Geology of the Newcastle Area, Weston County Wyoming

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

CONTRIBUTIONS TO GENERAL GEOLOGY

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

ABSTRACT

The Newcastle area includes about 220 square miles on the west side of the Black Hills in Weston County, Wyo.

Exposed in the area are sedimentary rocks that have an aggregate thickness of about 5,300 feet and range in age from Permian to Cretaceous. These rocks overlie as much as 1,900 feet of unexposed sedimentary rocks of Permian, Pennsylvanian, Mississippian, and Cambrian ages.

Shale, siltstone, and sandstone make up most of the exposed sedimentary sequence; limestone, gypsum, bentonite, and coal are present also, but in relatively minor amounts. The Spearfish Formation of Permian and Triassic age is the oldest formation exposed. It is overlain by the Gypsum Spring, Sundance, and Morrison Formations of 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, and Pierre Formations of Late Cretaceous age. Surficial deposits consisting of stream-terrace deposits, extensive landslide material, and alluvium cover the older rocks locally.

The sedimentary rocks are sharply folded by the Black Hills monocline, which trends irregularly northwestward across the area in a relatively narrow belt, at places about 1 mile wide. Rocks northeast of the monocline are abruptly elevated about 3,500 feet relative to rocks of the same formations southwest of it. Near Newcastle the monocline splits into the branches that enclose a structural terrace as much as 3 miles wide. Sedimentary rocks on both sides of the monocline flatten abruptly, and in the northeastern and southwestern parts of the area they dip generally 1° to 3° SW.

Five short faults, each with about 15 to 35 feet of displacement, cut the Fall River Formation or older rocks along the east side of the area, and one fault with about 25 to 50 feet of displacement cuts Upper Cretaceous rocks near the northwest corner.

The Newcastle Sandstone yields oil in the Skull Creek, North Skull Creek, and Southeast Skull Creek oil fields, which lie wholly within the southwestern part of the area, and in the Mush Creek field, which lies partly within the area. The Belle Fourche Shale contains oil in the Pedro field in the northwestern part of the area. Bituminous coal was once mined from the Lakota Formation at Cambria in the northcentral part of the area. Other mineral resources include bentonite, gypsum, and sand and gravel.

INTRODUCTION

LOCATION

The Newcastle area includes about 220 square miles on the west side of the Black Hills in Weston County, northeastern Wyoming (fig. 1). The area is bounded on the south and north by lats 43°45′ and 44°00′, respectively, on the west by long 104°22′30″, and on the east at most places by the east line of R. 61 W.

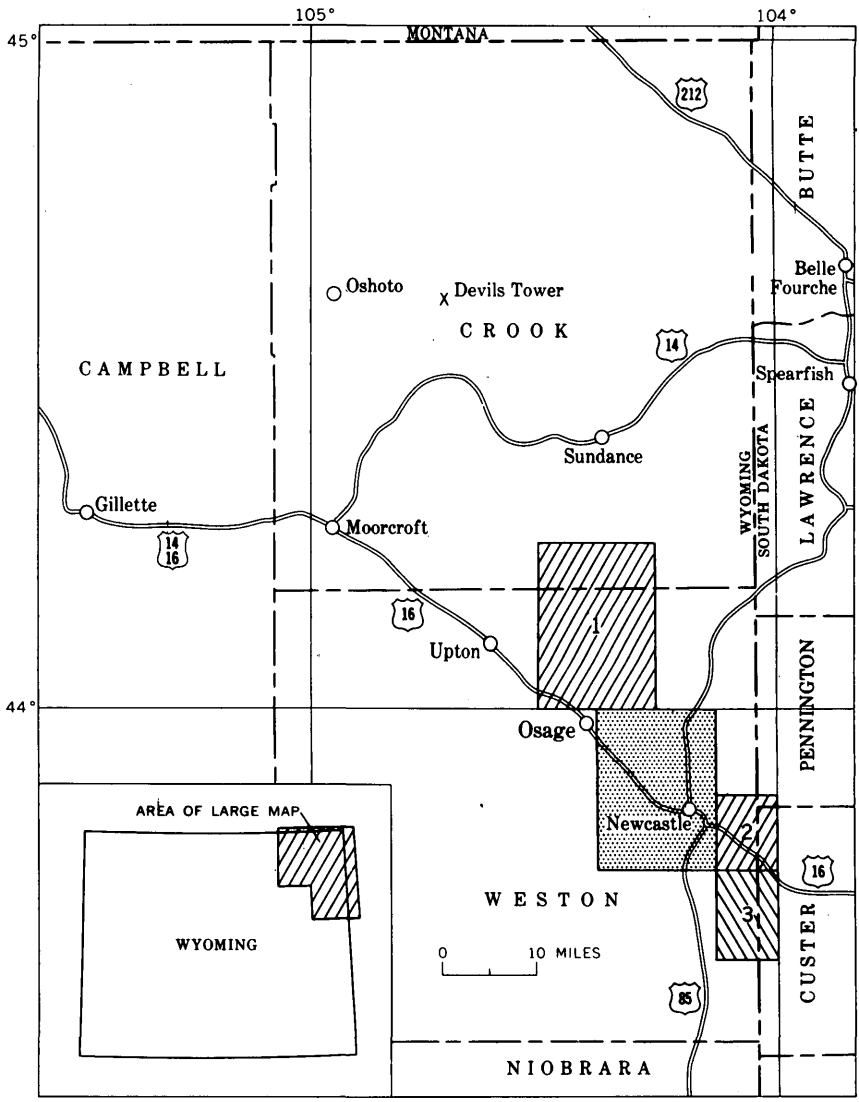

FIGURE 1.—Index map showing location of Newcastle area (stippled) and adjacent areas mapped by the Geological Survey from 1954 to 1958. 1, Inyan Kara Mountain quadrangle, Mapel and Pillmore (1963); 2, Fanny Peak quadrangle, Brobst (1963); 3, Clifton quadrangle, Cuppels (1963).

FIELDWORK AND ACKNOWLEDGMENTS

Investigations leading to the present report were made mostly from 1956 to 1958 on behalf of the U.S. Atomic Energy Commission as part of the study of a larger area on the west side of the Black Hills. Particular attention was given to determining the stratigraphic relations of the Fall River and Lakota Formations of Early Cretaceous age because of the occurrence of uranium deposits in these rocks in nearby areas in the Black Hills. Fieldwork during the summers of 1956 and 1957 consisted of measuring stratigraphic sections and locating geologic contacts on aerial photographs. This information provided control for geologic mapping done subsequently with a Kelsh plotter by C. L. Pillmore. The resulting map was checked and modified where necessary in the field during 1958. The area was revisited briefly for periods of about a week in 1959 and 1960.

The base map for the part of the area east of long 104°15′ is the Newcastle 15-minute topographic quadrangle map. The base for the southwest quarter of the area is the Osage SE 7½-minute quadrangle map, modified to show a topographic contour interval of 40 feet. The base map for the northwest quarter was made by C. L. Pillmore, using photogrammetric methods, during the course of the present investigation. Topographic contours for the northwest quarter were drawn at an interval of 100 feet; horizontal and vertical control for this part of the map are less precise than for the other parts.

Reconnaissance stratigraphic studies and geologic mapping were done in the area by C. S. Robinson and W. J. Mapel (Mapel, Robinson, and Theobald, 1959) at various times during 1954 and 1955, and the information gathered is incorporated in this report.

J. R. Gill made a detailed study of the lower part of the Pierre Shale on the flanks of the Black Hills and nearby areas as part of a separate investigation from 1957 to 1959, and he has kindly made his results available for use in this report. Mr. Gill and the writers collaborated in measuring three sections of Upper Cretaceous rocks near Newcastle.

Unpublished maps and notes by W. W. Rubey and C. R. Longwell covering the Newcastle area were used in the initial stages of the work. W. A. Cobban identified fossils from the marine Cretaceous rocks, consulted with the writers in the field on the stratigraphic relations of these rocks, and provided a detailed section of part of the Carlile Shale southwest of Newcastle.

PREVIOUS PUBLISHED WORK

The Newcastle area is in the northern part of the Newcastle 30-minute quadrangle, which was mapped and described by Darton (1904) in a comprehensive early report. Stone (1912, p. 32–44)

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gave considerable information on coal deposits in the vicinity of Cambria. Parts of the Newcastle area were included on maps of the Osage, Skull Creek, or Mush Creek oil fields by Collier (1922), Dobbin, Miller, and Walter (1935), Horn (1947), Dobbin and Horn (1949), and Dobbin, Kramer, and Horn (1957). Many other writers briefly described the stratigraphy or structure of the area in discussions of larger areas; their reports are cited at appropriate places in the text.

GEOGRAPHY

SURFACE FEATURES AND RELIEF

The land surface in the southwestern part of the Newcastle area is mostly rolling prairie that is locally dissected into small areas of badlands. The general altitude of the country rises several hundred feet rather steeply along a line of smooth slopes that crosses the area diagonally from northwest to southeast. To the northeast is more mountainous country in the form of a dissected plateau that slopes gently to the southwest and consists of broad even-topped divides separated by steep-sided canyons.

Beaver Creek is the largest stream in the area, and it flows southward across the southwest corner and joins the Cheyenne River south of the map area. Its main tributaries in the area include, from west to east, Skull Creek, Oil Creek and its branches East and West Plum Creeks, Little Oil Creek and its tributary Cambria Creek, Salt Creek, and Stockade Beaver Creek.

Total relief in the area is about 2,500 feet. Altitudes range from about 6,400 feet on Mount Pisgah, a flat-topped mesa in the northeastern part of the area, to about 3,860 feet along Beaver Creek in the southwestern part.

CLIMATE AND VEGETATION

The annual rainfall at Newcastle averages 13.8 inches, and during most years the temperature ranges to annual extremes of about 100° and −15°F. Extremely warm periods are usually short and are modified by cool nights.

The southwestern part of the area supports sparse vegetation, including sagebrush, greasewood, and short grasses common to much of the northern Great Plains. In the more mountainous northeastern part, fairly dense stands of pine and juniper cover many hillsides. Interspersed with the forested areas are open grasslands on some divides and meadowlands bordering the larger streams.

SETTLEMENT AND INDUSTRY

The only town in the area is Newcastle, the county seat of Weston County and a commercial center for northeastern Wyoming. Newcastle had a population of about 4,350 in 1960. Osage is about 3 miles northwest, and Upton is 15 miles northwest of the area.

The Chicago, Burlington, and Quincy Railroad crosses the area from northwest to southeast, connecting Newcastle with Gillette and Sheridan, Wyo., to the west, and with Edgemont, S. Dak., and Alliance, Nebr., to the southeast. U.S. Highways 16 and 85 cross at Newcastle, and these and other roads and trails provide access to almost all parts of the area.

The main industries are livestock raising and oil production and refining. Wheat and hay are grown locally on the more level tracts, but most of the land is used for grazing cattle and sheep. Some timber is cut for lumber and fence posts. Bentonite has been strip mined in the northwest corner of the area, but no bentonite mining was being done in the area in 1958. Coal formerly was mined and coke was manufactured at the now-abandoned town of Cambria, 6 miles north of Newcastle.

SEDIMENTARY ROCKS

Exposed sedimentary rocks in the Newcastle area, exclusive of surficial deposits, are about 5,300 feet thick and include strata from Permian to Cretaceous age. These rocks overlie as much as 1,900 feet of unexposed sedimentary rocks of Permian, Pennsylvanian, Mississippian, and Cambrian ages. The distribution of the exposed rocks is shown on the geologic map, plate 1, and a brief description of both the exposed and unexposed sedimentary rocks is given in table 1.

TABLE 1.—*Generalized stratigraphic section of rocks in the Newcastle area*

System or series	Group, formation, and member		Thickness (feet)	Lithology
Upper Cretaceous	Pierre Shale	Upper part	50–100+	Dark-gray shale; septarian limestone concretions that weather medium gray; marine fossils.
		Kara Bentonitic Member	75–100	Dark-gray bentonitic shale and impure bentonite; some barite concretions and a few septarian limestone concretions that weather medium gray; marine fossils.
		Middle part	1,100–1,200	Dark-gray shale, silty in the lower part; light-gray and tan septarian limestone concretions, some dark-red limestone concretions, and some light-gray "tepee butte" limestone concretions; marine fossils.
		Mitten Black Shale Member: Upper part	425–510	Grayish-black shale; dark-red limestone concretions and a few gray septarian limestone concretions; locally conspicuous bentonitic zone 5 to 8 ft thick about 150 ft below the top; marine fossils.
		Mitten Black Shale Member: Lower part	410	Medium-gray shale; weathers to hard brittle chips; abundant organic material on bedding surfaces; scattered large gray septarian limestone concretions and some dark-red limestone concretions in the upper part; bentonite beds in a zone about 60 ft thick at or near the base; marine fossils.
		Gammon Ferruginous Member	35–70	Medium- to dark-gray shale; weathers to hard platy chips; upper part contains fish scales and other organic material; the lower part contains a few tabular siderite concretions.
		Niobrara Formation	155–220	Marl and shale; weathers mostly light gray and yellowish orange; thin beds of bentonite; marine fossils.

TABLE 1.—*Generalized stratigraphic section of rocks in the Newcastle area*—Con.

System or series	Group, formation, and member	Thickness (feet)	Lithology
Upper Cretaceous	Carlile Shale: Sage Breaks Member	260	Grayish-black shale; several persistent beds of septarian limestone concretions that weather light gray and have veins of white and brown calcite; no fossils.
	Carlile Shale: Turner Sandy Member	150	Dark-gray shale and sandy shale; interlaminated and interbedded light-gray siltstone and very fine grained sandstone; prominent large tan-weathering sandstone concretions in the lower part; septarian limestone concretions with veins of yellow calcite in the upper part; marine fossils.
	Carlile Shale: Lower unnamed member	90–110	Dark-gray shale, locally calcareous in the basal part; a few silty partings; thin bentonite bed about the middle; marine fossils.
	Greenhorn Formation	250	Light- to dark-gray marl, dark-gray shale, and, at the top, thin beds of light-gray limestone; a few thin beds of bentonite; marine fossils.
	Belle Fourche Shale	340–370	Grayish-black shale; siderite concretions mostly in the lower part; several bentonite beds including one about 3 ft thick near the base and one about 3 ft thick near the top; marine fossils.
Lower Cretaceous	Mowry Shale	180–195	Siliceous light-gray shale grading to dary-gray shale in the basal 15 to 20 ft; many bentonite beds including one at the top as much as 1½ ft thick; marine fossils.
	Newcastle Sandstone	10–100	Light-gray sandstone, brown and gray carbonaceous shale and siltstone, and gray bentonite.
	Skull Creek Shale	180–200	Grayish-black shale; thin siltstone partings locally; a few marine fossils.
	Inyan Kara Group: Fall River Formation	125–200	Brown-weathering sandstone, light- to dark-gray siltstone, and dark-gray shale; locally carbonaceous.
	——Unconformity——		
	Inyan Kara Group: Lakota Formation	160–260	Light-gray sandstone and conglomeratic sandstone and variegated sandy claystone; local coal beds in lower part; nonmarine fossils.
	Morrison Formation	120±	Greenish-gray and grayish-red claystone, gray marl, and some grayish-white sandstone; nonmarine fossils.
Upper Jurassic	Sundance Formation: Redwater Shale Member	160–170	Greenish-gray shale, light-gray siltstone and sandstone, and gray sandy limestone; glauconitic; a few thin stringers of gypsum locally in the upper part; marine fossils.
	Sundance Formation: Lak Member	75	Pink siltstone and very fine grained sandstone; no fossils.
	Sundance Formation: Hulett Sandstone Member	70	Yellowish-gray cliff-forming sandstone; marine fossils.
	Sundance Formation: Stockade Beaver Shale Member	50–65	Greenish-gray shale; some interlaminated light-gray siltstone and sandstone at the top; marine fossils.
	Sundance Formation: Canyon Springs Sandstone Member	0–20	Light-gray, light yellowish-gray, or pink friable sandstone; local greenish-gray siltstone; marine fossils.
	——Unconformity——		
Middle Jurassic	Gypsum Spring Formation	0–15	Massive white gypsum.
	——Unconformity——		
Triassic	Spearfish Formation	465–535	Red siltstone, sandstone, and silty claystone; thick gypsum beds in the lower part; no fossils.

TABLE 1.—*Generalized stratigraphic section of rocks in the Newcastle area*—Con.

System or series	Group, formation, and member	Thickness (feet)	Lithology
Permian	Minnekahta Limestone	40	Light-gray thin-bedded limestone; marine fossils locally.
	Opeche Shale	75–90	Red siltstone; no fossils.
	—Unconformity—		
Carboniferous: Pennsylvanian	Minnelusa Formation	800–900	Light-gray and red sandstone, gray limestone and dolomite, red shale, and local gypsum and anhydrite; marine fossils.
	—Unconformity—		
Carboniferous: Mississippian	Pahasapa Limestone	450–500	Light-gray locally dolomitic limestone; marine fossils.
	Englewood Limestone	50±	Pinkish-gray moderately thin-bedded limestone; marine fossils.
	—Unconformity—		
Cambrian	Deadwood Formation	200±	Brown sandstone, some greenish-gray shale and siltstone and gray limestone; marine fossils.
	—Unconformity—		
Precambrian			Metamorphic and igneous rocks.

Most of the formations listed have been penetrated in drilling; their electric-log characteristics are shown by the logs on plate 1.

Shale, siltstone, and sandstone make up most of the exposed sedimentary sequence; gypsum, limestone, bentonite, and coal are present in lesser amounts. The Spearfish Formation of Permian and Triassic age is the oldest exposed formation. It is overlain by the Gypsum Spring Formation of Middle Jurassic age, followed in turn by the Sundance and Morrison Formations of Late Jurassic age; the Lakota and Fall River Formations, Skull Creek Shale, Newcastle Sandstone, and Mowry Shale of Early Cretaceous age; and the Belle Fourche Shale, Greenhorn Formation, Carlile Shale, Niobrara Formation, and Pierre Shale of Late Cretaceous age. For the most part, all the formations are concordant, but several disconformities can be recognized, including those between the Spearfish and Gypsum Spring Formations, the Gypsum Spring and Sundance Formations, and the Lakota and Fall River Formations.

Most of the Spearfish Formation and the Morrison and Lakota Formations, which have a combined thickness of about 800 feet, are nonmarine; the remainder of the exposed rocks, which have a combined thickness of about 4,500 feet, are marine. Stratigraphic sections of the Spearfish to Fall River Formations, inclusive, are shown graphically on plates 2 and 3.

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

Sedimentary rocks older than the Spearfish Formation were not studied during the investigation. They have been described from outcrops or drill holes at nearby places in the Black Hills by several writers, including Darton (1909, p. 12–31); Darton and Paige (1925, p. 5–7); Furnish, Barragy, and Miller (1936); Leatherock (1950); Agatston (1954); Andrichuk (1955, fig. 5); McCoy (1952, 1958a, 1958b); Brady (1931, 1958); Ross (1957); Foster (1958); Carlson (1958); Privrasky and others (1958); and Brobst (1963).

Rocks of Ordovician age that crop out in the northern Black Hills (Darton, 1909, p. 19–20; McCoy, 1952) thin southward at a rate which indicates that they are absent in the Newcastle area. However, according to oil-scout reports (Wyoming Geological Association, 1957, map in pocket), a well drilled in sec. 2, T. 44 N., R. 62 W., penetrated a thickness of 780 feet of rocks between the top of the Pahasapa Limestone (Mississippian) and the top of the Deadwood Formation (Cambrian); and if this thickness is correct, Ordovician rocks may be present in the area locally. A log of this well was not available to the writers.

The ages of Jurassic and Cretaceous rocks in the Newcastle area are given in terms of European stages in the chart on the facing page.

PERMIAN AND TRIASSIC SYSTEMS

SPEARFISH FORMATION

The Spearfish Formation crops out in the broad valley of Stockade Beaver Creek in the northeastern part of the area; the top of the formation is exposed locally along Sweetwater and Salt Creeks and along a tributary to Salt Creek south of Mount Pisgah in the northern part of the area. The formation is about 465 feet thick in outcrops along Stockade Beaver Creek in T. 46 N., Rs. 60 and 61 W., as shown on plate 2. It is reported to be 492 feet thick at Newcastle in the Sioux Oil Co. Sioux well, 1, SW¼ sec. 29, T. 45 N., R. 61 W.; about 490 feet thick at Cambria in a well in sec. 29, T. 46 N., R. 61 W.; 510 feet thick in the northwestern corner of the area in the Wadley System Terminal Corp. well, 1, NW¼ sec. 18, T. 46 N., R. 62 W.; and about 535 feet thick in the southeastern part of the area in the Coronado Oil Co. LAK Ranch well 1, SW¼SW¼ sec. 12, T. 44 N., R. 61 W.

