Fourche Shales, oil in the Thornton and Wakeman Flats fields is from the Turner Sandy Member of the Carlile Shale, and oil in the Tomcat Creek and Barton fields is from the basal part of the Fall River or upper part of the Lakota Formations.

Information on some of the deeper test wells drilled in the quadrangle is given in table 2.

Wind Creek oil field.—The Wind Creek oil field lies wholly within sec. 23, T. 49 N., R. 66 W., in the northwestern corner of the quadrangle. The field was discovered in May 1958 by the Wyoming Oil Co. Arthur Degner 1–A well, which initially produced 7 barrels of oil per day from a sandstone at a depth of 795–798 feet. Eight more producing wells were drilled in the field in 1958 and 1959. The oil-producing zone reportedly is in the upper part of the Lakota Formation and averages about 7 feet thick. The average initial daily production of oil for the 9 wells was 12 barrels, and the maximum was 30 barrels. Several of the wells also produced water. Oil from the Wind Creek field has an API gravity of 24.0°. Production of oil in 1960 totaled 10,291 barrels (Wyoming Geol. Assoc., 1961, p. 579).

The Fall River and Lakota Formations in the vicinity of the Wind Creek field dip uniformly 80–100 feet per mile southeastward (pl. 1). A decrease in porosity or a pinchout of the oil-bearing sandstone apparently provides the trap for the oil. In 1962 none of the wells in the Wind Creek field had been drilled in rocks deeper than the Morrison Formation.

TABLE 2.—*Selected wells drilled for oil and gas in the Upton quadrangle*

Location			Operator and well	Year completed	Total depth (feet)	Oldest formation reached	Remarks
T. N.	R. W.	Section					
47	64	SE¼SE¼NW¼ 28	Union Oil Co. of California, Alverson 1.	1921	2,235	Minnelusa	
47	65	C NW¼NE¼ 6	Mule Creek Oil Co., Materi 1	1962	5,001	do	
		NE¼SW¼NE¼ 28	R. G. Gose Oil Syndicate, V. O. Gose 1.	1958	5,060	Sundance	Oil and gas show, Lakota (?).
		SW¼SE¼SE¼ 34	Trigood Oil Co., Jessee C-1	1949	4,570	Skull Creek	
47	66	C SE¼SE¼ 1	Davis Oil Co., Federal-Materi 1.	1961	5,012	Lakota	
		SW¼NW¼NW¼ 24.	Delta-Continental Oil Co., David Nolan 1.	1948	5,171	Fall River	
48	64	NW¼SE¼SE¼ 15	Birdsall and Fischer, Government 1.	1954	2,504	Pahasapa	
		SW¼SE¼NW¼ 26	John Brorby and others, P. J. George 1.	1940	2,462	do	
		NW¼NW¼NW¼ 35.	L. O. Lilly 1	1926	700	Sundance	
48	65	W½SW¼SW¼ 8	Producers and Refiners Corp., Herbert R. Bush 1.	1924	2,505	Minnelusa	
		SE¼SE¼NE¼ 10	John Brorby 1	1936	685	Lakota	Oil show, Newcastle.
		C NE¼NW¼ 21	Tamarack Development Co., E. L. and B. P. Gleichner 1.	1958	2,121	Minnelusa	
		N½SE¼NW¼ 24	Murmax Drilling Co., Inc., W. L. Venable 1.	1957	2,525	Pahasapa	
		NW¼SW¼SW¼ 35.	John S. Wold, Government 1	1961	2,723	do	
48	66	C SW¼NE¼ 2	Earl Mallette, Mirich 1	1960	2,309	Minnelusa	Oil show, Minnelusa.
49	64	NW¼SW¼SW¼ 20.	Glenwood Oil Co., Wallace May 1-WW.	1957	1,735	do	Do.
		NW¼NW¼SE¼ 29.	Euclid Oil Co. 2	1927	1,675	do	
49	65	NW¼NE¼NE¼ 15.	C. B. Simmons, Government 1.	1957	340	Lakota	Oil show, Lakota.
		SE¼NW¼ 16	Mory Ohrel Producing and Development Co., State 3.	1961	394	do	Do.
		NW¼SW¼SE¼ 22	Teton Exploration Drilling Co., A. W. Deuel 1-AB.	1957	400	do	Do.
49	66	SW¼SW¼SE¼ 12	Syl-Del Mines, Inc., Barton 5	1958	728	Morrison	Do.
		SE¼NW¼NE¼ 23	Syl-Del Mines, Inc., Wagner 2	1958	759	Lakota	30 barrels oil per day, Lakota.