The Spearfish is divided on the geologic map (pl. 1) into a lower part about 280 feet thick and an upper part 180 to about 200 feet thick. The lower part consists of thin-bedded red claystone and clayey siltstone interbedded with white granular gypsum in beds as much as 30 feet thick. The gypsum appears to be concentrated in three roughly equally spaced zones of interbedded gypsum and claystone that range

System and series		European stages	Formation in Newcastle area
Cretaceous	Upper	Maestrichtian (part)	Pierre Shale
		Campanian	
		Santonian	
		Coniacian	Niobrara Formation
		Turonian	Carlile Shale
			Greenhorn Formation
		Cenomanian	Belle Fourche Shale
	Lower	Albian	Mowry Shale
			Newcastle Sandstone
			Skull Creek Shale
			Fall River Formation
			?—
		Aptian	?—
			Lakota Formation
			?—
		Neocomian: Barremian	
		Neocomian: Hauterivian	
		Neocomian: Valanginian	
		Neocomian: Berriasian	
Jurassic	Upper	Portlandian	?—
		Kimmeridgian	Morrison Formation
		Oxfordian	Sundance Formation
		Callovian	
	Middle	Bathonian	
		Bajocian	Gypsum Spring Formation
	Lower	Toarcian	
		Pliensbachian	
		Sinemurian	
		Hettangian	

from 15 to 40 feet in thickness. The stratigraphically lowest gypsum bed lies about 100 feet above the base of the formation and is the thickest. The top of the stratigraphically highest persistent gypsum bed marks the top of the lower part of the formation.

The upper part of the Spearfish is mostly red silty claystone and siltstone, but contains some sandstone that is silty, red, slabby, and ripple marked. Gypsum also occurs in this part of the formation, but mostly as secondary deposits that fill narrow fractures within the top few feet.

The sequence of beds in the lower part of the Spearfish Formation is shown by the following section measured about 1½ miles east of the area boundary.

Lower part of the Spearfish Formation, NW¼SW¼ and NW¼NE¼ sec. 8, T. 46 N., R. 60 W., Weston County, Wyo.

[Loc. 6, pl. 2]

Top of hill.

Spearfish Formation (part):	Feet
11. Covered	35
10. Gypsum, white, granular; forms ledges	10
9. Claystone, red, silty; many thin stringers of gypsum	40
8. Gypsum, white, lenticular; forms a ledge	5
7. Siltstone, red, lenticular; a few stringers of gypsum	5
6. Gypsum, white, granular; interbedded with red siltstone and claystone in lenticular beds; forms ledges	26
5. Poorly exposed; mostly red siltstone	49
4. Gypsum, white; interbedded with red sandy siltstone	4
3. Gypsum, white, granular; forms a single massive ledge	27
2. Siltstone, red; locally very fine grained slightly calcareous thin-bedded sandstone	107
Partial thickness, Spearfish Formation	308
Minnekahta Limestone (part):	
1. Limestone, light- to medium-gray, finely crystalline; forms blocky ledges	5

The gypsum-bearing lower part of the Spearfish Formation contains small discontinuous bodies of halite in the Powder River Basin, a few miles west of the Newcastle area (E. K. Maughan, oral communication, 1962). Analyses of water from a spring in the Spearfish Formation along Salt Creek in the SW¼ sec. 9, T. 46 N., R. 61 W., indicate that halite is present in or near the northern part of the Newcastle area, probably here too in the lower part of the Spearfish. Darton reported in 1904 (p. 9) that the spring along Salt Creek flowed at the rate of about 1 gps (gallon per second) and that the water contained a little more than 5 percent sodium chloride. According to Darton's calculations, about 35,000 pounds of salt was produced every 24 hours. The spring flowed at about the same rate when visited in 1962, and, as shown by the analysis given below, the concentration of sodium chloride at that time was nearly 6 percent.

Analysis of brine from a spring along Salt Creek, SW¼ sec. 9, T. 46 N., R. 61 W., Weston County, Wyo.

[C. W. Hall, analyst; sample 4818 collected May 1962]

	Parts per million	*Equivalents per million*		*Parts per million*	*Equivalents per million*
Silica	18		Bicarbonate	214	3. 51
Aluminum	. 55		Carbonate	0	. 00
Iron	. 00		Sulfate	3, 780	78. 70
Manganese	. 00		Chloride	35, 500	1, 001. 46
Calcium	1, 440	71. 36	Fluoride	1. 8	. 09
Magnesium	297	24. 43	Nitrate	9. 0	. 15
Sodium	22, 900	996. 15	Phosphate	. 06	
Potasium	38	. 97	Dissolved solids	[1] 65, 300	
Lithium	. 40	. 06			
ph	7. 0				
Density	1. 049				

[1] Residue on evaporation at 180°C.

The lower gypsiferous part of the Spearfish Formation is equivalent to part of the Goose Egg Formation of Burk and Thomas (1956), which is thought to contain equivalents of both the Phosphoria Formation of Permian age and the Dinwoody Formation of Early Triassic age (Burk and Thomas, 1956; Privrasky and others, 1958; McKee and others, 1959, table 1). The Little Medicine Tongue of the Dinwoody Formation of Thomas (1934, p. 1669–1670) was correlated by E. K. Maughan (oral communication, 1960) with gypsum beds that mark the top of the lower part of the Spearfish of this report. According to Maughan (oral communication, 1960), the boundary between the Permian and Triassic systems is probably at about the top of the next lower sequence of gypsum beds. Rocks below this horizon are considered Late Permian in age; and rocks in the overlying part of the formation, Early Triassic in age (E. K. Maughan, oral communication, 1960; Oriel *in* McKee and others, 1959, p. 9 and table 1).

JURASSIC SYSTEM

MIDDLE JURASSIC SERIES

GYPSUM SPRING FORMATION

The Gypsum Spring Formation in the Newcastle area consists of a single massive bed of white gypsum that crops out in a prominent ledge between red beds of the underlying Spearfish Formation and light-gray sandstone and green shale of the lower part of the overlying Sundance Formation. The formation is especially well exposed on steep eastward-facing slopes along the east side of the area where it makes a thin, almost continuous white band that can be seen from distances of several miles.

The Gypsum Spring Formation is 5 to 10 feet thick along Salt Creek at the north edge of the area, and it is 8 to 12 feet thick where examined at several places in the valley of Stockade Beaver Creek on the east side of T. 46 N., R. 61 W. The formation is lacking for a distance of a few hundred feet in the SE¼ sec. 15, T. 46 N., R. 61 W. (loc. 3, pl. 2), but it is 6 to 9 feet thick in outcrops nearby. The Gypsum Spring Formation has been followed southward across the Fanny Peak quadrangle and for a short distance into the Clifton quadrangle, which lie east and southeast of the Newcastle area, respectively (D. A. Brobst, oral communication, 1960). The formation is absent in outcrops farther to the south.

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

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mation to the overlying and underlying formations in the northern Black Hills has been described by Mapel and Bergendahl (1956).

UPPER JURASSIC SERIES

SUNDANCE FORMATION

The Sundance Formation crops out extensively in the valleys of Salt and Stockade Beaver Creeks in the northeastern part of the Newcastle area, and the upper part is exposed along Oil and East and West Plum Creeks in the north-central part. The formation is about 360 to 370 feet thick and includes, in ascending order, the Canyon Springs Sandstone, Stockade Beaver Shale, Hulett Sandstone, Lak, and Redwater Shale Members as defined by Imlay (1947).

The age and correlation of the Sundance Formation in the Black Hills has been discussed by Imlay (1947, p. 244–266), who stated that the Lak and older members are Callovian in age, and that the Redwater Shale Member is Oxfordian in age. Fossils have been found in all but the Lak Member and include ammonites, pelecypods, belemnites, and brachiopods (Imlay, 1947, 1948, 1953); Foraminifera (Loeblich and Tappan, 1950a, b); and ostracodes (Swain and Peterson, 1952).

Some details of the lithology of the Sundance Formation are shown on plate 2 and are given in the measured sections, pages N13–N15.

CANYON SPRINGS SANDSTONE MEMBER

The Canyon Springs Sandstone Member of the Sundance Formation ranges in thickness from 2 to 19 feet where examined in outcrops in the Newcastle area. It is thinnest along Salt Creek in sec. 9, T. 46 N., R. 61 W., and at the east edge of the area in the SE¼ sec. 36 of the same township; it is thickest south of Mount Pisgah in the SE¼ sec. 15, T. 46 N., R. 61 W. (loc. 3, pl. 2). The Canyon Springs Sandstone Member is absent three-fourths of a mile east of the Newcastle area in sec. 18, T. 45 N., R. 60 W. (loc. 1, pl. 2). The member consists mostly of sandstone that is very fine grained, friable, and calcareous; it generally is nonresistent and makes few good outcrops. In the SE¼ sec. 15, T. 46 N., R. 61 W., the member includes some pale-red, yellow, and orange sandstone and, at the base, a bed a few inches to as much as 3 feet thick of coarse-grained to conglomeratic sandstone. Scattered coarse grains and granules of gray chert and frosted quartz occur in the basal 1 foot of the member in the SE¼ sec. 36, T. 46 N., R. 61 W. The chert was probably derived from the underlying Gypsum Spring Formation by erosion of cherty limestone beds such as those that crop out in the vicinity of Hulett, Wyo. (Mapel and Bergendahl,

1956, p. 88–89). Some light greenish-gray siltstone is interbedded with the sandstone in most outcrops.

Gypsum Spring and Sundance Formations on the west side of Stockade Beaver Creek, NW¼NE¼ sec. 18, T. 45 N., R. 60 W., Weston County, Wyo.

[After R.W. Imlay (1947, p. 271); loc. 1, pl. 2]

	Feet
Top of the exposure.	
Sundance Formation (part):	
Redwater Shale Member (part):	
14. Poorly exposed; mostly very light gray very fine grained calcareous sandstone and siltstone interbedded and interlaminated with green silty shale; contains many belemnites	75
13. Sandstone, very light gray, very fine grained, calcareous, thin-bedded, nonresistant; contains sparse glauconite	8
12. Shale, greenish-gray; some interlaminated very light gray siltstone	7
11. Sandstone, very light gray, very fine grained to silty, calcareous, glauconitic; interlaminated greenish-gray silty shale	5
10. Sandstone, very light gray, very fine grained, calcareous, glauconitic, friable; sharp contact with the underlying unit	2
Partial thickness, Redwater Shale Member	97
Lak Member:	
9. Siltstone and sandstone, pink to pale red; a bed 2 ft thick of light greenish-gray siltstone 15 ft below the top	75
Hulett Sandstone Member:	
8. Sandstone, very light gray, very fine grained to silty; shaly interbeds; friable; top of unit somewhat indefinite	8
7. Siltstone, shale, and some very fine grained sandstone, greenish-gray to yellowish-gray; weathers pink to buff	9
6. Sandstone, light yellowish-gray, fine-grained, sparsely glauconitic, thick-bedded, ripple-marked; weathers buff; forms a cliff	30
5. Shale, greenish-gray, silty; interbedded shaly to thin-bedded light yellowish-gray sandstone; forms recess in cliff; contains *Camptonectes*	12
4. Sandstone, light yellowish-gray, very fine grained to fine-grained, sparsely glauconitic, medium- to thick-bedded, ripple-marked; weathers buff; some shaly partings; grades into adjacent units; forms ledges	12
Thickness, Hulett Sandstone Member	71
Stockade Beaver Shale Member:	
3. Shale, dark-gray to dark greenish-gray, soft; some nodules of limestone in lower 10 ft and some limonitic shaly sandstone in lower foot; contains selenite crystals and *Camptonectes*	63
Partial thickness, Sundance Formation	306
Unconformity.	
Gypsum Spring Formation:	
2. Gypsum, white, granular; forms a massive ledge; rests sharply on slightly irregular surface of the Spearfish Formation	8–12
Unconformity.	
Spearfish Formation (part):	
1. Sandstone, red, silty	10

Lower part of the Sundance Formation south of Mount Pisgah, SE¼ SE¼ sec. 15, T. 46 N., R. 61 W., Weston County, Wyo.

[Loc. 3, pl. 2]

	Feet
Top of the ridge.	
Sundance Formation (part):	
Hulett Sandstone Member (part):	
10. Covered; light-gray sandy soil	9
9. Sandstone, light yellowish-gray, very fine grained, calcareous, ripple-marked, friable; thin bedded in lower part, becoming thick bedded in upper part; forms a cliff	33
8. Sandstone, light yellowish-gray and light greenish-gray, very fine grained to silty, thin bedded; grades into adjacent units	6.5
7. Sandstone and siltstone, very light yellowish gray to light greenish-gray, thin-bedded to shaly	4.5
Thickness, Hulett Sandstone Member	53
Stockade Beaver Shale Member:	
6. Siltstone and shale, interlaminated, light-gray and greenish-gray	10
5. Partly covered; scattered outcrops of greenish-gray shale	34
4. Shale, greenish-gray, soft	5
Thickness, Stockade Beaver Shale Member	49
Canyon Springs Sandstone Member:	
3. Sandstone, yellow and orange in lower part grading to very light gray in the upper part, very fine grained, calcareous, very friable, nonresistant	16
2. Sandstone, pale-red, calcareous, mostly fine-grained; many medium to very coarse rounded frosted grains of quartz; local shell fragments; rests on underlying rocks with a sharp, uneven contact; forms a ledge	3
Thickness, Canyon Springs Sandstone Member	19
Partial thickness, Sundance Formation	121
Unconformity.	
Spearfish Formation (part):	
1. Sandstone, red, very fine grained, massive	10

The Canyon Springs Sandstone Member rests unconformably on a smooth, even surface cut on the underlying Gypsum Spring Formation or, where the Gypsum Spring is absent, on the Spearfish Formation.

STOCKADE BEAVER SHALE MEMBER

The Stockade Beaver Shale Member of the Sundance Formation was named by Imlay (1947, p. 251) for exposures along Stockade Beaver Creek. The type section is in sec. 18, T. 45 N., R 60 W., just east of the Newcastle area and is given on pages N13. The member ranges in thickness from about 50 to 65 feet. Measurements in the Newcastle area, and in the Inyan Kara Mountain quadrangle (Mapel and Pillmore, 1963), which adjoins the Newcastle area on the north, indicate that the Stockade Beaver Shale Member is thinnest where the underlying Canyon Springs Sandstone Member is thick, and

thickest where the Canyon Springs is thin or absent. The combined thickness of the two members is generally about 65 to 70 feet.

The Stockade Beaver Shale Member consists mostly of nonresistant greenish-gray noncalcareous to slightly calcareous shale and some interlaminated and interbedded light-gray calcareous siltstone and sandstone in the top 10 to 15 feet. The contact with the Canyon Springs Sandstone Member is conformable and fairly abrupt.

HULETT SANDSTONE MEMBER

The Hulett Sandstone Member of the Sundance Formation is about 70 feet thick along the west side of Stockade Beaver Creek and consists mostly of light-gray to light yellowish-gray friable fines to very fine grained calcareous sandstone that forms prominent cliffs and ledges. The lower few feet of the member is thin-bedded sandstone intercalated with some greenish-gray siltstone and silty shale; the middle part is thicker bedded and more resistent sandstone; and the upper few feet is thin-bedded and slabby sandstone. Ripple marks are common in the upper part of the Hulett, and some beds are cross-laminated.

The Hulett Sandstone Member grades downward through a thickness of about 5 to 10 feet into the underlying Stockade Beaver Shale Member.

LAK MEMBER

The Lak Member of the Sundance Formation was named by Imlay (1947, p. 257) for the LAK Reservoir in sec. 6, T. 44 N., R. 60 W. The type section, which is about 3 miles north of the reservoir, is at the same locality as the type section of the Stockade Beaver Shale Member and is given on page N13. The Lak Member is about 75 feet thick and consists of pink to pale-red friable noncalcareous siltstone and very fine grained sandstone. The member erodes easily and is generally poorly exposed. The Lak grades downward into the Hulett Sandstone Member through a few inches to several feet of alternating pink and yellowish-gray sandstone and siltstone.

REDWATER SHALE MEMBER

The Redwater Shale Member of the Sundance Formation is about 160 feet thick in the Newcastle area. The member is nonresistant and poorly exposed. On steep slopes it forms extensive landslides.

Most of the Redwater Shale Member is greenish-gray shale interbedded and interlaminated with light-gray calcareous siltstone and very fine grained sandstone. A few coquinoid or oolitic limestone beds that are generally about half a foot thick form slabby ledges in the upper part of the member. Thin stringers 1 or 2 inches thick of pink and white gypsum occur in a zone 10 to 15 feet thick about 25

feet below the top of the member in Dey Draw, 2 to 3 miles east of Newcastle, and also along the west side of the LAK Reservoir in sec. 6, T. 44 N., R. 60 W. At Dey Draw, lenticular platy masses of white chert 1 to 2 inches thick and about 1 foot long are interbedded with sandstone and shale in the top 20 feet of the member. Sandstone, siltstone, and limestone in the Redwater Member generally are glauconitic, especially the sandstone in the basal part of the member. The topmost bed of the Redwater Shale Member is a bed of calcareous yellow-weathering sandstone or sandy limestone, generally 1 to 5 feet thick, that can be traced for many miles along the west side of the Black Hills. A similar bed in other parts of Wyoming was included at the top of the Sundance Formation by Pipiringos (1957, p. 24–25) and at the base of the Morrison Formation by Love (1958, p. 68–70).

The contact of the Redwater Shale Member with the underlying Lak Member is marked by an abrupt change from sandstone that is light gray, calcareous, and abundantly glauconitic in the Redwater to sandstone, or siltstone that is pink and nonglauconitic in the Lak. Imlay (1947, p. 257) suggested that the contact is a disconformity.

MORRISON FORMATION

The Morrison Formation forms a narrow band of outcrops on the sides and in the bottoms of many of the deeper valleys in the northern part of the Newcastle area. Talus and landslide material cover the formation at many places, but the Morrison is locally well exposed on the west side of Oil Creek (locs. 1, 3, pls. 1, 3), at the head of East Plum Creek, near the mouth of Salt Creek (locs. 13, 14, 28, pls. 1, 3), and on the west side of the LAK Reservoir (loc. 32, pls. 1, 3). The Morrison Formation ranges in thickness from 100 to about 140 feet at the above-mentioned localities.

The Morrison can be divided into two lithologically distinct parts. The lower part attains a thickness of about 80 to 100 feet and consists mostly of greenish-gray and grayish-red calcareous claystone and marl interbedded with nodules and thin beds of light-gray argillaceous limestone. The basal 30 to 40 feet of the formation contains some thin beds of grayish-white very fine grained sandstone that commonly are ripple marked and crossbedded. Lenses of grayish-white sandstone 30 feet thick crop out at the base of the Morrison along Oil Creek in sec. 4, T. 46 N., R. 62 W., and on the west side of Salt Creek in secs. 15 and 22, T. 45 N., R. 61 W. At both localities the sandstone is friable, very fine grained to fine grained, massive, and closely resembles the Unkpapa Sandstone which locally replaces the Morrison Formation at the south end of the Black Hills (Darton and Paige, 1925, p. 11). The sandstone bed along Oil Creek extends northward

Morrison and parts of adjacent formations at Dey Draw, SW¼ sec. 23, T. 45 N., R. 61 W., Weston County, Wyo.

[Loc. 14, pls. 1, 3]

	Feet
Lakota Formation (part):	
13. Sandstone, light-gray to grayish-yellow, fine-grained, cross-bedded, well-sorted; forms a cliff	41
12. Claystone, dark-gray to olive-gray, silty to sandy, very carbonaceous, noncalcareous	6
Partial thickness Lakota Formation	47
Morrison Formation:	
Upper part:	
11. Mostly covered; grayish-green noncalcareous claystone exposed by digging at the top of the interval	16
10. Claystone, grayish-green, noncalcareous	15±
Section below offset about 1,000 ft southwest to a small knob near the center of the SE¼ sec. 23.	
Lower part:	
9. Claystone, greenish-gray, noncalcareous to slightly calcareous; a lens of light-gray limestone about 1 ft thick that contains greenish-gray clay pellets crops out at the top of the unit and at the top of the hill	11
8. Limestone, light-gray, lenticular; contains many greenish-gray pellets as much as ¼ inch in diameter	1½
7. Claystone, banded greenish-gray and grayish-red, calcareous; a few thin lenticular beds of light-gray argillaceous limestone in the lower half; a bed 1 ft thick of grayish-white very fine grained sandstone 8 ft above the base; unit contains locally abundant ostracodes and charophytes USGS loc. 26899, 30 ft above base; *Darwinula* sp., *Bisulcocypris*? sp. (similar to Peck, 1959, pl. 2, No. 25), *"Metacypris"* sp., *Theriosynoecum wyomingensis* (similar to Peck, 1959, pl. 2, No. 24), smooth genus, undet., Chara. USGS loc. 26900, 3 ft above the base; *Darwinula* sp., *Bisulcocypris*? sp. (same as above), *"Metacypris"* spp., *Theriosynoecum wyomingensis* (same as above), smooth genus, undet. (same as above); large genus, undet., Chara	65
6. Sandstone, grayish-white, very fine grained, very calcareous, ripple-marked; forms a slabby ledge	1
5. Claystone, greenish-gray, silty to sandy	½
Thickness, rounded, Morrison Formation	110±
Sundance Formation (part):	
Redwater Shale Member (part):	
4. Sandstone, moderate-yellow, very fine grained, very calcareous, friable	2½
3. Sandstone and shale, interbedded and interlaminated; sandstone is light gray, very fine grained, calcareous, friable; shale is dark gray, noncalcareous; a lens ½ ft thick of very light gray chert about 10 ft above the base	23
2. Sandstone and gypsum, interbedded; sandstone is light gray to light greenish gray, very fine grained, calcareous; gypsum is white and pink, in beds ½ to 2 in. thick; some interlaminated green shale	12
1. Sandstone, light-gray to light greenish-gray, very fine grained to silty, calcareous, friable; some green shale laminae	5
Partial thickness, rounded, Sundance Formation	42

for about 2 miles into the southern part of the adjacent Inyan Kara Mountain quadrangle, where locally it reaches a thickness of 150 feet (Mapel and Pillmore, 1963). The sandstone along Salt Creek was traced for about 1 mile in outcrops between localities 13 and 28 (pl. 1); its extent and thickness underground to the east is unknown.

The upper part of the Morrison Formation is as much as 40 feet thick and consists of noncalcareous claystone that is generally dark greenish gray in the lower part and grades upward to dark gray or dark brownish gray at the top. The noncalcareous upper part of the formation rests sharply on the lower calcareous part.

The Morrison grades downward into the Sundance Formation within 2 or 3 feet stratigraphically. The contact is taken to be the top of a persistent bed of yellow-weathering sandstone that marks approximately the transition from marine rocks in the Sundance to nonmarine rocks in the Morrison.

The stratigraphic section on page N17 is typical of the Morrison Formation. A second complete section of the Morrison is given with a description of the overlying Lakota Formation on page N21.

Ostracodes and charophytes are common in the lower calcareous part of the Morrison Formation. The fossils so far reported are generally regarded as Late Jurassic (Kimmeridgian) in age (Reeside *in* Yen, 1952, p. 22–26; Peck, 1957, p. 8; Sohn, 1958, p. 124). Ostracodes collected at Dey Draw are listed in the stratigraphic section above; ostracodes from Oil Creek (loc. 3, pls. 1, 3) are given below (fossils identified by I. G. Sohn):

1. USGS loc. 26901. Greenish-gray marl about 5 ft above creek level:
   Genus indet.; small, round.
   Smooth elongate genus similar to the form illustrated by Peck (1959, pl. 2, no. 23)
   Smooth genus, indet.
   Darwinula sp.
   Bisulcocypris? sp.; similar to the form illustrated by Peck (1959, pl.2, no. 25).
   Theriosynoecum wyomingensis
2. USGS loc. 26902. Greenish-gray marl 17 ft above creek level:
   Theriosynoecum wyomingensis
   Darwinula sp.
   Smooth genus, indet., same as in USGS 26901.
3. USGS 26903. Gray marl 37 ft above creek level:
   Large genus, undet.
   Darwinula sp.
   Smooth genus, indet.; same as in USGS 26901.

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

LAKOTA FORMATION

The Lakota Formation consists mostly of sandstone, conglomeratic sandstone, claystone, and intermediate rock types. It crops out in cliffs and ledges in all the main canyons in the north-central part of the Newcastle area, and it caps high ridges on the divide east of Salt

Creek in the northeastern part. The formation is about 160 feet thick along Oil Creek in sec. 4, T. 46N., R. 62 W.; elsewhere, it ranges in thickness from 175 to 260 feet. Variations in the thickness and lithology of the formation and correlations of some intraformational units are shown in the columnar sections on plate 3.

In the northern part of the Newcastle area a local unconformity divides the Lakota formation into a lower part and an upper part of contrasting lithology. These two parts have been followed northwestward for several miles into the adjoining Inyan Kara Mountain 15-minute quadrangle (Mapel and Pillmore, 1963).

The lower part of the Lakota is generally between 50 and 100 feet thick in the upper valleys of Oil and West Plum Creeks in the northwestern part of the area and between 100 and 140 feet thick at most other places. The variation in thickness results partly from erosional relief on the surface of unconformity. In some areas, however, thinning of the lower part is not compensated for by thickening of the upper part. At these places, slight folding and erosion during or after deposition of the lower part of the Lakota may account for the thinning. The lower part of the Lakota Formation is only about 20 feet thick along Oil Creek at locality 1 (pls. 1, 3). This locality is on the south flank of the small Oil Creek dome, which lies in the Inyan Kara Mountain quadrangle to the north, and which was folded during Lakota time (Izett, Pillmore, and Mapel, 1961). Thinning in this area seems clearly due to folding and erosion of the lower part of the Lakota Formation before deposition of the upper part.

The lower part of the Lakota consists mostly of light-gray to light yellowish-gray very fine grained to fine-grained friable sandstone in thin to thick tabular beds. Locally the sandstone is crossbedded. Thin beds of brown carbonaceous siltstone and silty shale are locally interbedded with the sandstone, particularly at the base of the formation and in a zone a few inches to as much as 15 feet thick about 50 to 60 feet above the base. At Cambria, in and near sec. 29, T. 46 N., R. 61 W., and at a few other places nearby, the upper carbonaceous zone contains coal deposits and has been widely prospected. The coal bed or beds in the zone are discontinuous, but the carbonaceous zone itself can be traced over most of the northern part of the Newcastle area and is useful for correlation. (See pl. 3.) Commonly the basal few inches or few feet of the Lakota contains interbedded gray or brown claystone, and the formation appears to grade downward into the noncalcareous upper part of the Morrison. No unconformity was recognized. The Lakota-Morrison contact is picked arbitrarily at the base of the stratigraphically lowest bed of sandstone or siltstone above the calcareous part of the Morrison.

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The upper part of the Lakota Formation is as thin as 60 feet on the divide west of the LAK Reservoir, and it may be only about 20 feet thick locally at the mouth of Cambria Canyon (loc. 12, pls. 1, 3); elsewhere in the northern part of the Newcastle area, it is mostly between 100 and 160 feet thick. The upper part of the Lakota is more varied lithologically than the lower part. It is characterized by conspicuously crossbedded conglomeratic sandstone that contains granules and pebbles of chert and quartzite in discontinuous lenses. Beds of variegated sandy to conglomeratic claystone and siltstone alternate and intertongue with the sandstone. Polished rounded pebbles and cobbles of quartzite and chert are concentrated in thin zones in some of the sandy claystone beds. Locally claystone or siltstone is silicified to form lenticular blocky ledges of chert 1 or 2 feet thick and several feet long.

The Lakota Formation at most places in the area contains no limestone and little or no calcite cement. However, at locality 21 (pls. 1, 3), near the junction of Grant and Cambria Canyons, a bed of fine- to coarse-grained sandstone about 20 feed thick is brecciated and recemented with laminated brown, yellow, and white calcite. Parts of the bed contain more than 50 percent calcite. The breccia was traced about 200 yards.

Siltstone and claystone in the topmost 5 to 10 feet of the Lakota Formation at places contain many small ferruginous pellets about 1 mm or less in diameter that weather dark red to yellow brown. Several of these were picked from a sample of weathered siltstone collected near Devils Tower, about 60 miles northwest of Newcastle, and were found by X-ray diffraction to consist of the iron oxides goethite and hematite (L. G. Schultz, analyst). Waagé (1959, p. 55–56) reported that spherules from drill cores in Crook County, Wyo., consist of siderite with a spherulitic structure. The ferruginous pellets are less numerous or are absent where the topmost beds of the Lakota consist of sandstone rather than siltstone or claystone. Beds containing the ferruginous pellets generally weather to shades of light gray, pink, yellow, and purple. The ferruginous zone is a widespread feature of the uppermost part of the Lakota Formation in the Black Hills (Waagé, 1959, p. 55–58).

Lakota, Morrison, and parts of adjacent formations on the west side of Oil Creek, in the NW¼ sec. 4, T. 46 N., R. 62 W., Weston County, Wyo.

[Loc. 1, pls. 1, 3]

Top of the ridge.
Fall River Formation (part):
Lower part (part):

	Feet
21. Sandstone, light-gray, very fine grained, thin-bedded; weathers yellowish-gray; a few seams cemented with iron oxides; locally carbonaceous; forms slabby ledges	8

Fall River Formation (part)—Continued

	Feet
Lower part (part)—Continued	
20. Shale, very dark gray, silty, carbonaceous	15
19. Sandstone, light-gray, fine-grained, thin-bedded; locally carbonaceous; some medium- to coarse-grained sandstone and scattered pebbles of chert and quartzite in the basal part; forms a prominent ledge	19
Partial thickness, Fall River Formation	42

Lakota, Morrison, and parts of adjacent formations on the west side of Oil Creek, in the NW¼ sec., T. 46 N., R. 62 W., Weston County, Wyo.—Continued

Unconformity.

Lakota Formation:

	Feet
Upper part:	
18. Claystone; mostly light olive gray; some dark-red to reddish-purple bands; silty to slightly sandy	15½
17. Sandstone; mostly light gray, mottled purple, red, and yellow; very fine grained; forms a blocky ledge	2
16. Siltstone; mostly olive gray, mottled red and yellow; some interbedded very fine grained to fine-grained sandstone in the middle part	7
15. Sandstone; mostly yellowish gray, mottled red, fine-grained; forms a ledge	6
14. Siltstone, light olive-gray, friable	1½
13. Sandstone, light-gray to light yellowish-gray; mostly fine grained; a few lenses of medium- to coarse-grained sandstone and a few scattered granules of chert; friable; cross-bedded; basal 1 ft impregnated with iron oxides; forms a massive cliff	112
Local unconformity.	
Lower part:	
12. Sandstone, light-gray, fine-grained, carbonaceous, hard; forms a blocky ledge	2
11. Claystone; mostly light gray; a grayish-black band near the top; noncalcareous; very sandy in the basal 3 ft	19
Thickness, Lakota Formation	165

Morrison Formation:

Upper part:	
10. Claystone, dark greenish-gray, noncalcareous; slightly sandy near the middle	19½
Lower part:	
9. Claystone, dark greenish-gray; locally weathers purplish gray; calcareous; silty	22
8. Covered	5
7. Claystone, greenish-gray, calcareous, silty	6
6. Covered	12
5. Sandstone, grayish-white, very fine grained, very friable, calcareous, massive, nonresistant	38
Thickness, rounded, Morrison Formation	102

Sundance Formation (part):

Redwater Shale Member (part):	
4. Sandstone, dark yellowish-gray, very fine grained, calcareous, friable; makes a yellow band on the hillside	5
3. Shale and sandstone, interbedded and interlaminated; shale is dark greenish gray, noncalcareous; sandstone is light gray, very fine grained to silty, calcareous, friable	4½
2. Sandstone, grayish-white, very fine grained, calcareous, friable, thin-bedded	8½

Sundance Formation (part)—Continued

	Feet
Redwater Shale Member (part)—Continued	
1. Shale, dark greenish-gray, micaceous, silty; contains laminae of light-gray very fine grained sandstone and siltstone; a thin bed of sandy glauconitic light-gray limestone at the base	22
Partial thickness, Sundance Formation	40

Parts of the Fall River and Lakota Formations along a tributary to Oil Creek, about the center N½ sec. 26, T. 46 N., R. 62 W., Weston County, Wyo.

[Loc. 6, pls. 1, 3]

Top of the ridge.

Fall River Formation (part):

	Feet
Upper part (part):	
20. Sandstone, very light gray, locally stained yellowish-gray and red, fine-grained, friable, well-sorted; scattered nodules cemented by iron oxides; locally crossbedded; forms rounded ledges. (Unit thickens to at least 75 ft and locally replaces most or all of the lower part of the Fall River Formation within about 200 yds northwest.)	33
Lower part:	
19. Covered	9
18. Siltstone, laminated light- and dark-gray, nonresistant	1½
17. Sandstone, light yellowish-gray, very fine grained to silty, thin-bedded, nonresistant	1½
16. Sandstone, very light-gray to light yellowish-gray; mostly very fine grained to silty; scattered coarse grains and granules in top one-half foot; cross-laminated; calcareous at the top; forms a ledge	9
15. Sandstone, very light gray, yellowish-gray weathering, coarse-grained; scattered granules; lenticular	½
14. Siltstone and sandstone, interbedded; very light gray and light yellowish gray; in beds as much as 1 ft thick; ripple marked; locally forms slabby ledges	18
13. Covered	18
12. Siltstone, very dark gray, shaly, very carbonaceous	8
Partial thickness, rounded, Fall River Formation	98

Unconformity.

Lakota Formation (part):

Upper part:	
11. Covered	13
Section below offset about 200 yd southeast on top of the underlying unit.	
10. Sandstone, light-gray to yellowish-gray, fine-grained, crossbedded; forms ledges	15
9. Claystone, olive-gray, very sandy	3
8. Sandstone, light-gray to yellowish-gray; mostly fine grained; some irregular lenses of medium- to coarse-grained sandstone at the base; hard; forms splintery ledges	13
7. Siltstone, red, shaly	1
6. Sandstone, light-gray to light yellowish-gray, poorly sorted, clayey; lower part nonresistant, upper 4 ft cherty and forms a ledge	18
5. Mostly covered; some red and olive-gray siltstone and silty claystone	10
4. Sandstone, light-gray; mostly fine to medium grained; grades downward to coarse-grained to granule sandstone in the basal 20 ft; polished pebbles of red and white chert and gray and pink quartzite in the top 5 ft; friable; crossbedded; forms ledges and cliffs	95

Lakota Formaton (part)—Continued
Local unconformity.
Lower part (part):

	Feet
3. Sandstone, light-gray, fine-grained; friable in the lower part, becoming firmly cemented in the top 6 ft; massive to indistinctly tabularly bedded; forms ledges	40
2. Mostly covered; some light gray fine grained friable sandstone in the middle part	20
1. Sandstone, light-gray, fine-grained, massive to indistinctly tabularly bedded, friable; forms ledges	24
Partial thickness, Lakota Formation	252

Base of the exposure, about 5 ft above creek level.

Parts of the Fall River and Lakota Formations along a tributary of Oil Creek, about the center N½ sec. 11, T. 45 N., R. 62 W., Weston County, Wyo.

[Loc. 9, pls. 1, 3]

Top of the ridge.
Fall River Formation (part):
Upper part (part):

	Feet
16. Sandstone, very light gray, light-brown weathering, fine-grained, friable; locally crossbedded; scattered nodules cemented with iron oxides; forms massive cliff	50

Lower part:

15. Covered	33
14. Sandstone, light-gray, tan weathering, very fine grained to fine-grained; contains thin lenses and nodules cemented with iron oxides; cross-laminated, in beds mostly less than than one-half foot thick; forms slabby ledges	11
13. Mostly covered; some very dark gray carbonaceous siltstone	10
Partial thickness, Fall River Formation	104

Unconformity.
Lakota Formation (part):
Upper part:

12. Partly covered; very light gray silty sandstone in scattered outcrops	5
11. Sandstone, light-gray, brown weathering, very fine grained, to fine-grained, crossbedded; forms a ledge locally	16
10. Covered	17
9. Claystone, medium-gray, very sandy	5
8. Sandstone, very light gray; mostly fine grained; clayey; non-resistant	38
7. Sandstone, light-gray; mostly fine grained; coarse-grained to pebbly streaks and lenses; friable; crossbedded; forms ledges	13

Local unconformity.
Lower part (part):

6. Sandstone, very light gray, very fine grained to fine-grained; in beds mostly ½ to 2 ft thick; locally carbonaceous; forms ledges	15
5. Shale, dark-brown, very carbonaceous	2½
4. Sandstone, very light gray, very fine grained; in beds mostly ½ to 1 ft thick; forms blocky ledges	6
3. Shale, dark-brown, very carbonaceous	1½
2. Sandstone, light-gray, very fine grained, quartzitic; forms a hard blocky ledge	4
1. Sandstone, very light gray, very fine grained to fine-grained; in irregular beds mostly ½ to 2 ft thick; friable; locally cross-laminated; slightly carbonaceous in top 10 ft; forms ledges	65
Partial thickness, Lakota Formation	188

Lakota and parts of the adjacent formations near the junction of East Plum Creek and North Draw, NW¼ sec. 7, T. 46 N., R. 61 W., Weston County, Wyo.

[Loc. 23, pls. 1, 3]

	Feet
Top of the ridge.	
Fall River Formation (part):	
Upper part (part):	
18. Sandstone, very pale orange; some pink stain on weathered surfaces; fine-grained; faintly crossbedded; forms a massive cliff	55
Lower part:	
17. Covered	54
16. Sandstone, light-gray, to very fine grained to fine-grained, massive, slightly carbonaceous; forms a persistent ledge that can be traced for at least a mile in this vicinity	3
15. Mostly covered; some dark-gray carbonaceous shale at the base	5
Partial thickness, Fall River Formation	117
Unconformity.	
Lakota Formation:	
Upper part:	
14. Covered	7
13. Claystone, gray to olive-gray; mottled pink and red in the top 3 to 4 ft; locally silty to sandy	40
12. Partly covered; scattered exposures of light-gray and purplish-gray fine-grained clayey sandstone and sandy claystone; a few lenses of very coarse grained sandstone in the lower half of the unit; nonresistant	27
11. Sandstone; mostly grayish white; a few dark-red and pink laminae in the lower 10 to 15 ft; mostly very fine grained to silty and clayey; a few stringers of coarser grained sandstone in the upper part; thinly and irregularly bedded; grades laterally into thick-bedded cliff-forming sandstone within a few hundred feet to the north	33
10. Covered	10
9. Claystone, dark purplish-red, noncalcareous; sandy in the lower part	8½
8. Poorly exposed; appears to be mostly fine grained very friable yellowish-gray sandstone	20
7. Sandstone, light-gray; mostly fine- to medium-grained; granules and small pebbles of chert and quartzite in thin lenses; crossbedded; forms a ledge	20
Local unconformity.	
Lower part:	
6. Sandstone, light-gray, very fine grained to fine-grained; locally silicified; forms slabby to blocky ledges	7
5. Claystone, dark-gray, medium gray weathering; very sandy in the upper part	5½
4. Sandstone, light-gray; locally stained grayish orange, fine to medium grained; locally inconspicuously crossbedded; forms a cliff locally	51
3. Covered	22
Thickness, Lakota Formation	251
Morrison Formation (part):	
Upper part (part):	
2. Claystone, grayish-black, noncalcareous	2
1. Mostly covered; some greenish-gray noncalcareous claystone in the lower part	12
Partial thickness, Morrison Formation	14
Base of the exposure.	

Lakota and parts of adjacent formations at Cambria, about the center sec. 29, T. 46 N., R. 61 W., Weston County, Wyo.

[Loc. 26, pls. 1, 3]

	Feet
Top of the hill.	
Fall River Formation (part):	
Lower part (part):	
21. Sandstone, very light gray, fine-grained; in indistinct beds about 2 ft thick, friable; forms a cliff	40±
Unconformity.	
Lakota Formation:	
Upper part:	
20. Covered	10
19. Claystone, medium-gray; locally mottled red and yellowish orange; ferruginous pellets about 1 mm in diameter in thin zones in the upper half	10
18. Mostly covered; a ledge-forming bed of granule sandstone about 2 ft thick, 24 ft above the base	64
17. Sandstone, very light gray; stained red locally; fine to coarse grained; many granules and pebbles of chert, quartzite, and siltstone; crossbedded; forms rounded ledges	12
16. Sandstone, very light gray; mostly fine grained; some thin lenses of coarser grained sandstone; crossbedded; friable; forms rounded ledges	33
Local unconformity.	
Lower part:	
15. Covered	24
14. Sandstone, very light gray to light yellowish-gray, fine-grained; in irregular beds 2 to 4 ft thick; indistinctly crossbedded; forms rounded ledges	17
13. Partly covered; scattered outcrops of slabby light yellowish-gray fine-grained carbonaceous sandstone	21
12. Sandstone, siltstone, and coal as follows:	
Sandstone, brownish-black, very fine grained, very carbonaceous (Feet: 1.4)	
Siltstone, brown, massive, carbonaceous (Feet: 1.5)	
Siltstone, yellowish-gray (Feet: .8)	
Coal (Feet: .8)	
Total	4
11. Sandstone, light-gray, very fine grained to fine-grained, carbonaceous; beds mostly less than 4 in. thick; cross-laminated; locally ripple marked; forms ledges	25
10. Sandstone; mostly light-gray; some brown carbonaceous laminae; very fine grained; very thin bedded	6
9. Sandstone, very light gray, very fine grained to fine-grained, carbonaceous; forms a minor ledge	3
8. Covered	5
7. Claystone, grayish-brown to brownish-black, carbonaceous, slightly silty, noncalcareous	6
6. Sandstone, light yellowish-gray to grayish-white, very fine grained; some interlaminated brown carbonaceous silty shale; a bed 1½ ft thick of dark-gray carbonaceous shale about 6 ft above the base	12
5. Claystone, dark-gray to brownish-gray, carbonaceous, very sandy	2
4. Sandstone, grayish-yellow, very fine grained; forms a minor ledge	1
Thickness, Lakota Formation	255
Morrison Formation (part):	
Upper part:	
3. Claystone, brownish-gray to dark-gray; grades downward to greenish gray in the bottom 4 to 6 ft; noncalcareous	28
2. Covered	14
1. Claystone, greenish-gray and grayish-red, calcareous; nodules and thin lenticular beds of light-gray limestone; slightly sandy	45
Partial thickness, Morrison Formation	87
Base of the exposure.	