Oil and gas possibilities.—Potential oil-bearing rocks in the Upton quadrangle include the Turner Sandy Member of the Carlile Shale, which underlies the southwestern one-third of the quadrangle; the Belle Fourche and Mowry Shales and the Newcastle Sandstone, which underlie the southwestern one-half to two-thirds of the quadrangle; and the Fall River, Lakota, and Minnelusa Formations, which underlie all or nearly all of the quadrangle. The oil and gas possibilities of these rocks have been unsuccessfully tested by drilling at many places in the quadrangle. Moreover, anticlines in the quadrangle have all been tested to moderate depths without success. These include Thornton dome and the Arch Creek anticline, both of which have been drilled to the Minnelusa Formation, and the Pump Creek anticline, which has been drilled to the Pahasapa Limestone. It seems unlikely, therefore, that the area contains large amounts of undiscovered oil or gas although small oil pools such as the one at the Wind Creek field might still be found.

Where seen in outcrops, sandstone beds in both the Newcastle and Fall River Formations show substantial changes in thickness within short distances (figs. 2, 4). Similar local changes underground might cause traps for oil. On this basis, the two formations offer possibilities for future exploration although the location of areas of thickening and thinning cannot be predicted specifically as a result of the present work.

BENTONITE

Bentonite has been extensively strip mined in the Upton quadrangle for many years. The commercially important beds are the Clay Spur Bed (known locally as the "Commercial bed") at the top of the Mowry Shale and bed E in the lower part of the Belle Fourche Shale. Other thick beds occur in the Newcastle Sandstone and in the Mowry, Belle Fourche, and Pierre Shales. Outcrops of most of the thicker beds typically weather to light-colored bands of gumbo soil having a rough granulated surface texture that sharply distinguishes them from adjacent outcrops of shale (fig. 6). Bentonites in the Mowry Shale that are older than the Clay Spur Bed swell only slightly on weathering, and their outcrops are correspondingly less conspicuous. Knechtel and Patterson (1962, p. 952–953) noted that the physical properties of bentonite, including the swelling capacity, depend mostly

FIGURE 6.—Light-colored outcrops of bentonite in the southeastern part of the Upton quadrangle, sec. 23, T. 47 N., R. 64 W. Man is standing on the Clay Spur Bentonite Bed at the top of the Mowry Shale; bed E in the lower part of the Belle Fourche Shale caps the bench at the base of the trees.

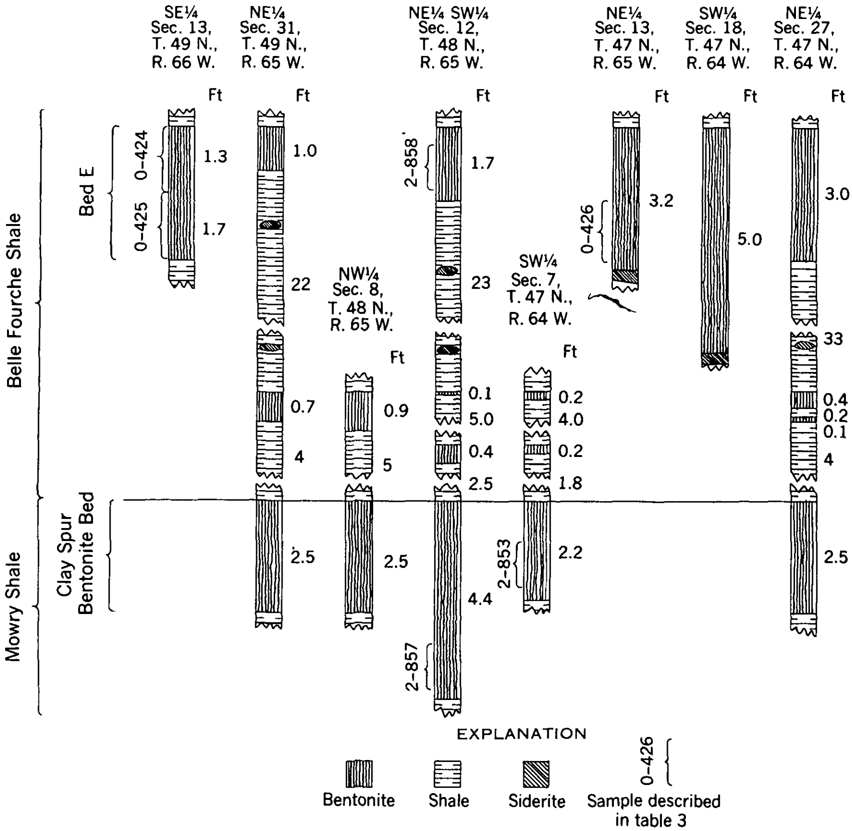

FIGURE 7.—Sections of bentonite beds at the top of the Mowry and base of the Belle Fourche Shales, Upton quadrangle.

on the kinds of cations in exchange positions in the lattices of clay minerals in the bentonite, and that types with calcium rather than sodium as exchangeable cations tend to have slight dilatancy.