The lower, coal-bearing part of the Lakota in the Newcastle area corresponds closely to the Chilson Member, and the upper conglomeratic part corresponds to the Fuson Member of the Lakota Formation as described by Post and Bell (1961) in the southern part of the Black Hills.

Except for carbonaceous material, the Lakota Formation is sparsely fossiliferous in the Black Hills. Fossils reported from the formation include cycad, fern, and conifer foliage (Fontaine, 1899); ostracodes (Sohn, 1958), charophytes (Peck, 1957, p. 11); and a few fresh-water mollusks and dinosaur bones. These fossils indicate an Early Cretaceous (Aptian?) age for the formation. No fossils were collected from the Newcastle area.

FALL RIVER FORMATION

The Fall River Formation is about 125 to 145 feet thick in outcrops in most parts of the Newcastle area. It is 200 feet thick at the mouth of Cambria Canyon (loc. 12, pls. 1, 3), but at this locality a thick sandstone at the base of the Fall River fills a channel that may cut 50 to 60 feet into the underlying Lakota Formation. Thick sandstone beds in the Fall River resist erosion, and the formation characteristically underlies broad divides and dip slopes in much of the north-central and northeastern parts of the area.

The formation is divided into two parts on the geologic map (pl. 1) and in stratigraphic sections (pl. 3). The lower part is commonly 50 to 65 feet thick, although in secs. 6 and 34, T. 46 N., R. 62 W., it is locally 80 to 90 feet thick; and near the mouth of Cambria Creek, sec. 20, T. 45 N., R. 61 W., it is locally more than 100 feet thick. This part of the formation is generally nonresistant and underlies grass-covered slopes above forested ledges and cliffs of the underlying Lakota Formation. Typically it consists of light- to dark-gray siltstone and silty shale interbedded and interlaminated with thin beds of light-gray to light yellowish-gray siltstone and very fine grained sandstone. Along Oil and East and West Plum Creeks, sandstone beds 30 to 50 feet stratigraphically above the base of the formation commonly contain inconspicuous lenses 1 or 2 inches thick of coarse-grained to granule sandstone in which quartz and light-colored chert make up most of the larger fragments. The basal 10 to 20 feet of the formation generally is dark-gray siltstone and shale that contains abundant carbonaceous material. These beds rest unconformably on a nearly plane surface cut on underlying lighter colored generally nonfissile beds of the Lakota.

Firmly cemented tan-weathering siltstone or very fine grained sandstone commonly make thin persistent ledges in the lower 20 to 40 feet of the formation at places along Oil and Plum Creeks. East

of Skull Creek, in and near secs. 6 and 7, T. 46 N., R. 62 W., a bed as much as 20 feet thick of very fine grained to fine-grained sandstone makes prominent rounded ledges in this lower part. From place to place along Oil Creek and on the divides bordering Cambria and Camp Canyons, sandstone near the base of the Fall River thickens to more than 50 feet, becomes fine to medium grained, thick bedded, friable, and locally, conspicuously crossbedded (fig. 2). The largest of these sandstone bodies trends northward through Newcastle and Cambria, as shown by the index map on plate 3, and is at least 7½ miles long and 2½ miles wide. At Newcastle (loc. 12, pls. 1, 3) it appears to fill a broad channel cut perhaps 50 to 60 feet deep in the Lakota Formation. Crossbeds in the channel at this locality dip steeply N. 10° E. Sandstone lenses at the base of the Fall River formation along Oil Creek are somewhat thinner and less well defined than the one near Newcastle, but they also appear to be elongated northward. Granules and small pebbles of sandstone and siltstone, and less commonly granules of chert, occur locally at the base of the sandstone lenses.

The upper part of the Fall River Formation is 40 to 80 feet thick. At its base is a bed of massive to inconspicuously crossbedded very fine grained to fine-grained, well-sorted friable sandstone that is locally more than 50 feet thick and that commonly forms rounded tan-weathering ledges and cliffs on the crests of high divides (fig. 2). The sandstone generally contains scattered nodules of 1 or 2 inches in diameter impregnated with dark-brown iron oxides. The massive sandstone rests sharply on thinner bedded siltstone and sandstone in the lower part of the formation at most places. Where the sandstone is thinner and less conspicuous, however, as at locality 12 near Newcastle (pls. 1, 3), and at places on the divide between Oil and Skull Creeks in the northwest corner of the area, the lower part of the sandstone sequence is broken by silty partings in a gradational zone a few feet thick in which the two parts of the formation apparently intertongue.

Near locality 6 (pls. 1, 3) the massive sandstone in the upper part of the Fall River Formation thickens abruptly in an area of several acres from about 35 to at least 75 feet and appears to truncate most or all of the lower part of the formation.

Overlying the thick sandstone in the upper part of the Fall River and comprising the remainder of the formation are nonresistant thin-bedded sandstone, siltstone, and shale beds that grade upward into black marine shale of the overlying Skull Creek Shale.

Nodules and beds 1 or 2 inches thick of siltstone and sandstone impregnated with dark-brown iron oxides are common in both the lower and the upper parts of the Fall River Formation. Many silt-

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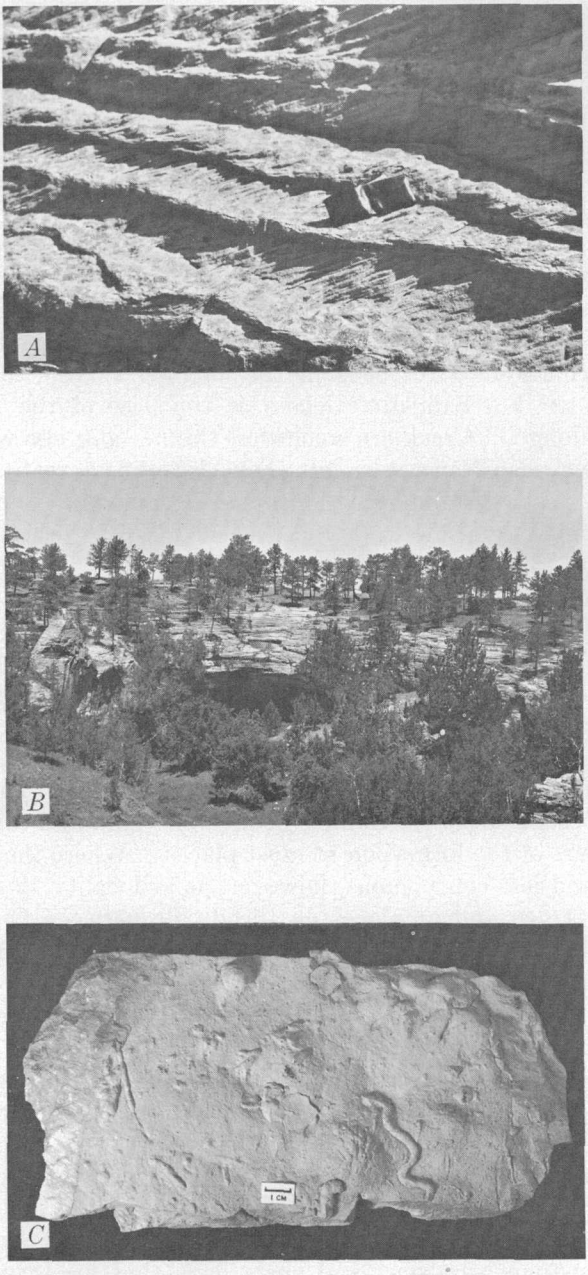

FIGURE 2.—Fall River Formation, Newcastle area. *A*, Steeply dipping crossbeds in sandstone at the base of the Fall River Formation at the mouth of Cambria Canyon, locality 12, plates 1 and 3. Wallet gives scale. *B*, Thick sandstone in the upper part of the Fall River Formation at head of Cave Spring Canyon, sec. 12, T. 45 N., R. 62 W., Weston County, Wyo. *C*, Raised markings on sandstone slab from the Fall River Formation.

stone and thin sandstone beds are cross-laminated and ripple marked, and markings that resemble worm trails and burrows cover the surfaces of many thin beds (fig. 2). These features and the thin relatively even bedding of much of the formation suggest that the Fall River Formation was deposited in quiet shallow water, perhaps in broad estuaries or on tidal flats (Waagé, 1959, p. 75). Local high-angle crossbeds like those shown on figure 2 and the broad, U-shaped cross sections of the sandstone lenses in the basal part of the formation

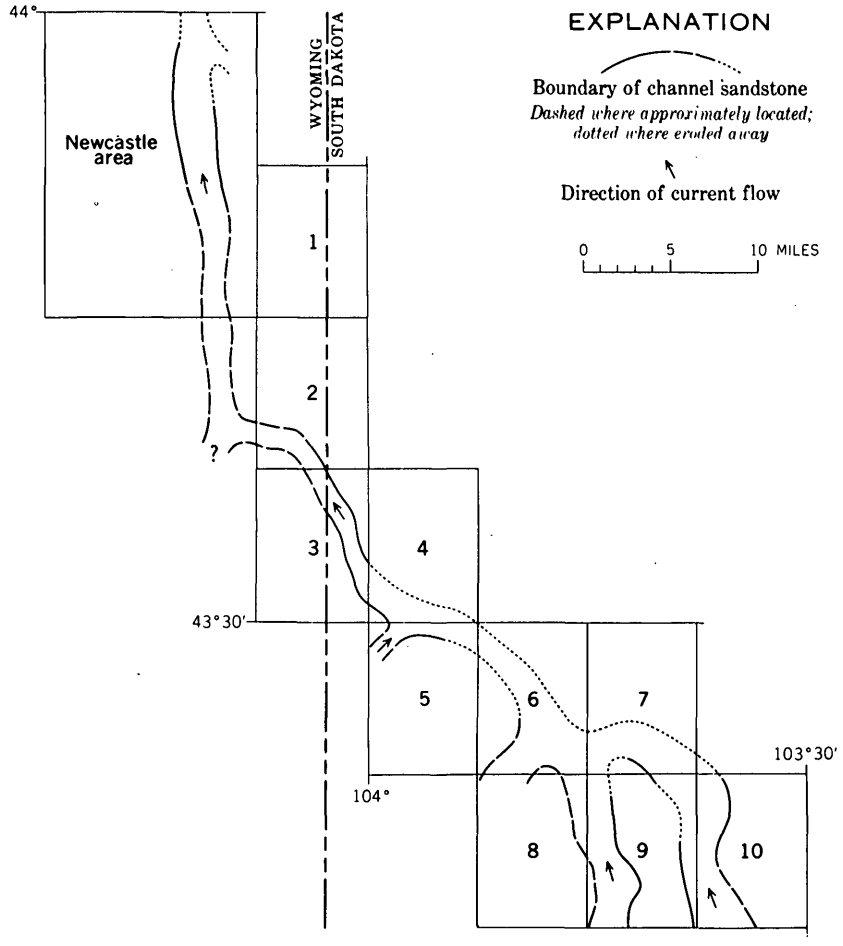

FIGURE 3.—Channel sandstone in the basal part of the Fall River Formation, southwestern part of the Black Hills. Distribution of sandstone in quadrangles southeast of the Newcastle area from Brobst (1956, fig. 24). Quadrangles: 1, Fanny Peak; 2, Clifton; 3, Dewey; 4, Jewel Cave SW; 5, Burdock; 6, Edgemont NE; 7, Minnekahta; 8, Edgemont; 9, Flint Hill; 10, Cascade Springs.

are features that might be expected in the channel deposits of streams that were perhaps feeding a low-lying coastal area or delta plain. Brobst (1956, p. 180, fig. 24) described a system of northward-trending channel sandstones at or near the base of the Fall River Formation in the southwestern part of the Black Hills. As shown on figure 3, the thick basal sandstone lens in the Fall River at Newcastle may be a continuation of this system.

Uniformly good sorting and the relatively flat basal contact of the thick sandstone beds in the upper part of the formation suggest that these deposits had a different origin. They represent, perhaps, a system of barrier bars laid down offshore where little scouring of the bottom took place.

Four stratigraphic sections of the Fall River Formation given below illustrate its lithologic details. Other sections are given with description of the Lakota Formation, pages N21–N25.

Part of the Fall River Formation along a tributary to Skull Creek, SW¼SW¼ sec. 6, T. 46 N., R. 62 W., Weston County, Wyo.

Top of the ridge.
Fall River Formation (part):

	Feet
Upper part (part):	
13. Sandstone, light-gray to light yellowish-gray; locally stained pink; very fine grained to fine grained; friable; forms rounded ledges	15
Lower part:	
12. Covered	3
11. Sandstone, very light gray, very fine grained to silty, calcareous; forms slabby ledges	1½
10. Covered	5
9. Sandstone, very light yellowish gray, very fine grained to silty, thin-bedded; forms slabby ledges	11
8. Sandstone and siltstone, light-gray to olive-gray, interbedded, nonresistant	2
7. Sandstone, light-gray; mostly very fine grained; scattered coarse to very coarse grains; calcareous; cross-laminated; forms a ledge	1½
6. Sandstone and siltstone, light-gray and olive-gray, interlaminated, locally carbonaceous; raised markings on bedding surfaces that resemble worm trails; nonresistant	21
5. Sandstone, very light gray, very fine grained to fine grained, cross-laminated; forms prominent ledges. Nearby unit is ripple marked, and top one-half foot contains scattered granules and pebbles of chert	19
4. Siltstone, light-gray to olive-gray, shaly; a few seams cemented with iron oxides; raised markings on bedding surfaces that resemble worm trails; nonresistant	11
3. Sandstone, very light gray, very fine grained; forms a blocky ledge	3
2. Siltstone, medium- to dark-gray, carbonaceous; a few nodules cemented with iron oxides	4
1. Siltstone, very dark gray, shaly, carbonaceous; base of unit probably approximately the base of the Fall River Formation	7
Partial thickness, Fall River Formation	104

Stream bottom.

Parts of the Fall River and Lakota Formations near the mouth of Oil Creek Canyon, NE¼ sec. 4, T. 45 N., R. 62 W., Weston County, Wyo.

[Loc. 8, pls. 1, 3]

Top of the ridge.

	Feet
Fall River Formation (part):	
Upper part (part):	
18. Sandstone, grayish-orange to grayish-yellow, fine-grained; bottom half mainly a single bed, becomes medium to thin bedded in the upper part; crossbedded; scattered nodules cemented by iron oxides; forms a cliff	50
Lower part:	
17. Sandstone and siltstone, interbedded; sandstone is light gray, very fine grained; siltstone is medium gray	3½
16. Siltstone; dark gray at the base becoming medium gray at the top; contains contorted light- and dark-gray laminae; a few seams cemented with iron oxides; very thin bedded; nonresistant	5
15. Sandstone, light-gray to grayish-yellow, very fine grained; in beds mostly less than one-half foot thick, somewhat thicker bedded at the top; cross-laminated; many thin seams cemented with iron oxides; markings that resemble worm trails locally on bedding surfaces; forms slabby ledges	29
14. Siltstone, laminated light- and dark-gray, thin-bedded	2
13. Siltstone, dark-gray, carbonaceous, massive	3
12. Siltstone and sandstone, interlaminated; siltstone is dark gray; sandstone is light gray, very fine grained; some thin layers cemented with iron oxides; thin bedded at the base, thicker bedded at the top; markings that resemble worm trails on some bedding surfaces; nonresistant	5½
11. Shale, dark-gray, silty	½
10. Siltstone, light- to medium-gray, carbonaceous, shaly; top 2 ft forms a blocky ledge	4
9. Shale, dark-gray, silty, slightly carbonaceous	2½
Partial thickness, rounded, Fall River Formation	105

Unconformity.

Lakota Formation (part):	
Upper part:	
8. Sandstone, light-gray, fine- to medium-grained; locally stained yellow; a few seams and nodules cemented with iron oxides, friable; massive; forms ledges locally	18
7. Mostly covered; some sandy light-gray claystone about 6 ft above the base	24
6. Sandstone, light-gray; mostly medium grained; a few thin lenses of coarse-grained to granule sandstone in the lower half; crossbedded; forms a cliff; grades into unit below	40
5. Conglomerate, light-gray; larger fragments mostly granules of dark- to light-gray chert and white cleyey siltstone; some sandstone fragments in basal 1 ft; many seams and lenses of medium- to coarse-grained sandstone; forms a cliff	14
Local unconformity.	
Lower part (part):	
4. Sandstone, light-gray, grayish-yellow weathering, fine- to medium-grained; in blocky beds as much as 3 ft thick; a few carbonaceous seams and laminae; contains a lens 3 in. thick of coal 2 ft below the top; forms a cliff	17
3. Siltstone, light- to medium-gray, silicified	3
2. Covered	20
1. Sandstone, light-gray, fine- to medium-grained, massive; stained pink locally	24
Partial thickness, Lakota Formation	160

Base of the exposure.

Fall River and part of the Lakota Formations near Newcastle in the SE¼ sec. 20, T. 45 N., R. 61 W., Weston County, Wyo.

[Loc. 12, pls. 1, 3]

Section begins in the railroad cut at the mouth of Cambria Canyon.

	Feet
Skull Creek Shale (part):	
25. Shale, grayish-black, very fissile, noncalcareous	15
Fall River Formation:	
Upper part:	
24. Sandstone, yellowish-gray, very fine grained to fine-grained, thin-bedded; cemented in top 6 in. with dark reddish-brown iron oxides; cross-laminated; some interlaminated grayish-black shale; forms a ledge	9
23. Shale, grayish-black; interlaminated ferruginous yellowish-gray very fine grained sandstone and siltstone; sandier at the base	6
22. Sandstone, interlaminated and interbedded with siltstone and shale; sandstone is light gray, very fine grained, cross-laminated, and in irregular beds mostly about 2 in. thick but including beds as much as 2 ft thick about 2 ft below the top and about 6 ft above the base; several thin seams cemented with iron oxides; markings that resemble worm trails on some bedding surfaces; siltstone and shale is medium to dark gray; forms slabby ledges	24
21. Conglomerate, dark reddish-brown; consists of angular fragments of siltstone and sandstone cemented with iron oxides; lenticular	0–1
20. Sandstone; interlaminated and interbedded with siltstone and shale as in unit 22; more shaly at the base	6½
19. Coal, shaly	½
Section offset about 100 yd upstream to the top of the ridge on the west side of Cambria Creek.	
18. Sandstone, light-gray; some red stain; very fine grained to fine grained; in blocky beds as much as 2 ft thick separated by thin partings of gray siltstone; ripple marked; forms ledges	12½
17. Siltstone and sandstone, interlaminated; siltstone is medium gray; sandstone is light gray, very fine grained, in beds mostly less than one-half an inch thick; gradational with underlying unit	7
16. Sandstone, light-gray, very fine grained, cross-laminated; in lenticular beds as much as 2 ft thick separated by partings of medium-gray siltstone; forms ledges; gradational with underlying unit	14½
Lower part:	
15. Sandstone, light-gray, very fine grained; many wavy dark-gray micaceous siltstone partings; cross-laminated; a few thin seams cemented with iron oxides; in beds mostly 1 to 2 in. thick; gradational with the underlying unit	16
14. Siltstone, laminated dark- and light-gray, shaly; a few thin lenses and partings as much as 4 in. thick of light-gray very fine grained cross-laminated sandstone	11
Section below offset about 200 ft northward along the ridge.	
13. Sandstone, light-gray, light yellowish-brown weathering; very fine grained; in beds mostly less than 1 in. thick; some dark-gray siltstone and silty shale partings and laminae; cross-laminated; some layers cemented by iron oxides; ripple marked; forms thin slabby ledges	16
12. Sandstone, light grayish-yellow, fine-grained; forms an overhanging ledge	3
11. Sandstone, light-gray, very fine grained, carbonaceous; in beds about 2 in. thick	1
10. Coal and carbonaceous shale; shaly in top 18 in. and bottom 6 in.; lenticular; pinches out northward	3

Fall River and part of the Lakota Formations near Newcastle in the SE¼ sec. 20, T. 45 N., R. 61 W., Weston County, Wyo.—Continued

	Feet
Fall River Formation—Continued	
Lower part—Continued	
9. Sandstone, light-gray; medium- to dark-gray laminae; very fine grained to fine grained; very carbonaceous; friable; in irregular thin beds	5
8. Sandstone, light-gray to light grayish-yellow; mostly medium grained at the base becoming very fine grained to fine grained in the upper part; some scattered coarse grains in the basal 5 ft; friable; in tabular beds mostly 2 to 6 ft thick; locally crossbedded with crossbeds inclined mostly to the north; forms a cliff in the stream bank on the west side of the canyon	65
Thickness, Fall River Formation	200

Section below offset to the east side of the canyon.

Unconformity.	
Lakota Formation (part):	
7. Covered. Local unconformity between the upper and lower parts of the formation probably in this interval of rocks	20±
6. Sandstone, light-gray to light greenish-gray, very fine grained to clayey, friable, nonresistent	5
5. Claystone; gray at the base, mottled red and green in the upper part; sandy	7
4. Sandstone, light-gray, very fine grained, thin-bedded; grades upward to gray siltstone in the top 2 ft; upper part nonresistent, lower part forms blocky ledges	7
3. Shale, very dark gray, slightly carbonaceous: weathers to brittle chips	4
2. Sandstone and shale, interbedded; sandstone is light gray, very fine grained, thin and irregularly bedded; shale is dark gray, sandy, slightly carbonaceous; grades into unit below	14
1. Sandstone, light-gray to light yellowish-gray, fine-grained; in beds mostly 2 to 4 ft thick; cross-laminated; friable; a few thin partings of gray sandy shale; forms a cliff in the stream bank	30
Partial thickness, Lakota Formation	87±
Base of the exposure.	

Part of the Fall River Formation along a tributary to Coal Mine Creek, NW¼SE¼ sec. 36, T. 45 N., R. 61 W., Weston County, Wyo.

[Loc. 31, pls. 1, 3]

	Feet
Top of the ridge.	
Fall River Formation (part):	
Upper part (part):	
7. Sandstone, light-gray to tan, fine-grained; locally stained pink and yellow; scattered nodules cemented with iron oxides; friable; forms thick rounded ledges	16
Lower part:	
6. Sandstone and siltstone, interlaminated, light- and dark-gray, slightly carbonaceous; local thin lenses cemented with iron oxides; markings on bedding planes that resemble worm trails; nonresistant	8
5. Sandstone, light-gray to light yellowish-gray; mostly fine grained; beds 1 in. thick of coarse-grained sandstone in bottom 2 ft; a few nodules and thin lenses cemented with iron oxides; locally cross-laminated; in beds as much as 3 ft thick; forms blocky ledges	28
4. Sandstone and siltstone, interlaminated, light- and dark-gray; a few thin layers cemented with iron oxides; nonresistant	11

	Feet
Fall River Formation (part)—Continued	
Lower part—Continued	
3. Sandstone, very light gray, very fine grained; locally carbonaceous; in beds mostly less than one-half foot thick; partings of medium-gray siltstone; a few thin layers cemented with iron oxides; raised markings on the bedding surfaces that resemble worm trails; forms ledges	19
2. Siltstone, light- to dark-gray, carbonaceous	2
Partial thickness, Fall River Formation	84
Unconformity.	
Lakota Formation (part):	
Upper part (part):	
1. Sandstone, grayish-white, mottled yellow and brown, massive; numerous ferruginous nodules about 1 mm in diameter in the basal part	5
Base of the exposure.	

The Fall River is generally regarded as Early Cretaceous (Albian) in age because of its Cretaceous plant fossils (Fontaine, 1899) and because it grades upward into the Skull Creek Shale which contains the marine fossil *Inoceramus bellvuensis* of Albian age (Cobban, 1951, p. 2175).

SKULL CREEK SHALE

The Skull Creek Shale is about 180 to 200 feet thick near Newcastle. It consists mostly of grayish-black flaky shale that contains scattered red-weathering siderite concretions and, in the upper part, a few yellow- or tan-weathering cone-in-cone concretions. The formation is exposed in a line of northeastward-facing ridges that extends northwestward across the area at the base of dip slopes formed on the underlying Fall River Formation. The Skull Creek is mostly covered by talus and small landslides and generally is poorly exposed. The formation grades downward into the Fall River Formation, and the contact, which is picked at the top of a transitional zone of interbedded siltstone, shale, and sandstone, can usually be determined within 3 to 5 feet stratigraphically.

Foraminifera have been reported from the Skull Creek Shale in the Black Hills (Crowley, 1951, p. 83–84; Skolnick, 1958a, p. 280–284; Eicher, 1958, p. 81), and a few marine mollusks are also found locally. The age of the formation is Albian (Cobban, 1951, p. 2197).

NEWCASTLE SANDSTONE

The Newcastle Sandstone crops out in a steep hogback that extends diagonally northwestward across the area, passing north of the town of Newcastle. The formation varies considerably in thickness. It is more than 80 feet thick in a partial section in roadcuts along U.S. Highway 85 on the outskirts of Newcastle; it is at least 50 feet thick in a partial section about a mile west of Newcastle in the NW¼NE¼ sec. 25, T. 45 N., R. 62 W.; and it is 14 feet thick near the northwest

corner of the area in the SE¼ sec. 25, T. 46 N., R. 63 W. Electric logs of wells drilled in the southwestern part of the area indicate the thickness in the subsurface ranges from less than 10 to more than 80 feet, as shown on figure 4.

The formation consists of interbedded sandstone, siltstone, shale, and bentonite. The sandstone is very light gray, very fine grained to fine grained, and is firmly cemented at outcrops. Along Salt Creek, in and near sec. 2, T. 44 N., R. 61 W., sandstone at the top of

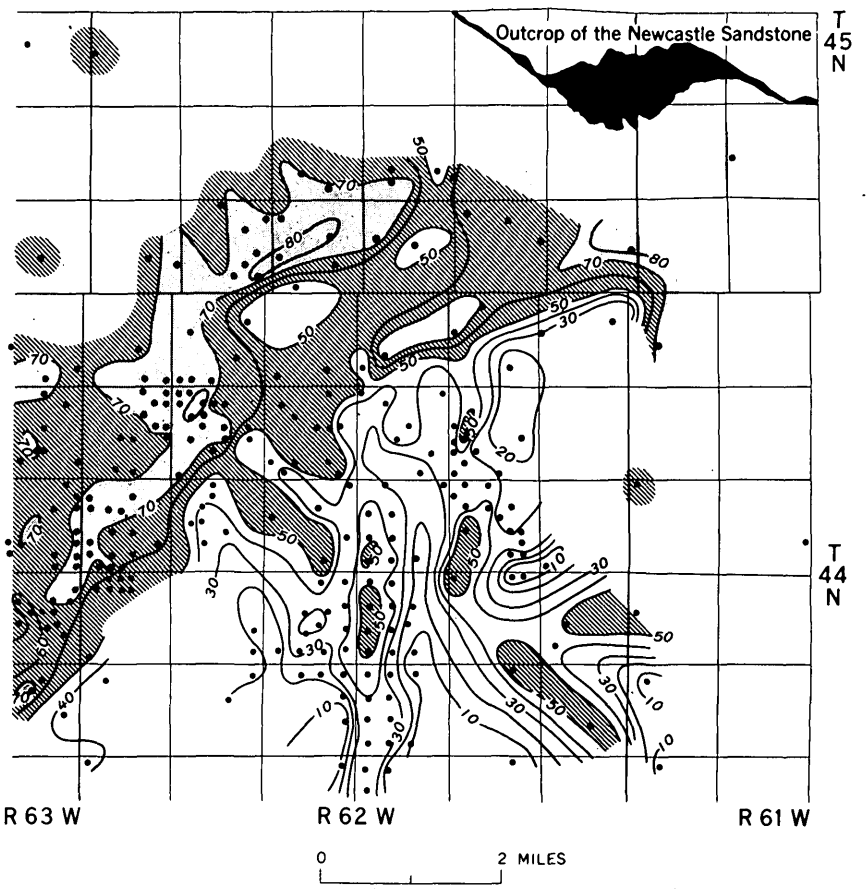

FIGURE 4.—Thickness of the Newcastle Sandstone in the southwestern part of the Newcastle area.

the formation is stained brown by oil. Summerford and others (1949, 1950) differentiated five sandstone beds in the subsurface near Newcastle, where the formation is thick. The uppermost sandstone beds apparently persist over the largest area; the lower ones are locally thickest but appear to pinch out laterally within the Skull Creek Shale.

Minerals with specific gravity greater than 2.87 were separated in bromoform from the very fine grained sand fraction of two samples from the top and the base of the formation, respectively, along U.S. Highway 87, sec. 28, T. 45 N., R. 61 W. The following nonopaque minerals were identified:

Nonopaque minerals in samples of Newcastle Sandstone

[Analyses are in percent. Total nonopaque fraction considered 100 percent. –, not present; x, less than 1 percent]

Stratigraphic position	Zircon			Tourmaline			Garnet	Rutile	Staurolite	Chloritoid	Brookite	Anatase	Sphene	Total grains counted
	Angular grains	Rounded grains	Total	Angular grains	Rounded grains	Total								
Top	14	5	19	57	10	67	x	9	–	4	–	x	–	131
Base	31	27	58	28	4	32	1	7	x	x	x	x	x	159
Average	22	16	38	43	7	50	x	8	x	2	x	x	x	----

Skolnick (1958b, p. 794) reported a similar nonopaque mineral suite from the Newcastle Sandstone, except for chloritoid. The same minerals are found in about the same relative abundance in samples from the sandstone in the Fall River in nearby areas (Bergenback, Chisholm, and Mapel, 1957, table 24, p. 406).

Brown and black carbonaceous material derived from plants is fairly common in the sandstone and siltstone and is extremely abundant in some beds of brown to black shale. A bed of bentonite and bentonitic shale, mostly 1 or 2 feet thick, but locally as much as 7 feet thick, crops out 5 to 10 feet below the top of the formation and appears to persist in outcrops for at least several miles to the northwest beyond the area.

Graphic sections of the Newcastle Sandstone are shown on figure 5, and some lithologic details are given by the following two stratigraphic sections. The second of the two sections was measured along U.S. Highway 85 at the type locality. Grace (1952, p. 25–26) reported a thickness of 86 feet for the Newcastle at this locality; Dobbin and Horn (1949), a thickness of 94 feet; and Skolnick (1958b, p. 812), a thickness of 93 feet.

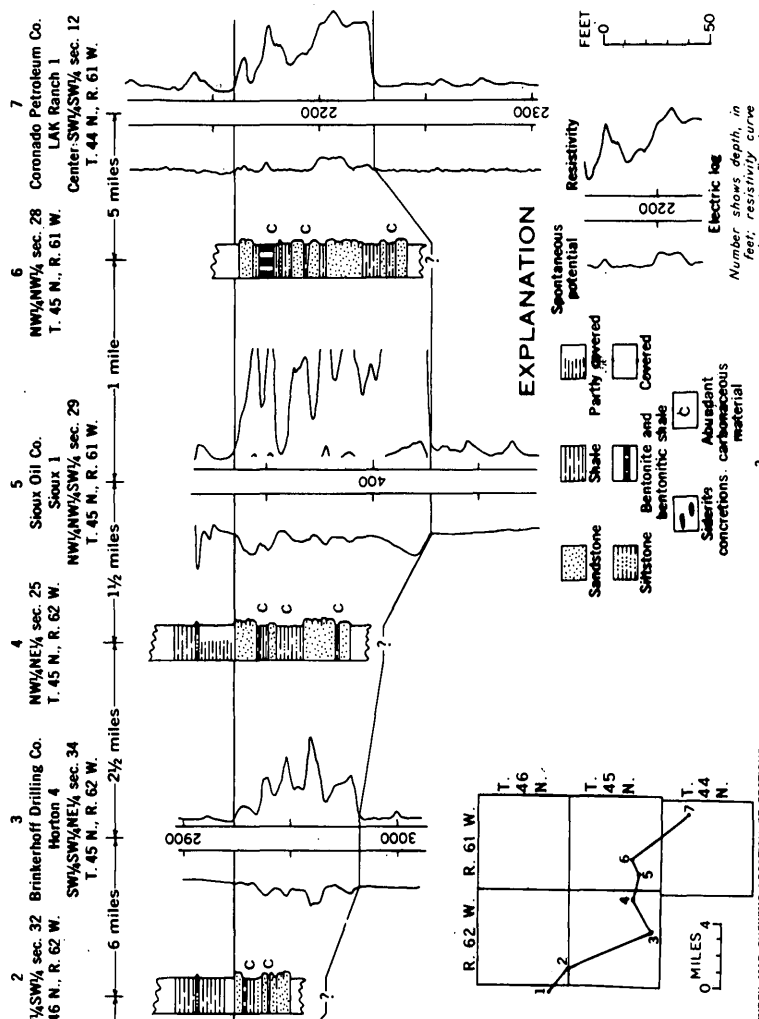

FIGURE 5.—Columnar sections and selected electric logs of the Newcastle Sandstone, Newcastle area, Weston County, Wyo.

Newcastle Sandstone and part of the Mowry Shale west of Skull Creek in the SE¼ sec. 25, T. 46 N., R. 63 W., Weston County, Wyo.

	Feet
Mowry Shale (part):	
7. Shale, dark-gray; weathers dark gray in lower part and light gray in upper part; upper part siliceous; forms slopes that are tree covered but bare of grass	20
6. Poorly exposed; appears to be mostly dark-gray shale	10
Partial thickness, Mowry Shale	30
Newcastle Sandstone:	
5. Sandstone, light-gray, very fine grained, calcareous, thin-bedded, slightly carbonaceous; forms a slabby ledge	2
4. Bentonite, light-gray; shaly in upper half	5
3. Shale, dark- to medium-gray, carbonaceous	1½
2. Shale, dark-gray; laminae of very fine grained yellowish-gray sandstone	5½
Thickness, Newcastle Sandstone	14
Skull Creek Shale (part):	
1. Shale, black; a bed of dark-red-weathering siderite concretions about 15 ft below top	20+

Part of the Newcastle Sandstone in roadcut along U.S. Highway 85 east of Newcastle in the NW¼NW¼ sec. 28, T. 45 N., R. 61 W., Weston County, Wyo.

[Measured by K. M. Waagé and Copeland MacClintock (written communication, 1955)]

	Feet
Newcastle Sandstone (part):	
19. Sandstone, yellowish-gray to brown weathering, very fine grained to fine-grained, hard; in thick massive beds (about the top of the formation)	5.9
18. Siltstone and silty shale, interbedded; local lenses of very fine grained sandstone; basal 0.5 ft mostly gray silty shale with laminae of siltstone	1.5
17. Shale, gray, silty, micaceous; some thin beds of siltstone	1.3
16. Bentonite and bentonitic shale, light-green to blue-green	6.9
15. Shale, black, very carbonaceous; locally grades to carbonaceous shaly siltstone	1.4
14. Sandstone, fine-grained, and siltstone; gray to light gray; weathers light brownish gray; ferruginous stain on bedding surfaces; irregularly bedded; scattered carbonaceous fragments	1.0
13. Shale; dark gray to black in upper part, becoming light gray in lower 1 ft; silty; irregularly interbedded with siltstone and very fine grained sandstone; carbonaceous	4.8
12. Sandstone, very fine grained to fine-grained, hard; in beds 0.4 to 2.0 ft thick separated by shaly partings; "worm" borings and casts and possibly dinosaur footprints on bedding surfaces	5.6
11. Shale, dark-gray, silty; interlaminated to thinly interbedded siltstone	.8
10. Claystone, gray; at the base a bed of white porcelanite 0.1 to 0.2 ft thick	.6
9. Shale, black, carbonaceous; silty at base; thickens to northeast as unit 8 thins, and a thin bed of porcelanite appears 1.7 ft from base; gray siltstone beneath porcelanite	1.7–3.5
8. Sandstone, light-gray, fine-grained, hard, tabular to massive, cross-laminated	5.5–3.0
7. Claystone, light-gray, silty, blocky to splintery fracture	2.8
6. Sandstone, gray, fine-grained; some interbedded siltstone; laminated to thin bedded; a few cross-laminated layers; forms a shelving ledge	15.5
5. Sandstone, fine-grained, friable, thin-bedded; contains laminae of black carbonaceous shale	1.7
4. Claystone; grades downward to siltstone; dark gray, sandy at base	8.0

Part of the Newcastle Sandstone in roadcut along U.S. Highway 85 east of Newcastle in the NW¼NW¼ sec. 28, T. 45 N., R. 61 W., Weston County, Wyo.—Con.

	Feet
Newcastle Sandstone (part)—Continued	
3. Sandstone, fine-grained, carbonaceous; forms a single massive ledge	2.6
2. Siltstone interlaminated and thinly interbedded with dark-gray silty shale; some beds disturbed by "worm" borings and casts; carbonaceous	4.4
1. Sandstone, fine-grained; locally silty; thin bedded to platy; laminae and partings of carbonaceous shale	4.8
Partial thickness, rounded, Newcastle Sandstone	77
Minor fault. (Skull Creek Shale probably no more than 10 ft stratigraphically below unit 1.)	

The Newcastle contains some Foraminifera (Crowley, 1951, p. 85; Skolnick, 1958a; 1958b, p. 791), and poorly preserved marine pelecypods are reported from the formation locally (W. W. Rubey, written communication, 1954). The age is regarded as Early Cretaceous (Albian) (Cobban, 1951, p. 2197; Skolnick, 1958b, p. 791).

MOWRY SHALE

The Mowry Shale crops out in a narrow band adjacent to the dip slopes formed on the underlying Newcastle Sandstone. The Mowry forms low hills and flats that are nearly bare of soil but that support a fairly dense growth of pine trees at many places. The Mowry ranges in thickness from 180 to 190 feet in drill holes in the Newcastle area; it is 195 feet thick in outcrops about 2 miles southeast of Newcastle in sec. 35, T. 45 N., R. 61 W. Rubey (1929) has discussed the composition and origin of the Mowry in detail, and Reeside and Cobban (1960) gave information on the regional stratigraphic relations and fossils.

The Mowry consists mostly of dark-gray siliceous shale that weathers to hard platy light- to medium-gray chips. The basal 15 to 20 feet of the formation erodes more easily than the upper part and weathers grayish black. Collier (1922, p. 82) called this part of the formation the Nefsy Shale Member of the Graneros Shale; however, few writers now use the name, and it has been abandoned by the U.S. Geological Survey. The Mowry contains several beds of siltstone that are generally about ½ to 1 foot thick, including one persistent siltstone bed that makes minor slabby ledges about 20 feet above the base of the formation. An increased resistivity and decreased spontaneous potential identifies this bed on electric logs, as shown on figure 5.

Many beds, generally less than half a foot thick, of very light gray nonswelling bentonite characterize the Mowry. At the top of the formation is a commercially valuable bed of swelling bentonite called the Clay Spur Bentonite Bed. This bentonite is 1.4 feet thick near

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Skull Creek in the SE¼ sec. 31, T. 46 N., R. 62 W.; 1.1 feet thick at Fourmile Draw in sec. 23, T. 45 N., R. 62 W.; and consists of thin bentonite stringers interbedded with shale in a zone 2 feet thick southeast of Newcastle in sec. 35, T. 45 N., R. 61 W.

The following stratigraphic section measured southeast of Newcastle shows the sequence of beds and lithologic character of the Mowry Shale.

Mowry Shale and parts of adjacent formations southwest of Salt Creek, SW¼SW¼ sec. 35, T. 45 N., R. 61 W., Weston County, Wyo.

	Feet
Belle Fourche Shale (part):	
43. Shale, grayish-black, soft; scattered siderite concretions that weather dark red	10
42. Covered; grayish-black shale nearby	10
41. Bentonite; pale yellow in the lower part; grayish tan in the upper part; slightly swelling	3.0
40. Shale, grayish-black, soft; a few siderite concretions that weather dark red; siderite layer about 0.3 ft. thick at the top of the unit	20
Partial thickness, Belle Fourche Shale	43
Mowry Shale:	
39. Bentonite and shale as follows (Clay Spur Bentonite Bed):	
Bentonite, light-gray, nonswelling	0.2
Shale, black	.3
Bentonite, light-gray, nonswelling	.1
Shale, black	.8
Bentonite, pale-yellow, nonswelling	.1
Shale, black	.4
Bentonite, light-gray, nonswelling	.1
Total	2.0
38. Shale, grayish-black, medium- to dark-gray-weathering; fairly hard	23
37. Covered	6
36. Bentonite, light-gray, nonswelling	.7
35. Shale, dark-gray	1.5
34. Shale, dark-gray, bentonitic	.4
33. Shale, dark-gray	2.5
32. Bentonite, light-gray to olive-gray, nonswelling	.5
31. Shale, dark-gray	2.9
30. Bentonite, light-gray, nonswelling	.2
29. Shale, dark-gray	1.2
28. Bentonite, light-gray, shaly	.4
27. Shale, dark-gray	.6
26. Bentonite, light-gray, nonswelling	.5
25. Shale, dark-gray, medium-gray-weathering, hard; contains fish scales	23
24. Bentonite, light-gray, nonswelling	.1
23. Shale, dark-gray, medium gray-weathering, hard; contains fish scales	32
22. Sandstone, very light gray, very fine grained to silty, hard; forms ledges	.5
21. Shale, dark-gray, medium-gray-weathering, hard	8
20. Bentonite, pale olive-gray, nonswelling	.5
19. Partly covered; mostly hard dark-gray shale that weathers medium gray and contains fish scales	25
18. Sandstone, very light gray, very fine grained to silty; a few fragments of carbonaceous material; some fish scales; forms a minor ledge	.5

Mowry Shale and parts of adjacent formations southwest of Salt Creek, SW¼SW¼ sec. 35, T. 45 N., R. 61 W., Weston County, Wyo.—Continued

	Feet
Mowry Shale—Continued	
17. Shale, dark-gray, medium-gray-weathering, hard	5
16. Sandstone, as in unit 18 above	1.4
15. Shale, dark-gray, medium-gray-weathering, hard	4.7
14. Bentonite, light-gray, nonswelling	.3
13. Shale, dark-gray, medium-gray-weathering, hard	12
12. Bentonite, light-gray, nonswelling	.2
11. Shale, dark-gray, medium-gray-weathering, hard	9
10. Bentonite, light-gray, nonswelling	.4
9. Shale, dark-gray, medium-gray-weathering, hard, silty	3
8. Siltstone, light-gray; dark-gray laminae; sandy; upper part forms a minor ledge	3.5
7. Bentonite, light olive-gray, nonswelling	.2
6. Shale, grayish-black, silty, soft; contains two thin streaks of bentonite	8.5
5. Bentonite, olive-gray, nonswelling	.6
4. Shale, grayish-black, soft	14
Thickness, rounded, Mowry Shale	195
Newcastle Sandstone (part):	
3. Sandstone, brown, light-gray-weathering, fine-grained, oil-stained, slightly carbonaceous; forms ledges	12.5
2. Siltstone, brown, carbonaceous	.5
1. Sandstone, very light gray, fine-grained; forms ledges	5
Partial thickness, Newcastle Sandstone	18

The Mowry is well known for containing abundant fish scales and bones. Other megascopic fossil remains are rare, however, and none was found in the Newcastle area during the present investigation. The formation is considered latest Early Cretaceous in age (Cobban, 1951, p. 2197; Reeside and Cobban, 1960, p. 28–30).