Physical and chemical properties of bentonites in the northern Black Hills, including beds continuous with those found near Upton, were described in detail by Knechtel and Patterson (1962). Figures 7 and 8 show graphically the thickness and relative stratigraphic position of the Clay Spur Bentonite Bed and of bentonites in the Belle Fourche Shale in the Upton quadrangle. Some physical and chemical properties of these and some other bentonite beds in the quadrangle are given in table 3.

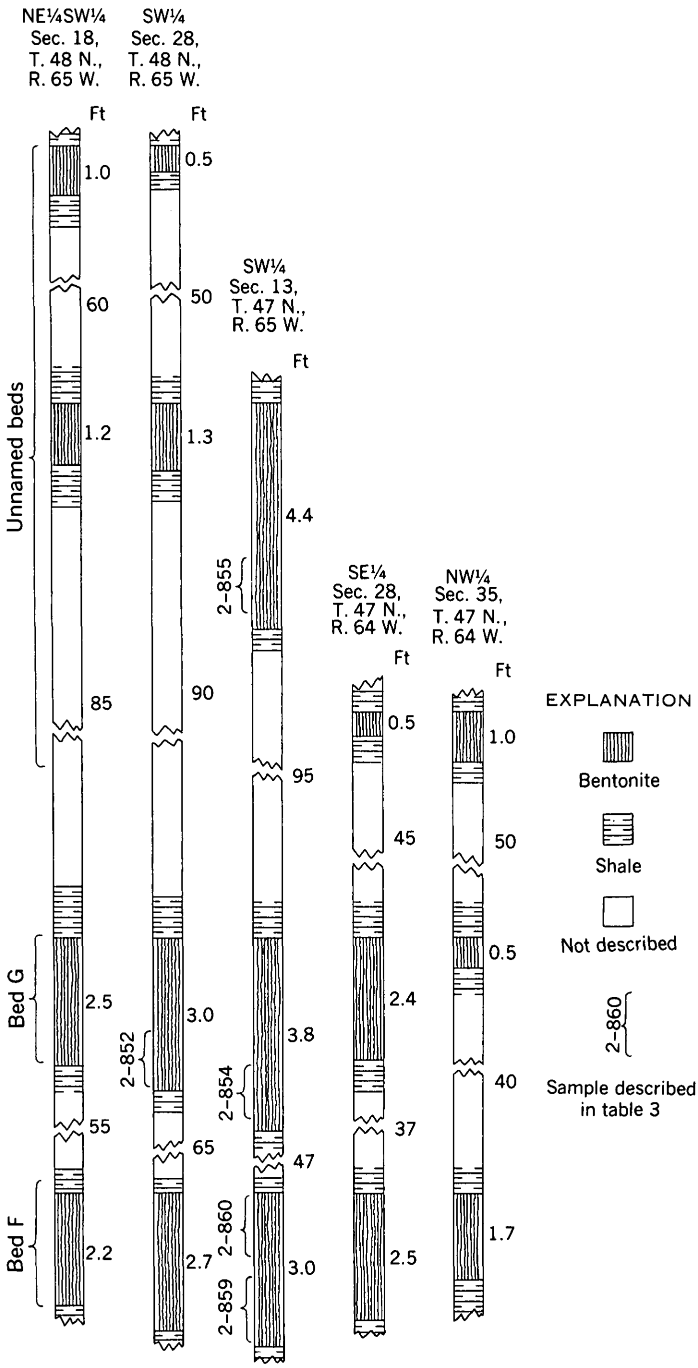

FIGURE 8.—Sections of bentonite beds in the upper part of the Belle Fourche Shale, Upton quadrangle.