UPPER CRETACEOUS SERIES

BELLE FOURCHE SHALE

The Belle Fourche Shale forms a narrow band of low hills and flats adjacent to outcrops of the underlying Mowry Shale. It is as much as 370 feet thick at outcrops and in drill holes in the central part of the area; it thins to about 340 feet locally in drill holes in the southeastern part.

The formation is mostly grayish-black nonresistant shale that weathers grayish black and thereby contrasts with outcrops of light-colored shale in the underlying Mowry. Some beds are slightly silty, and the upper part locally contains a few laminae and thin beds of siltstone. Ellipsoidal oligonite (manganiferous siderite) concretions that are medium gray when fresh and dark red to purplish black when weathered characterize the basal 40 to 80 feet of the Belle Fourche. The core of one of these concretions collected near Upton, a few miles

northwest of the Newcastle area, had the following composition (J. A. Thomas, analyst):

	Percent
Fe (soluble in HCl)	37.4
$FeCO_3$	76.5
Mn	5.0
Mg	Trace
Insoluble in HCl	7.9

The formation contains several thin bentonite beds that are less than 1 foot thick and two prominent bentonite beds that are each more than 2 feet thick. The lowermost of the two thick bentonite beds lies 20 to 35 feet stratigraphically above the base of the formation and ranges from 2.5 to 4.8 feet in thickness where examined at several places along its outcrop. This bed has the stratigraphic position of bentonite bed E described by Knechtel and Patterson (1955) farther to the north in the Black Hills. The second thick bed is 15 to 30 feet stratigraphically below the top of the formation and is 2.5 to 3.0 feet thick; farther north in the Black Hills it has been called bentonite bed F by Knechtel and Patterson (1955) and the gray-red bed by Bramlette and Rubey (*in* Moore, 1949, p. 27). Marked decreases in resistivity identify beds E and F on electric logs in the Newcastle and nearby areas (pl. 1).

The Belle Fourche grades downward into the Mowry Shale. The contact is the top of the Clay Spur Bentonite Bed, where there is a downward change in the shale from a nonsiliceous variety that weathers grayish black to a siliceous variety that weathers medium gray. Oligonite concretions that characterize the basal part of the Belle Fourche are absent in the Mowry. Haun (1958, p. 86) stated that the lithologic change described above occurs 20 to 30 feet below the Clay Spur Bed, but it seems possible that he has mistaken bentonite bed E in the Belle Fourche near Newcastle for the Clay Spur Bed.

The following stratigraphic section shows the lithology of the formation near Newcastle.

Belle Fourche Shale south of Fourmile Draw, NW ¼ sec. 23, T. 45 N., R. 62 W., Weston County, Wyo.

Greenhorn Formation (part):	Feet
24. Shale, dark-gray, olive-gray-weathering, calcareous	20
23. Limestone, light-gray, tan-weathering, very fossiliferous; lenticular	3.0
22. Bentonite, very light gray and light reddish-brown, nonswelling	2.0
21. Limestone, as in unit 23 above	.5
Partial thickness, rounded, Greenhorn Formation	23

Belle Fourche Shale south of Fourmile Draw, NW¼ sec. 23, T. 45 N., R. 62 W., Western County, Wyo.—Continued

	Feet
Belle Fourche Shale:	
20. Shale, grayish-black, soft	17
19. Bentonite; very light gray in the lower part, tan in the upper part; swelling. (Gray-red bed)	2.0
18. Shale, grayish-black, soft	16
17. Shale, grayish-black; interlaminated light-gray siltstone; a few red-weathering slabby calcareous siltstone concretions that locally contain a few shell fragments	27
16. Bentonite, very light gray, nonswelling	.2
15. Shale and siltstone, as in unit 17 above	7.5
14. Bentonite, very light gray, nonswelling	.4
13. Shale and siltstone, as in unit 17 above	13
12. Shale, grayish-black, soft	102
11. Bentonite, light yellowish-gray, nonswelling	.6
10. Partly covered; mostly grayish-black slightly silty shale	87
9. Shale, grayish-black, slightly silty	32
8. Bentonite, very light gray, nonswelling	.3
7. Shale, black, bentonitic	.3
6. Bentonite, very light gray, nonswelling, impure	.8
5. Shale, grayish-black, soft; scattered siderite concretions that weather dark red	41
4. Bentonite, very light gray, swelling	2.5
3. Shale, grayish-black, soft; scattered siderite concretions that weather dark red; siderite layer 0.3 ft thick at the top of the unit makes a hard floor for overlying bentonite bed	21
Thickness, rounded, Belle Fourche Shale	370
Mowry Shale (part):	
2. Bentonite, very light gray and light brownish-red, slightly swelling. (Clay Spur Bed)	1.1
1. Shale, dark-gray, medium-gray-weathering, hard	10
Partial thickness, rounded, Mowry Shale	11

Fossils are rare in the Belle Fourche Shale, and none was found in the Newcastle area during the present investigation. The age of the formation is considered earliest Late Cretaceous (Cenomanian) (Cobban, 1951, p. 2197).

GREENHORN FORMATION

The Greenhorn Formation is well exposed on the crest and north-facing slopes of a low hogback south of Newcastle, and the upper part of the formation underlies a low narrow ridge that extends across the area northwest and southeast of Newcastle. The formation is about 250 feet thick.

The Greenhorn consists mostly of alternate beds of dark-gray calcareous and noncalcareous shale in the lower part and grades upward to dark-gray marl interbedded with thin beds of light-gray limestone in the top 50 to 90 feet of the formation. The limestone-marl sequence forms a ridge on which the limestone beds crop out in

thin light-colored bands and low slabby ledges. Shale in the Greenhorn mostly weathers medium to light gray and brownish gray, in contrast to the darker color of shale in the underlying Belle Fourche. The lower part of the Greenhorn contains several beds of bentonite that generally are less than one-half foot thick, but it includes a bed at the base of the formation that locally is 2 feet thick. The lower part also contains a few discontinuous lenses of brown-weathering fossiliferous limestone, generally less than a foot thick, and a few beds of yellow- or tan-weathering limestone concretions.

Darton (1904, p. 5; 1909, p. 54–55), Collier (1922, p. 84), and Dobbin and Horn (1949) included in the Greenhorn only the upper, ridge-forming limestone; but in later work of some geologists (Haun, 1958, chart 5) and in the present report the contact of the Greenhorn with the underlying Belle Fourche was chosen to include in the Greenhorn the stratigraphically lowest beds of calcareous shale. This contact conforms closely to that described by Cobban (1951, p. 2183–2184) farther north in the Black Hills and mapped by Knechtel and Patterson (1955) in parts of northern Crook County, Wyo.

The stratigraphic section below shows the lithology of the formation.

Greenhorn Formation on the south side of Fourmile Draw, NE¼NE¼ sec. 22 and NW¼NW¼ sec. 23, T. 45 N., R. 62 W., Weston County, Wyo.

	Feet
Greenhorn Formation:	
13. Partly covered; upper part mostly thin-bedded very light gray fossiliferous limestone that forms thin slabby ledges; lower part mostly gray marl with some interbedded light-gray limestone; bentonite bed 0.1 ft thick about 30 ft above the base; unit forms a ridge	88
12. Shale, dark-gray, very calcareous; a few thin layers of tan-weathering fossiliferous limestone; a bed of tabular medium-gray limestone concretions with veins of white calcite at the top of the unit	24
11. Shale, dark-gray, brown weathering, very calcareous; interbedded tan-weathering fossiliferous limestone in beds mostly less than one-half inch thick; bentonite bed 0.1 ft thick at about the middle; unit forms a ridge	19
10. Shale, dark-gray, brown weathering, calcareous	21
9. Bentonite, very light gray, nonswelling	.1
8. Shale, dark-gray, brown weathering, calcareous; a few platy gray- to tan-weathering limestone concretions	28
7. Bentonite, very light gray, nonswelling	.1
6. Shale, dark-gray, brown weathering, calcareous; scattered yellow- to tan-weathering limestone concretions about 20 feet above the base	51
5. Limestone, light-gray, tan weathering, fossiliferous	.2
4. Shale, dark-gray, tan weathering, calcareous	20
3. Bentonite, light-gray and reddish-brown, nonswelling	2
2. Limestone, light-gray, tan weathering; lenticular; contains *Inoceramus pictus* Sowerby, *Ostrea* sp., *Metoicoceras*? n. sp., and *Calycoceras*? sp. (fossils identified by W. A. Cobban, USGS loc. D2622)	0–.5
Thickness, rounded, Greenhorn Formation	253
Belle Fourche Shale (part):	
1. Shale, grayish-black, soft	10

Fossil shells form layers of coquina in some thin limestone beds in the Greenhorn. Pelecypods of the genus *Inoceramus* and fish teeth and bones are the most common fossils. W. W. Rubey collected *Globigerina bulloides* D'Orbigny, *Inoceramus labiatus* Schlotheim, *Ostrea* sp., *Metoicoceras whitei* Hyatt, and fish scales and bones from beds about 70 feet below the top of the formation south of Newcastle in the SE¼ sec. 31, T. 45 N., R. 61 W. He collected *Globigerina bulloides* D'Orbigny, *Inoceramus* cf. *fragillis* Hall and Meek, and fish teeth from beds 20 feet stratigraphically higher in the same vicinity (USGS locs. 12692 and 12706, respectively; fossils identified by J. B. Reeside, Jr.). Haun (1958, chart 5) reported *Inoceramus labiatus* and *Collignoniceras woollgari* from the top of the formation in sec. 23, T. 45 N., R. 62 W. Other fossils are listed in the preceding stratigraphic section.

The Greenhorn is Cenomanian and Turonian in age (Cobban, 1951, p. 2197).

CARLILE SHALE

The Carlile Shale consists of dark-gray shale interbedded in the lower half with siltstone and sandstone. It is 520 to 540 feet thick and includes, from oldest to youngest, the lower unnamed member, the Turner Sandy Member, and the Sage Breaks Member. The Turner Sandy Member locally makes low ridges, the other two members are nonresistant and crop out on gentle slopes and flats.

LOWER UNNAMED MEMBER

The lower unnamed member of the Carlile Shale is 90 to 110 feet thick and consists mostly of dark-gray shale that is calcareous in the basal 30 to 55 feet and noncalcareous in the upper part. The upper half of the member contains laminae of light-gray siltstone, and these become very abundant at the top. One or more thin bentonite beds in a zone one to several feet thick crop out in about the middle part of the member. Gray- to tan-weathering fossiliferous septarian limestone concretions occur in the middle part of the member.

The following section shows the sequence of beds south of Newcastle.

Lower unnamed member of the Carlile Shale and adjacent beds near Newcastle in the NW¼ sec. 31, T. 45 N., R. 61 W., Weston County, Wyo.

[Measured by W. A. Cobban]

	Feet
Carlile Shale (part):	
Turner Sandy Member (part):	
14. Sandstone and shale; sandstone is light gray, very fine grained; shale is dark gray; brown concretionary sandstone bed at the top; forms a hogback	10
13. Shale, dark-gray, sandy; becomes increasingly sandy upward	10
12. Sandstone, light-gray; many dark-gray chert grains; calcareous	.5
Partial thickness, rounded, Turner Sandy Member	20

Lower unamed member of the Carlile Shale and adjacent beds near Newcastle in the NW¼ sec. 31, T. 45 N., R. 61 W., Weston County, Wyo.—Continued

	Feet
Carlile Shale (part)—Continued	
Lower unnamed member:	
11. Shale, dark-gray; a few thin stringers of light-gray siltstone	33
10. Bentonite, light yellowish-gray	.1
9. Shale, dark-gray; contains limestone concretions that weather light gray and yield *Collignoniceras woollgari*	3
8. Bentonite, light yellowish-gray	.2
7. Shale, dark-gray	.6
6. Bentonite, light-gray	.2
5. Shale, dark-gray; contains limestone concretions about one-half foot long that weather light gray; locally abundant *Collignoniceras woollgari*	2
4. Bentonite, light-gray; shaly at the top	1.0
3. Shale, dark-gray; some partings of light-gray siltstone	5
2. Shale, dark bluish-gray, grayish-brown weathering; variably calcareous; contains a few thin limestone lenses and some soft yellowish-gray limestone concretions	55
Thickness, rounded, lower unnamed member	100
Greenhorn Formation (part):	
1. Shale, gray, calcareous; numerous thin lenticular beds of finely crystalline very light gray limestone that contain *Inoceramus labiatus;* forms a hogback	40

The following fossils were collected from the lower unnamed member by W. W. Rubey and identified by J. B. Reeside, Jr.:

USGS locs. 11190 and 12665, 1 to 1½ miles south of Newcastle, SE¼ sec. 32, T. 45 N., R. 61 W., and N½ sec. 5, T. 44 N., R. 61 W.

Inoceramus fragilis Hall and Meek
Ostrea sp. (small simple form)
Anchura n. sp.
Anisomyon n. sp.
Scaphites larvaeformis Meek and Hayden
Collignoniceras woollgari (Mantell)
Trayodesmoceras sp.
Hypsodon? sp.
Fish scales

USGS locs. 11198 and 11199, about 1 mile east of Pedro, SE¼ sec. 5, T. 45 N., R. 62 W.

Inoceramus fragilis Hall and Meek
Collignoniceras woollgari (Mantell)
Tragodesmoceras n. sp.
Ostrea sp.

TURNER SANDY MEMBER

The Turner Sandy Member of the Carlile Shale is about 150 feet thick in the Newcastle area. It consists mostly of dark-gray shale interbedded and interlaminated with very light gray very fine grained sandstone and siltstone as shown on figure 6.

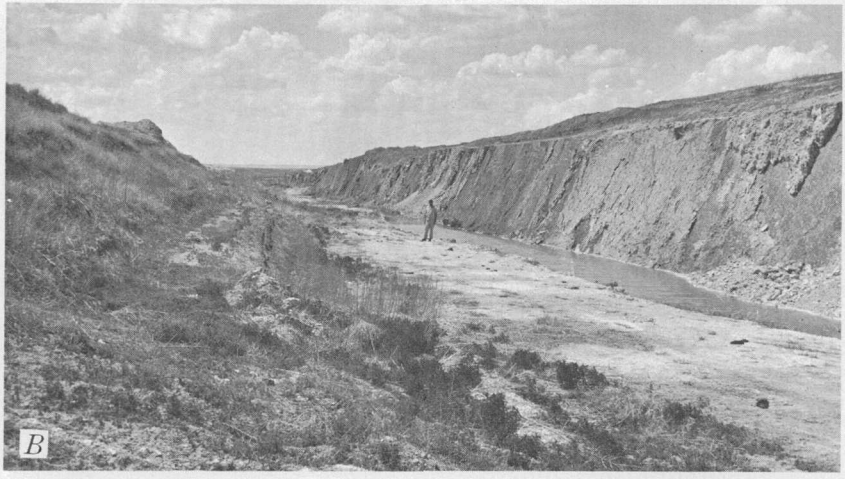

FIGURE 6.—Some Upper Cretaceous rocks, Newcastle area. *A*, Interbedded and interlaminated sandstone, siltstone, and shale in the lower part of the Turner Sandy Member of the Carlile Shale southeast of Newcastle, sec. 2, T. 44 N., R. 61 W., Weston County, Wyo.; *B*, Pedro Bentonite Bed in a pit about 1 mile southeast of Pedro, sec. 8, T. 45 N., R. 62 W., Weston County, Wyo. Man is standing on bentonite bed about 30 feet thick. Wall on the right is steeply dipping marl at the top of the Niobrara Formation. Slopes on the left made by the Mitten Black Shale Member of the Pierre Shale.

The base of the member is a distinctive bed 1 to 5 feet thick of light-gray fine- to medium-grained calcareous crossbedded sandstone that contains dark-colored grains of chert and phosphatic material and, locally, abundant fish teeth. Brown-weathering tabular concretionary masses of calcareous sandstone and siltstone as much as 20 feet in diameter and 5 feet thick crop out 20 to 40 feet above the base of the member and form a prominent ridge. The upper part of the member contains tan-weathering silty septarian limestone concretions with veins of yellow calcite.

The following fossils were collected by W. W. Rubey from the Turner Sandy Member in the Newcastle area and identified by J. B. Reeside, Jr.:

USGS loc. 12702, fish teeth in basal sandstone of the Turner Sandy Member north of Pedro, sec. 6, T. 45 N., R. 62 W.

Ptychodus sp.
Isurus sp.
Lamna sp.
Corax sp.
Myliobatis? sp.
Fuchodus sp.

USGS loc. 11185, brown-weathering concretions 20 to 30 feet above the base of the Turner Sandy Member near Newcastle, sec. 2, T. 44 N., R. 61 W.

Inoceramus fragilis Hall and Meek
Scaphites warreni Meek and Hayden
Fish bones

USGS loc. 12691, concretions about 20 feet above the base of the Turner Sandy Member near Newcastle, sec. 31, T. 45 N., R. 61 W.

Inoceramus fragilis Hall and Meek
Fusus aff. *F. shumardi* Hall and Meek
Fusus n. sp.
Scaphites warreni Meek and Hayden
Scaphites warreni var. *ubiquitosus* Cobban
Prionocyclus wyomingensis Meek

USGS loc. 11184, about the top of the Turner Sandy Member west of Newcastle, SE¼ sec. 25, T. 45 N., R. 62 W.

Inoceramus fragilis Hall and Meek
Lunatia? sp.
Aporrhais prolabiata (White)
Prionocyclus wyomingensis Meek
Helioceras? n. sp.

USGS locs. 11200 to 11203, inclusive, stratigraphic positions not reported, collected near Pedro, sec. 5, T. 45 N., R. 62 W.

Scaphites corvensis Cobban
Inoceramus fragilis Hall and Meek
Inoceramus cf. *I. dimidius* White
Baculites cf. *B. basairiei* Collignon
Ostrea sp.

SAGE BREAKS MEMBER

The Sage Breaks Member of the Carlile Shale is about 260 feet thick in the Newcastle area. It consists of grayish-black shale in which beds of distinctive septarian limestone concretions are spaced at intervals of about 5 to 20 feet. The concretions weather light gray; have veins of white and brown coarsely crystalline calcite or, more rarely, white and brown barite; and generally are about 1 to 3 feet in diameter. Shale near the top of the Sage Breaks Member is locally calcareous, and at some places it contains a few black phosphatic nodules an inch or more in diameter. The gray-weathering concretions in the Sage Breaks Member contrast markedly with the tan-weathering silty concretions in the underlying Turner Sandy Member, and this difference, together with the absence of sandstone and siltstone in the Sage Breaks, distinguishes the two members. The contact between the two members generally can be determined within 10 to 20 feet stratigraphically.

Fossils are rare in the Sage Breaks Member, and none have been reported from the Newcastle area.

NIOBRARA FORMATION

The Niobrara Formation is nonresistant and generally is poorly exposed in the Newcastle area and elsewhere along the west side of the Black Hills. It forms scattered discontinuous outcrops in a narrow band that extends more or less diagonally across the area from northwest to southeast. The formation is partly exposed in road cuts along U.S. Highway 16 northwest of Newcastle, and locally is fairly well exposed southeast of Pedro in secs. 8 and 9, T. 45 N., R. 62 W., and west of Skull Creek in sec. 1 of the township to the west.

The formation generally is between 200 and 220 feet thick in the Newcastle area, as determined from the electric logs of wells. It thins in the vicinity of Pedro, however, and is 155 feet thick at outcrops in sec. 8, T. 45 N., R. 62 W. (J. R. Gill, written communication, 1958) and about 165 feet thick nearby to the west in sec. 1, T. 45 N., R. 63 W.

The Niobrara consists mostly of dark-brown to dark-gray calcareous shale and marl that weather tan, yellow, or orange. Thin beds of bentonite are fairly abundant in the upper part of the formation, and locally the Niobrara contains a few soft yellow- or red-weathering limestone concretions. The contact with the underlying Sage Breaks Member of the Carlile Shale appears to be gradational and is picked at the base of the main body of orange-weathering shale or marl.

On electric logs the Niobrara is characterized by its high resistivity and relatively negative spontaneous potential (pl. 1). The section below shows the sequence of beds near Pedro.

Niobrara Formation southeast of Pedro in the NE¼ sec. 8, T. 45 N., R. 62 W., Weston County, Wyo.

[Measured by J. R. Gill]

	Feet
Pierre Shale (part):	
10. Bentonite, pale greenish-gray, swelling; fairly abundant flakes of biotite; about 12 ft above the base is a hard light-gray bed 1.3 ft thick composed of zeolite; unit rests sharply on underlying unit. (Pedro Bentonite Bed)	19. 5
Niobrara Formation:	
9. Marl, dark gray-brown, yellowish-brown-weathering; top 1 to 2 ft hard and massive	6. 0
8. Bentonite and shale as follows:	
Bentonite, yellowish-gray, nonswelling	0. 2
Shale, brown-weathering, very calcareous	1. 1
Bentonite, yellowish-gray, nonswelling	. 1
Shale, gray-weathering, calcareous	2. 5
Bentonite, yellowish-gray, nonswelling	. 1
Total	4. 0
7. Shale, dark-gray to black, calcareous	4. 0
6. Shale, orange-brown-weathering, very calcareous	7. 0
5. Shale and bentonite as follows:	
Shale, dark-gray, noncalcareous	0. 3
Bentonite, gray, nonswelling	. 1
Shale, tan-weathering, very calcareous	1. 0
Bentonite, light-gray, nonswelling	. 5
Shale, black, noncalcareous	. 6
Bentonite, yellowish-gray, nonswelling	. 2
Shale, black, noncalcareous	. 2
Bentonite, yellowish-gray, nonswelling	. 1
Shale, gray-brown, bentonitic	. 7
Bentonite, light-gray, nonswelling	. 2
Shale, black, noncalcareous	. 5
Bentonite, light-gray, nonswelling	. 6
Shale, black, noncalcareous	. 2
Bentonite, yellowish-gray, nonswelling	. 1
Total	5. 3
4. Shale, black, noncalcareous	3. 6
3. Shale, orange-brown- and tan-weathering, very calcareous; numerous white specks on the bedding planes; a bed of red-weathering limestone concretions 0.1 to 0.2 ft in diameter at about the top of the unit	124
2. Shale and bentonite as follows:	
Bentonite, light-gray, nonswelling	0. 2
Shale, gray, noncalcareous, bentonitic	. 6
Bentonite, light-gray, nonswelling	. 1
Total	. 9
Thickness, rounded, Niobrara Formation	155
Carlile Shale (part):	
Sage Breaks Member (part):	
1. Shale, grayish-black; locally calcareous; small black phosphatic pebbles in the soil at about the top of the unit; at the bottom of the unit is a bed of septarian limestone concretions that weathers light gray; the concretions have veinlets of white and brown calcite and are as much as 4 ft in diameter	40

Thin platy masses of limestone composed of *Ostrea congesta* Conrad occur in the Niobrara, but other megafossils are rare; none was found during this study.

PIERRE SHALE

The Pierre Shale crops out on sparsely vegetated flats and low hills in most of the southwest half of the Newcastle area. The formation is about 2,700 feet thick in wells drilled about 15 miles southwest of Newcastle in the south half of T. 44 N., R. 63 W.; all but the top 250 to 300 feet is present in the Newcastle area.

The Pierre Shale along the west side of the Black Hills has been divided into several members (Rubey, 1931, p. 4; Robinson, Mapel, and Cobban, 1959), and five mappable units are recognized in the Newcastle area. These include, from oldest to youngest, the Gammon Ferruginous Member, Mitten Black Shale Member, an unnamed middle part of the Pierre Shale, the Kara Bentonitic Member, and an unnamed upper part of the Pierre Shale. The diagram, figure 7, shows the stratigraphic relations of these units.

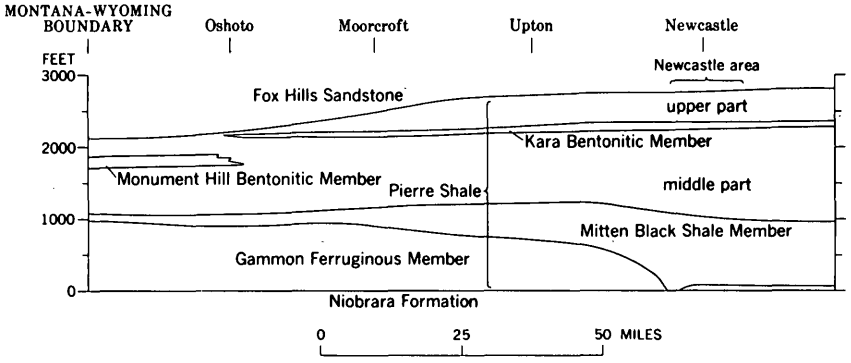

FIGURE 7.—Diagrammatic section showing subdivisions of the Pierre Shale and their stratigraphic relations, Crook and Weston Counties, Wyo.

Much of the Pierre is fossiliferous, and at least 15 fossil zones can be recognized in the formation on the west side of the Black Hills near Newcastle. Critical dating fossils that mark the zones and that are referred to in the following discussion of the Pierre Shale are given in table 2.

GAMMON FERRUGINOUS MEMBER

The Gammon Ferruginous Member of the Pierre Shale consists of dark-gray shale that lies between the Niobrara Formation and a prominent zone of bentonite beds at the base of the younger Mitten Black Shale Member of the Pierre. The member is about 35 feet thick near Newcastle in sec. 6, T. 44 N., R. 61 W., and about 70 feet thick 4 miles southeast of Pedro in sec. 23, T. 45 N., R. 62 W. It has

TABLE 2.—*Pierre Shale index fossils in northeast Powder River Basin and lithologic units near Newcastle*

[Modified from Cobban (1958a,b; 1962). Index fossils found near Newcastle are indicated by asterisk]

<table>
<tr><th>Index fossils, northeast part Powder River Basin</th><th colspan="2">Lithologic units near Newcastle</th><th></th></tr>
<tr><td>Baculites grandis*</td><td colspan="2" rowspan="2">Upper part</td><td rowspan="14">Pierre Shale</td></tr>
<tr><td>Baculites baculus*</td></tr>
<tr><td>Baculites eliasi*</td><td colspan="2">Kara Bentonitic Member</td></tr>
<tr><td>Baculites reesidei</td><td colspan="2" rowspan="8">Middle part</td></tr>
<tr><td>Baculites compressus</td></tr>
<tr><td>Baculites corrugatus</td></tr>
<tr><td>Exiteloceras jenneyi*</td></tr>
<tr><td>Didymoceras? stevensoni*</td></tr>
<tr><td>Baculites psuedovatus</td></tr>
<tr><td>Baculites scotti*</td></tr>
<tr><td>Baculites gregoryensis*</td></tr>
<tr><td>Baculites gilberti*</td><td rowspan="2">Upper part</td><td rowspan="4">Mitten Black Shale Member</td></tr>
<tr><td>Baculites perplexus*</td></tr>
<tr><td>Baculites asperiformis</td><td rowspan="2">Lower part</td></tr>
<tr><td>Baculites obtusus</td></tr>
<tr><td>Scaphites hippocrepis</td><td colspan="2">Gammon Ferruginous Member</td></tr>
</table>

about the same range in thickness in wells throughout most of the southeastern part of the area. The member is absent in outcrops west of Oil Creek in the vicinity of Pedro, and in the subsurface, in a well drilled nearby in sec. 13, T. 45 N., R. 63 W. The member reappears in outcrops a short distance west of the Newcastle area and thickens rapidly to as much as 800 feet in northern Weston County. The stratigraphic relations of the member between Newcastle and Pedro are shown on figure 8.

Shale in the Gammon Ferruginous Member weathers medium to dark gray. The upper part of the member contains fairly abundant fish scales and other organic material, and the shale weathers to hard platy chips. The lower part is less resistant and at places contains a few tabular siderite concretions that weather dark red.

The contact between the Gammon Ferruginous Member of the Pierre Shale and the underlying Niobrara Formation is sharp, but

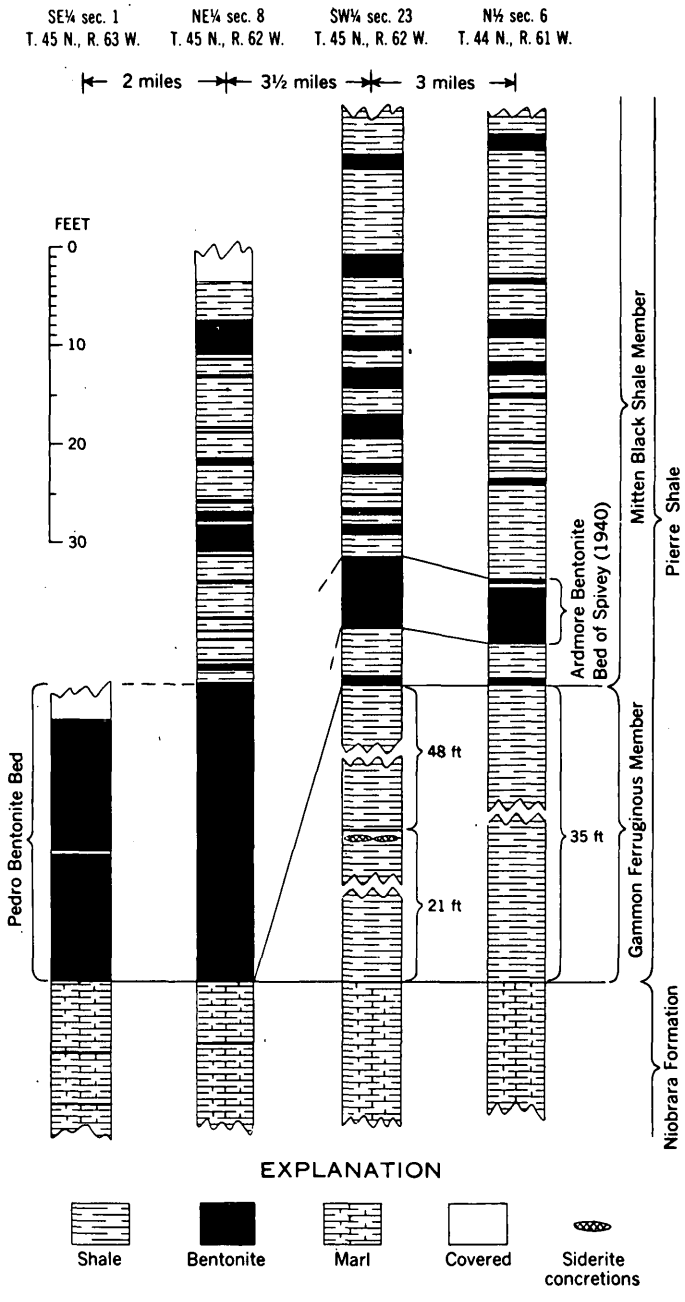

FIGURE 8.—Stratigraphic relations at the base of the Pierre Shale, Newcastle area.

with the exception of a small area near Pedro, there appears to be no unconformity. A local unconformity at Pedro is suggested by the wedging out of the member and by the reduced thickness of the Niobrara Formation in this vicinity.

In other parts of the Black Hills, the Gammon Ferruginous Member contains the index fossil *Scaphites hippocrepis,* which is common in the Eagle Sandstone and Telegraph Creek Formation of southern Montana.

MITTEN BLACK SHALE MEMBER

The Mitten Black Shale Member of the Pierre Shale is about 835 to 920 feet thick near Newcastle. It has been divided on the geologic map (pl. 1) into two parts of about equal thickness. The lower part which is 410 feet thick 2 miles southwest of Newcastle in sec. 6, T. 44 N., R. 61 W., is hard dark-gray shale that weathers medium gray to brownish gray and contains much organic material, including numerous fish scales and bones. It typically supports little or no soil or vegetation. Large septarian limestone concretions 5 to 10 feet in diameter that weather light gray and have veins of orange-brown calcite are conspicuous in the upper half of this part of the Mitten, and the upper 90 to 120 feet also contains scattered red-weathering siderite concretions.

Numerous bentonite beds occur in the lower part of the Mitten, as shown by the graphic sections, figure 8. Southwest of Newcastle the bentonite zone includes 13 bentonite beds, one about 6 feet thick, in an interval of about 60 feet. A thick bed near the base of the zone is the Ardmore Bentonite Bed of Spivey (1940, p. 3; Kepferle, 1959, p. 584, pl. 52), according to J. R. Gill (oral communication, 1958), who has traced it southward along the west side of the Black Hills. A few miles northwest of Newcastle, in sec. 23, T. 45 N., R. 62 W., the bentonite zone is about 60 feet thick and contains 14 bentonite beds. Near Pedro, the zone is at least 70 feet thick, and has at least 16 bentonite beds. The basal bentonite in this area, called the Pedro Bentonite Bed by Rubey (1931, p. 4), is about 30 feet thick and rests directly on the Niobrara Formation (fig. 6). The Pedro Bed apparently is a thickened equivalent of the Ardmore Bed of Spivey (1940). The bentonite zone is readily identified on electric logs by its low resistivity, as shown on plate 1.

The upper part of the Mitten Black Shale Member is about 425 feet thick southwest of Newcastle and consists of soft shale that weathers grayish black. It contains siderite concretions that weather dark red, some limestone cone-in-cone concretions that weather tan, and, in the upper part, a few septarian limestone concretions that weather light gray. It contrasts with the lower part of the Mitten

by its darker color in outcrops, and because it generally forms deep gumbo soil. A bentonite bed about one-half foot thick marks the base of this part of the Mitten Black Shale Member. About 150 feet below the top is a bentonitic zone that swells on weathering and forms a band of brown bentonitic soil several feet wide at outcrops between Little Oil Creek and the south edge of the Newcastle area.

The following stratigraphic section gives the lithology and sequence of beds in the Mitten Black Shale and Gammon Ferruginous Members of the Pierre Shale.

Mitten Black Shale Member of the Pierre Shale and adjacent rocks southwest of Newcastle, in the SW¼NE¼ and the SE¼ NW¼ sec. 6, T. 44 N., R. 61 W., Weston County, Wyo.

[Fossils identified by W. A. Cobban]

	Feet
Pierre Shale (part):	
Middle part (part):	
26. Shale, dark-gray, grayish-brown weathering; silty at the base, sandy in the upper part; several beds of closely spaced tabular septarian limestone concretions that weather light gray and form ledges; a few rusty-weathering concretions at the top of the unit; concretions contain the following fossils: USGS loc. D417, concretions about the top or slightly above the top of the unit nearby to the south: *Inoceramus sublaevis* Hall and Meek, *Inoceramus* sp., *Eutrephoceras* sp., *Baculites scotti* Cobban, *Anapachydiscus* sp. USGS loc. D418, gray-weathering concretions about the middle of the unit: *Inoceramus sublaevis* Hall and Meek, *Inoceramus* cf. *I. proximus* Tuomey, *Cuspidarea* cf. *C. moreauensis* (Meek and Hayden), *Anisomyon borealis* (Morton), *Baculites* aff. *B. gregoryensis* Cobban, *Placenticeras* sp.	150
Mitten Black Shale Member:	
Upper part:	
25. Shale, grayish-black, grayish-black weathering; scattered gray-weathering limestone concretions. USGS loc. D419, concretions in upper part of the unit; *Lucina subundata* Hall and Meek, *Baculites* n. sp., *Scaphites*? n. sp.	45
24. Shale, dark-gray, grayish-brown weathering, silty; several beds of rusty-weathering tabular limestone concretions	30
23. Shale, grayish-black, grayish-black weathering; three beds of limestone concretions that weather light gray to grayish red and are about 1 ft in diameter. USGS loc. D420, concretions; *Inoceramus barabini* Morton, *Baculites* cf. *B. haresi* Reeside	25
22. Covered; deeply weathered bentonitic soil bare of vegetation	9
21. Partly covered; mostly grayish-black shale; many beds of dark-gray tabular limestone concretions that weather dark red; some cone-in-cone limestone concretions that weather yellow and tan. USGS loc. D421, concretions about 25 ft below the top of the unit; *Baculites haresi* Reeside	315
20. Bentonite, light yellowish-gray, nonswelling	.5
Thickness, rounded, upper part Mitten Black Shale Member	425

Mitten Black Shale Member of the Pierre Shale and adjacent rocks southwest of Newcastle, in the SW¼NE¼ and the SE¼NW¼ sec. 6, T. 4 N., R. 61 W., Weston County, Wyo.—Continued

	Feet
Pierre Shale (part)—Continued	
Mitten Black Sale Member—Continued	
Lower part:	
19. Shale, medium- to dark-gray; weathers to fairly hard papery flakes; contains at least five beds of tabular red-weathering limestone concretions; supports relatively little vegetation	21
18. Shale as in unit 19 above; at least six beds of septarian limestone concretions that weather light gray, have veins of orange-brown calcite, and are as much as 8 ft in diameter; a few tabular silty red-weathering limestone concretions in the top 90 ft	160
17. Shale, medium- to dark-gray; weathers to fairly hard platy fragments; somewhat less fissile than the shale in units 18 and 19; contains fish scales and other organic fragments; supports relatively little vegetation	40
16. Mostly covered; bottom 5 ft is shale as in unit 17	45
15. Bentonite, very light gray, nonswelling	.2
14. Shale as in unit 17 above	12
13. Bentonite, very light gray, nonswelling	.1
12. Shale as in unit 17 above	74
11. Bentonite, very light gray, nonswelling; shaly at the top	1.9
10. Shale, medium- to dark-gray, platy, organic-rich	6.6
9. Bentonite, very light gray, nonswelling	1.5
8. Shale, medium- to dark-gray, platy, organic-rich	6.1
7. Shale and bentonite as follows:	
Bentonite, very light gray, nonswelling	0.7
Shale, medium- to dark-gray, platy, organic-rich	3.4
Bentonite, very light gray, nonswelling	1.8
Shale, medium- to dark-gray, platy, organic-rich	2.4
Bentonite, very light gray, nonswelling	1.2
Shale, medium- to dark-gray, platy, organic-rich	1.9
Bentonite, very light gray, nonswelling	.7
Shale; mostly medium to dark gray; brown band 0.5 ft thick near base; platy	4.2
Bentonite, very light gray, nonswelling	.1
Shale, medium- to dark-gray, platy	2.4
Bentonite, very light gray, nonswelling	.4
Shale, medium- to dark-gray platy	.7
Bentonite, very light gray, nonswelling	.9
Total	20.8
6. Shale, medium- to dark-gray, platy; much organic material	9.7
5. Bentonite and shale as follows (Ardmore Bentonite Bed of Spivey, 1940):	
Bentonite, very light gray, nonswelling	0.5
Shale, brown, bentonitic	.4
Bentonite, very light gray; upper 2.2 ft nonswelling, lower part slightly swelling	5.8
Total	6.7
4. Shale, medium- to dark-gray, platy; weathers brown in the bottom 2 ft; silicified in top 0.1 ft	3.6
3. Bentonite, very light gray, nonswelling	.8
Thickness, rounded, lower part Mitten Black Shale Member	410
Thickness, rounded, Mitten Black Shale Member	835

Mitten Black Shale Member of the Pierre Shale and adjacent rocks southwest of Newcastle, in the SW¼NE¼ and the SE¼NW¼ sec. 6, T. 4 N., R. 61 W., Weston County, Wyo.—Continued

	Feet
Pierre Shale (part)—Continued	
Gammon Ferruginous Member:	
2. Shale, medium- to dark-gray; weathers to fairly hard platy chips; contains fish scales	35
Partial thickness, rounded, Pierre Shale	1,020
Niobrara Formation (part):	
1. Marl, yellow and light-gray weathering, fissile	10

Except for fish remains, no identifiable fossils have been found in the lower part of the Mitten Black Shale Member in the Newcastle area. In areas farther south, hard organic-rich shale above the Ardmore Bed in the lower part of the Mitten Black Shale Member contains *Baculites obtusus* and *B. asperiformis* (J. R. Gill, oral communication, 1959). The lower part of the Mitten Black Shale Member is equivalent in large part to the Sharon Springs Member of the Pierre Shale described by Spivey (1940) and Kepferle (1959) at the south end of the Black Hills.