TABLE 3.—*Analyses of grab samples from some bentonite beds in the Upton quadrangle, Wyoming*

[T. C. Nichols, L. G. Schultz, and J. C. Thomas, analysts; stratigraphic position of samples shown on figs. 4, 7, and 8]

Laboratory No.	Bed	Location			pH	Swelling capacity of 2 grams of bentonite [1] (milliliters)	Swelling index (pounds per square foot) [2]	Nonclay material (approximate percent) foot [2]	Grit (mineral fragments larger than .053 mm) (percent)	Clay minerals, determined by X-ray methods, no dispersing agent, 50 percent humidity			Nonclay minerals (listed in order of abundance)
										Montmorillonite		Kaolinite (approximate percent)	
		Sec.	T.N.	R.W.						Amount (approximate percent)	Dominant exchangeable cations		
Newcastle Sandstone													
2-856	Unnamed	SW¼ 8	48	65	4.1	21	10,000	15	6.4	85	Na^{+1}	Trace	Quartz, plagioclase, sanidine, biotite (trace).
2-1116	do	SE¼ 11	47	64	3.6	7	7,850	20	5.7	80	Ca^{+2}	----------	Quartz, sanidine, plagioclase, biotite.
Mowry Shale													
2-857	Clay Spur	SW¼ 12	48	65	9.3	20	10,700	10	0.6	90	Na^{+1}	----------	Quartz (about 75 percent of nonclay fraction), plagioclase, orthoclase and (or) sanidine, biotite (trace), calcite (trace).
2-853	do	SW¼ 7	47	64	9.3	33	10,800	5	1.4	95	Na^{+1}	----------	Plagioclase, sanidine, biotite, quartz (trace), calcite (trace).

Belle Fourche Shale													
0-425	Bed E	SE¼ 13	49	66	8.7	24		50	18.0	50	Na^{+1}		Goethite, feldspar, quartz.
0-424	do	SE¼ 13	49	66	8.7	42		15	.8	85	Na^{+1}	Trace	Biotite, feldspar, quartz.
2-858	do	SW¼ 12	48	65	8.3	9	8,300	15	4.1	82-87	Ca^{+2}, Mg^{+2}		Biotite, sanidine and (or) orthoclase, plagioclase, gypsum, quartz (trace).
0-426	do	NE¼ 13	47	65	9.5	28		20	3.0	80	Na^{+1}		Quartz, feldspar.
2-859	Bed F	SW¼ 13	47	65	5.9	13	5,400	40	11.7	60	Na^{+1}	Trace	Goethite (about 50 percent of nonclay fraction), plagioclase, sanidine, gypsum, biotite.
2-860	do	SW¼ 13	47	65	5.5	10	5,700	15	4.8	85	Ca^{+2}(?)		Gypsum, sanidine, plagioclase, biotite, quartz (trace).
2-854	Bed G	SW¼ 13	47	65	8.0	8	8,500	10	.5	90	Ca^{+2}(?)	1-2	Quartz, gypsum, plagioclase, sanidine, biotite (trace).
2-852	do	SW¼ 28	48	65	8.2	28	14,500	10	3.4	90	Na^{+1}, Ca^{+2}	Trace	Plagioclase, sanidine, biotite, quartz (trace), calcite (trace).
2-855	Unnamed	SW¼ 13	47	65	7.6	22	8,800	10	7.0	85	Na^{+1}	5	Sanidine, plagioclase, gypsum (trace).
Mitten Black Shale Member, Pierre Shale [3]													
2-862	Bed I	NW¼ 32	47	64	9.6	20	9,400	15	0.9	82-87	Na^{+1}		Cristobalite (about 80 percent of nonclay fraction), clinoptilolite, plagioclase, biotite (trace), quartz (trace).
2-861	do	NW¼ 32	47	64	7.9	6	8,600	30	13.6	70	Ca^{+2}	Trace	Gypsum (about 70 percent of nonclay fraction), plagioclase, orthoclase and (or) sanidine, biotite (trace).

[1] Volume in milliliters of the gel resulting when 2 grams of dried and ground bentonite is added slowly to distilled water.
[2] Pressure exerted by a sample of compacted bentonite when it tries to swell against a restraining force after being wetted. A device described by Lambe (1960) measures this property.
[3] Stratigraphic position of beds sampled shown in stratigraphic section, p. J49.

The Newcastle Sandstone contains two bentonite beds at most places in the quadrangle. The upper bed, which has been mined at several places, is 3.5 feet thick on the north side of Thornton dome and is 3.6 feet thick on the east side of the Pump Creek anticline; the bed is thinner where seen elsewhere, and locally, in sec. 5, T. 47 N., R. 64 W., it appears to be missing. (See fig. 4.) The lower bentonite bed in the Newcastle is a greenish-gray silty bentonite as much as 3 feet thick that forms the base of the formation in areas where the Newcastle is thin.

The Mowry Shale contains many bentonite beds including the high-grade, commercially important Clay Spur Bed at the top of the formation. The Clay Spur generally is about 2.5 feet thick in the quadrangle, but locally it attains a thickness of 4.4 feet in sec. 12, T. 48 N., R. 65 W. (fig. 7). Several other beds in the Mowry are 1–2 feet thick, as shown by the measured section, p. J17–J18, but none of these has been mined.

The Belle Fourche Shale contains four thick bentonite beds. Bed E, about 25–35 feet above the base of the formation, is as much as 5 feet thick in a pit in sec. 18, T. 47 N., R. 64 W., and it is 3 feet or more thick at other places nearby (fig. 7); however, the bed thins to less than 1 foot in the northern part of the quadrangle. Bentonite beds F and G, which lie about 350 and 400 feet above the base of the formation, respectively, are 3 feet or more thick locally, and an unnamed bed about 450 feet above the base of the formation is 4.4 feet thick south of Upton in sec. 13, T. 47 N., R. 65 W. Graphic sections of these bentonites are shown on figure 8. Beds in the upper part of the Belle Fourche Shale have a moderately steep dip (10°–30°) at most places, which limits the amount of bentonite that can be removed by stripping. None of the bentonite beds above bed E has been mined in the quadrangle.

Bentonite beds having an aggregate thickness of more than 20 feet are interbedded with shale in a zone about 35 feet thick at the base of the Mitten Black Shale Member of the Pierre Shale in the southeastern part of the quadrangle. As already noted on page J31, the bentonite zone could not be traced in outcrops northwest of sec. 22, T. 47 N., R. 65 W. The following section gives some lithologic details of the zone; analyses of samples collected from bentonite units 2 and 13 are given in table 3:

Bentonite zone at the base of the Mitten Black Shale Member of the Pierre Shale, NW¼ sec. 32, T. 47 N., R. 64 W., Weston County, Wyo.

	Feet
Pierre Shale (part):	
Mitten Black Shale Member (part):	
Part above bentonite bed I (part):	
19. Shale, grayish-brown, platy; abundant fish remains	30. 0
18. Covered	15. 0
17. Shale, grayish-brown, platy	2. 0
Bentonite bed I:	
16. Bentonite; grayish yellow at base; gray and shaly at top	2. 2
15. Shale, brown	1. 5
14. Bentonite, very light gray, hard, platy; a sample from middle contains about 10 percent clinoptilolite according to X-ray analysis by L. G. Schultz	2. 5
13. Bentonite, very light gray to white; sample 2–862 from middle described in table 3	1. 6
12. Shale, dark-gray to brownish-gray, soft	4. 6
11. Bentonite, very light gray to white	3. 1
10. Shale, very dark gray, tough	2. 4
9. Bentonite, light- to medium-gray; some interbedded bentonitic shale	1. 8
8. Bentonite, very light gray	3. 8
7. Shale, black	. 3
6. Bentonite, very light gray to light yellowish-gray	3. 0
5. Shale, very dark gray, hard; bentonitic in the uppermost 1 ft	5. 1
4. Limestone, brownish-gray, shaly, hard; forms slabby ledge	. 2
3. Covered	. 7
2. Bentonite; light gray at base grading to pink at the top; locally abundant selenite crystals; sample 2–861 from about middle described in table 3	4. 0
Partial thickness (rounded), Mitten Black Shale Member	84
Aggregate thickness, measured bentonite	22. 0
Gammon Ferruginous Member (part):	
1. Shale, dark-gray; weathers medium gray	10

In the bank of Beaver Creek, about 2 miles southwest of the locality described in the preceding measured section, the upper part of the zone contains the following sequence of bentonite and shale:

Upper part of bentonite zone at the base of the Mitten Black Shale Member of the Pierre Shale, SE¼SE¼ sec. 32, T. 47 N., R. 64 W., Weston County, Wyo.

	Feet
Pierre Shale (part):	
Mitten Black Shale Member (part):	
Part above bentonite bed I (part):	
8. Shale, brown, soft and powdery; much yellow stain	10
7. Shale, dark-gray, bentonitic	2.3
Bentonite bed I (part):	
6. Bentonite, grayish-brown, silty	2.8
5. Bentonite, greenish-gray to light yellowish-gray	1.3
4. Shale, grayish-green; many flakes of biotite	.8
3. Bentonite, light-gray to light yellowish-gray	5.8
2. Shale, black, hard	.01
1. Bentonite, light-gray to light yellowish gray; base not exposed	3.4
Partial thickness (rounded), Mitten Black Shale Member	26.4
Aggregate thickness, measured bentonite	13.3

SAND AND GRAVEL

The small stream-terrace deposits west of Mason Creek in the northeastern part of the quadrangle and west of Turner Creek in the southeastern part consist mostly of sand and gravel of possible value for road-building material and similar uses. All the deposits contain moderately large amounts of gravel composed of sandstone and siltstone fragments impregnated with iron oxides, and these fragments are probably too weak for uses such as concrete aggregate.

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