Fossils collected from the upper part of the Mitten Black Shale Member belong in the zones of *Baculites perplexis* and *B. asperiformis*. In addition to the fossils listed in the stratigraphic section, pages N55–N57, the following fossils, identified by W. A. Cobban, were found in the upper part of the Mitten Black Shale Member:

USGS loc. D871, NW¼ sec. 13, T. 45 N., R. 63 W.
Inoceramus n. sp.
Baculites n. sp.
USGS loc. D2132, NW¼SW¼ sec. 10, T. 44 N., R. 61 W.
Inoceramus pertenuis Meek and Hayden
Lucina occidentalis (Morton)
Baculites n. sp.
USGS loc. D2134. NE¼NW¼SE¼ sec. 11, T. 44 N., R. 61 W.
Baculites n. sp.
USGS loc. D2136, NE¼NE¼ sec. 22, T. 44 N., R. 61 W.
Inoceramus sp.
Lucina sp.
Baculites n. sp.
USGS loc. D2135, SE¼SE¼ sec. 26, T. 44 N., R. 61 W.
Inoceramus sp.
Baculites n. sp.

MIDDLE PART

The middle part of the Pierre Shale consists of about 1,100 to 1,200 feet of poorly exposed dark-gray shale that is silty and sandy in the basal 200 to 300 feet and lies between the underlying Mitten Black Shale and overlying Kara Bentonitic Members. Septarian limestone

concretions that weather light gray are common in the middle part of the Pierre, and some red-weathering concretions are near the top in sec. 1, T. 44 N., R. 63 W. and in sec. 36 of the township of the north. So-called Tepee butte concretions consisting of resistant irregular masses of fossiliferous limestone also occur locally.

Fossils in the middle part of the Pierre are common to the Parkman Sandstone and part of the overlying Bearpaw Shale of south-central Montana (Cobban, 1958a, p. 117). The following fossils, identified by W. A. Cobban, were collected in the Newcastle area and represent, from oldest to youngest, the zones of *Baculites gregoryensis, B. scotti, Didymoceras? stevensoni, Exiteloceras jenneyi,* and *Baculites eliasi.* Fossils from the base of the middle part of the Pierre Shale in sec. 6, T. 44 N., R. 61 W. are listed with the stratigraphic section, pages N55–N57.

USGS loc. D2138, NE¼NW¼ sec. 33, T. 44 N., R. 61 W., near the base of the middle part of the Pierre Shale.
- *Inoceramus* aff. *I. cycloides* Wagner
- *Drepanochilus* sp.
- *Baculites gregoryensis* Cobban
- *Didymoceras* sp.
- *Placenticeras* sp.

USGS loc. D870, SW¼ sec. 7, T. 45 N., R. 62 W., near the base of the middle part of the Pierre Shale.
- *Inoceramus* cf. *I. barabini* Morton
- *Lucina subundata* Hall and Meek
- *Drepanochilus* n. sp.
- *Baculites* cf. *B. gregoryensis* Cobban

USGS loc. D2621, NW¼NW¼NE¼ sec. 17, T. 45 N., R. 62 W., lower part of middle part of the Pierre Shale.
- *Nuculana* sp.
- *Inoceramus sublaevis* Hall and Meek
- *Pteria nebrascana* (Evans and Shumard)
- *Lucina subundata* Hall and Meek
- *Baculites scotti* Cobban
- *Acanthoscaphites* n. sp.

USGS loc. D454, SE¼ sec. 19, T. 45 N., R. 62 W., estimated to be about 1,700 ft stratigraphically above the base of the Pierre Shale.
- *Inoceramus pertenuis* Meek and Hayden
- *Inoceramus convexus* Hall and Meek
- *Inoceramus* (*Endocostea*) *sulcatus* Roemer
- *Ostrea inornata* Meek and Hayden
- *Lucina subundata* Hall and Meek
- *Anisomyon sexsulcatus* (Meek and Hayden)
- *Eutrephoceras* sp.
- *Baculites crickmayi* Williams
- *Exiteloceras* sp.
- *Solenoceras mortoni* (Meek and Hayden)
- *Didymoceras* aff. *D. stevensoni* (Whitfield)
- *Acanthoscaphites nodosus* Owen
- *Acanthoscaphites* cf. *A. brevis* Meek

USGS loc. D455, NW¼NW¼ sec. 16, T. 44 N., R. 62 W., estimated to be about 1,750 ft stratigraphically above the base of the Pierre Shale.

Inoceramus cf. *I. sagensis* Owen
Inoceramus cf. *I. vanuxemi* Meek and Hayden
Anisomyon borealis (Morton)
Baculites n. sp.
Exiteloceras jenneyi (Whitfield)
Acanthoscaphites n. sp.
Placenticeras meeki Boehm

USGS loc. D2620, SE¼NE¼ sec. 34, T. 44 N., R. 62 W., estimated to be about 1,750 ft stratigraphically above the base of the Pierre Shale.

Nucula sp.
Nuculana sp.
Inoceramus sp.
Pteria linguaeformis (Evans and Shumard)
Anisomyon sexsulcatus (Meek and Hayden)
Baculites n. sp.
Exiteloceras jenneyi (Whitfield)
Acanthoscaphites n. sp.
Placenticeras meeki Boehm

USGS loc. D457, NW¼ sec. 36, T. 45 N., R. 63 W., estimated to be 50 ft stratigraphically below Kara Bentonitic Member of the Pierre Shale.

Inoceramus n. sp.
Baculites eliasi Cobban
Acanthoscaphites n. sp.

KARA BENTONITIC MEMBER

The Kara Bentonitic Member of the Pierre Shale crops out west of Beaver Creek in the southwestern corner of the Newcastle area. The member is about 75 to 100 feet thick and consists mostly of gray bentonitic shale that swells where weathered to form a locally conspicuous band of light-gray soil nearly bare of vegetation. The member contains a few septarian limestone concretions that weather light gray and locally abundant nodules of barite 1 or 2 inches in diameter.

Fossils collected from the Kara Bentonitic Member in nearby areas include *Baculites eliasi* Cobban (Robinson, Mapel, and Cobban, 1959, p. 113, 118).

UPPER PART

About 50 to 100 feet of dark-gray shale in the upper part of the Pierre overlies the Kara Bentonitic Member in the southwestern corner of the Newcastle area. The upper part of the Pierre also contains several beds of fossiliferous gray septarian limestone concretions including one conspicuous bed at the base in which the concretions are several feet in diameter. Concretions at the base of the unit contain *Baculites eliasi* Cobban, and concretions 200 to 300 feet stratigraphically above the base of the formation in nearby areas

contain *B. baculus* Meek and Hayden and *B. grandis* Hall and Meek (Robinson, Mapel, and Cobban, 1959, p. 112, 119).

QUATERNARY SYSTEM

TERRACE DEPOSITS

Poorly consolidated stream-laid deposits of sand, silt, and gravel cover small areas on the tops and along the sides of the divides bordering Skull and Oil Creeks in the western part of the area, on divides along Stockade Beaver Creek in the southeastern part, and on knobs along Little Oil and Cemetery Creeks near Newcastle. The highest and oldest deposit covers a small area in the E½ sec. 34, T. 44 N., R. 62 W., nearly 200 feet above the level of nearby Skull Creek. Most of the other terraces are 60 to about 120 feet above the levels of the adjacent main streams.

The thickness of the deposits ranges from about 5 to 12 feet. Pebbles of quartzite and chert and pebbles and granules of sandstone and siltstone cemented with iron oxides make up the larger fragments in most of the deposits. Limestone pebbles are fairly abundant in gravel along Stockade Beaver Creek, but they are relatively rare elsewhere. The larger fragments generally range from one-half inch to about 4 inches in diameter in most deposits, although scattered boulders 1 foot to 4 feet in diameter are also present.

The terrace deposits presumably were laid down during interglacial stages of the Pleistocene, as were other terrace deposits at about the same relative levels in nearby parts of the northern Great Plains (Alden, 1932, p. 1).

LANDSLIDE MATERIAL

Landslide material covers much of the Morrison Formation, the Redwater Shale Member, and underlying parts of the Sundance Formation in the northeastern part of the area. Smaller landslides have formed on the Lakota and Morrison Formations along the sides of steep divides near the heads of Oil, East Plum, and West Plum Creeks in the north-central part of the area. The largest slides are on the sides of Mount Pisgah and the outlying ridges where displaced rocks of the Lakota, Morrison, and Sundance Formations cover areas of several square miles.

The Skull Creek Shale also forms slides at many places, but most of them are too small and discontinuous to show on the geologic map (pl. 1).

Shrubs and small trees growing on the landslide material show no disarrangement that would indicate that the slides have been active recently.

ALLUVIUM

Alluvium of unknown thickness, consisting of sand, silt, and lenses of gravel, borders most of the larger streams in the area. Alluvial plains along Skull and Stockade Beaver Creeks are locally more than a mile wide. The streams are incised a few feet into the old flood plains, so that at most places only a narrow band of ground is covered by water during flood stage. Deposits on the remainder of the flood plains might more properly be called low terrace depsoits.

STRUCTURE

The Newcastle area 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 westward into the Powder River Basin, a structural depression that occupies at least 16,000 square miles in Wyoming and Montana. Figure 9 shows the configuration of these large structural features and the location of the Newcastle area in relation to them.

Structural details in the Newcastle area are shown on plate 1 by a cross section and by structure contours drawn at a vertical interval of 100 feet on the top of the Fall River Formation. The structure is relatively simple. Strata exposed in the northeastern part of the area dip southwestward at angles of 2° to 3°. The beds are sharply downfolded along a monoclinal fold, or locally a pair of folds, that trend more or less diagonally across the area from northwest to southeast. Strata southwest of this folded belt resume a nearly uniform southwestward dip of 1° to 2°.

The maximum structural relief in the area is about 6,800 feet.

FOLDS

Black Hills monocline.—The main structural feature in the Newcastle area is a steep monocline, or locally two monoclines, along which rocks on the northeast are abruptly elevated relative to those on the southwest. The belt of folding, which extends across the area from northwest to southeast, is the Black Hills monocline. It marks the west edge of the Black Hills uplift (fig. 9), and it can be followed as a major structural feature from the Newcastle area northwestward across Weston and Crook Counties, Wyo., for more than 60 miles.

In the Newcastle area, the Black Hills monocline is steepest and best defined between Oil and Little Oil Creeks. Dips in the steepest part of the monocline range from 55° to 75° in the Carlile Shale, Niobrara Formation, and basal part of the Pierre Shale. The middle part of the Pierre Shale crops out on the southwest side of the monocline within a mile of outcrops of the Fall River Formation on the

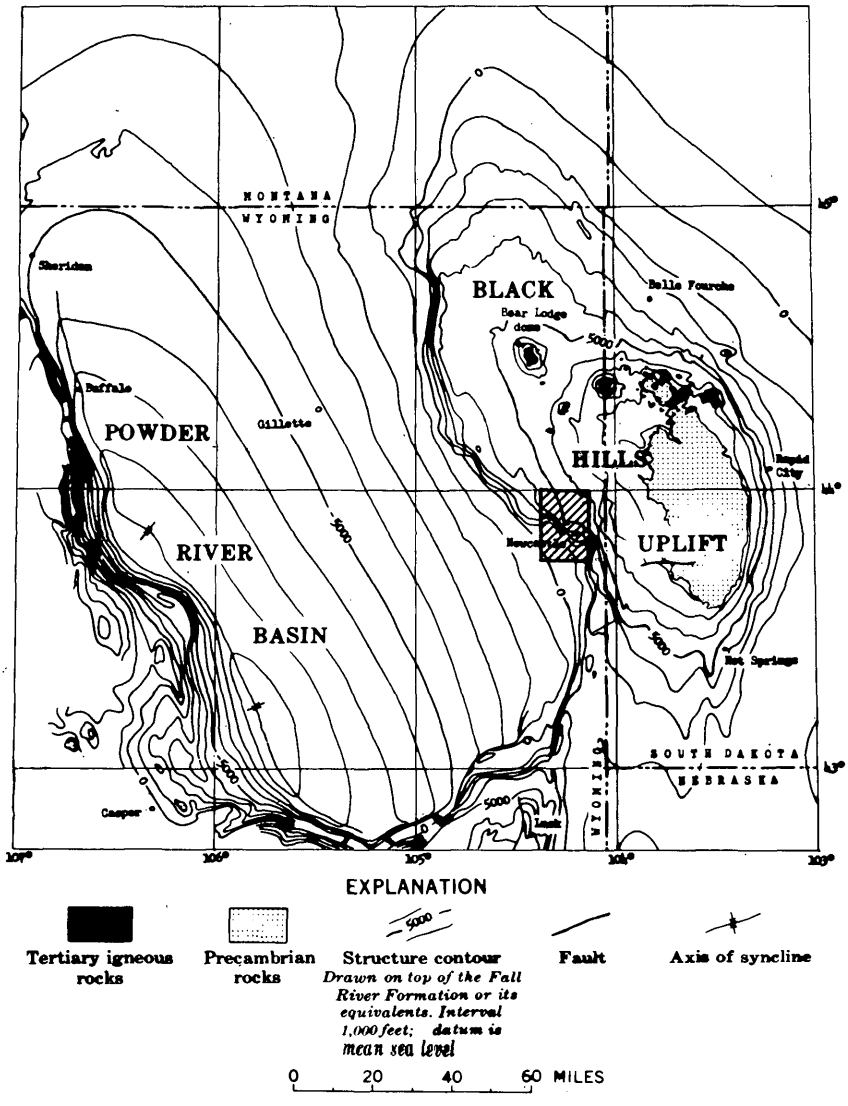

FIGURE 9.—Location of Newcastle area (crosshatched) in relation to major structural features of northeastern Wyoming and adjacent areas. Data from Pierce, Girard, and Zapp (1952), Noble (1952), and Dobbin and Erdmann (1955).

northeast side. The structural relief in this distance is about 3,500 feet. Younger rocks on the southwest side of the monocline flatten abruptly, and older rocks on the northeast side flatten slightly less abruptly away from the fold.

The monocline turns westward and becomes less steep in the vicinity of Pedro. At about this locality the fold splits, one branch continuing westward and the other northwestward on either side of a structural

terrace, the end of which is west of Skull Creek and barely within the area. Folding in the adjacent area to the northwest was described by Collier (1922), and by Dobbin, Miller, and Walter (1935).

The Black Hills monocline also splits at about the point where it crosses Little Oil Creek, 2 miles west of Newcastle. One branch turns northeastward and then southeastward in a sinuous curve along which formations from the Fall River to the Belle Fourche dip from 10° to about 30°S. or SW. The other branch continues southeastward for about 3 miles and then turns eastward roughly parallel to the northern branch; the two branches join near Stockade Beaver Creek about 3 miles southeast of Newcastle. The upper part of the Carlile Shale, the Niobrara Formation, and the lower part of the Pierre Shale, which crop out in a band about half a mile wide, mark the surface trace of the southern branch. The steeper dips of these rocks range from 30° to 60°. A structural terrace that is about 3 miles wide and dips gently southward separates the two branches of the monocline; the upper part of the Belle Fourche Shale, the Greenhorn Formation, and the lower part of the Carlile Shale crop out in this area.

East of the LAK Ranch at about the east boundary of the Newcastle area, the Black Hills monocline joins at right angles a northward-trending monocline that brings the Pierre Shale and older rocks sharply upward east of Stockade Beaver Creek. Formations ranging from the Pierre Shale to the Newcastle Sandstone are affected by the steepest folding, and these rocks attain maximum dips of about 55° W. The details of folding east of the LAK Ranch have been described by Brobst (1963).

A regional gravity map (Black and Roller, 1961) shows a good correlation between the monoclines and zones of steep gravity gradients. On the basis of the gravity data, Black and Roller (1961) surmise that the folds pass into faults at depth.

Other folds.—A low, broad, southward-plunging anticline underlies Antelope Flats on the upper side of the Black Hills monocline. The axis of the fold trends southwestward at about right angles to the Black Hills monocline in the southeast corner of T. 45 N., R. 62 W.; there, it bends gently southward, and at Alum Creek the axis trends southeastward, parallel to the Black Hills monocline. The anticline dies out farther southeastward in the structural terrace south of Newcastle. Dips in the Fall River Formation on Antelope Flats, on the flanks of this fold, range from 1° to 3°; and the fold may have a few feet of closure at the corner common to secs. 11, 12, 13, and 14, T. 45 N., R. 62 W. Local thickening in the upper part of the Fall River Formation, which forms the surface of Antelope Flats in this vicinity and consists of lenticular massive sandstone at least 65 feet

thick at Cave Spring in sec. 12 (fig. 7), may account for some of the apparent doming.

FAULTS

Rocks exposed in the Newcastle area are not greatly deformed by faulting. Five short faults of small displacement were seen in the Fall River or older rocks along the east side of the area, and one fault was mapped in Upper Cretaceous rocks north of Pedro. The dips of the fault planes could not be observed, but the map relations suggest that most of the faults are vertical. All the faults trend northwestward at angles ranging from about N. 20° W., for three small faults northwest of the LAK Ranch, to N. 80° W., for the fault near Pedro.

A fault has been traced for about 1,000 feet in sec. 6, T. 44 N., R. 60 W. The Lakota Formation on the east side of this fault is brought against the lower part of the Fall River Formation on the west side, and the maximum displacement is about 35 feet.

Two parallel faults cut outcrops of the Fall River and Lakota Formation in sec. 36, T. 45 N., R. 61 W. The easternmost and longest fault has been traced for about 1,500 feet into sec. 25 to the north. Along both these faults, the east sides are upthrown, and the maximum vertical displacement is about 30 feet.

A fault in the Sundance Formation in secs. 13 and 14, T. 45 N., R. 61 W. locally brings the Hulett Sandstone Member of the Sundance on the southwest side upward against the Lak Member on the northeast side; vertical displacement is about 20 feet. The fault is not readily seen on the ground, but on aerial photographs its trace makes a faint lineation at least 3,000 feet long.

The Spearfish, Gypsum Spring and Sundance Formations are cut by a short fault in secs. 14 and 15, T. 46 N., R. 61 W. The displacement along this fault is about 15 feet, upthrown on the southwest side. The Gypsum Spring Formation is absent adjacent to the fault on the downthrown side (loc. 3, pl. 2) but is about 6 to 9 feet thick on the upthrown side a few feet to the northeast.

A fault near Pedro in secs. 5 and 6, T. 45 N., R. 62 W. dropped the lower unnamed member of the Carlile Shale, the Greenhorn Formation, and the Belle Fourche Shale on the north side relative to the same formations on the south side. The displacement appears to be about 50 feet. This fault may extend for a short distance northwestward beneath the alluvium of Skull Creek into the Pedro oil field.

AGE OF DEFORMATION

The principal folding and faulting of sedimentary rocks in the Black Hills and the deformation responsible for the present form of the uplift

both occurred after deposition of the marine Cretaceous rocks, probably in latest Cretaceous or in early Tertiary time (Darton, 1909, p. 76). Some earlier periods of uplift and erosion are recorded by unconformities at the base of the Gypsum Spring, Sundance, and Fall River Formations. Local truncation of beds occurs within the Lakota Formation at places along the west side of the Black Hills near the Newcastle area, probably as a result of slight folding before and during deposition of the Lakota Formation (Izett, Pillmore, and Mapel, 1961). An area of at least several square miles near Pedro was either a shoal or a low island during deposition nearby of the basal part of the Pierre Shale, as shown by convergence of the Ardmore Bentonite Bed with the Niobrara Formation and the thinning of the Niobrara Formation in this area.

ECONOMIC GEOLOGY

OIL AND GAS

Oil has been produced from the Newcastle area since the close of the last century, and through the end of 1960, about 500 wells have been drilled. The oil and gas occurs in the small Pedro oil field about 2 miles northwest of Pedro, in the Skull Creek and Mush Creeks areas a few miles southwest of Newcastle, and in the Newcastle field 3 to 4 miles southeast of Newcastle. Random drilling to the Newcastle sandstone has accounted for most of the oil discoveries. The location of the oil and gas producing areas is shown on the geologic map, plate 1, and their geographic relation to oil producing areas in other parts of Weston County is shown on figure 10.

The Newcastle Sandstone has yielded nearly all the oil and gas produced in the Newcastle area. Oil and gas in this formation occur in stratigraphic traps formed by lensing and changes in porosity of the sandstone beds. The Newcastle Sandstone is oil stained at outcrops near Newcastle, and oil seeps in the formation in the NW¼ sec. 23 and the NE¼ sec. 25, T. 45 N., R. 62 W. were described by Darton (1904, p. 9). The Belle Fourche Shale contains oil in the Pedro field, and a show of gas is reported from the Turner Sandy Member of the Carlile Shale in one well in the Skull Creek field. The Minnelusa and Fall River Formations, which hold commercially valuable amounts of oil in nearby areas on the east side of the Powder River Basin, contain shows of oil in some wells drilled in the Newcastle area.

Through the end of 1959, about 5,580,000 barrels of oil was produced from the Skull Creek and North Skull Creek fields, which lie wholly within the southwestern part of the area, and about 13,000 barrels of oil was produced from the Pedro field. About 7,400,000 barrels of oil has been produced from the Mush Creek field, but about 85

percent of the productive area of the field is outside the Newcastle area.

Wells in the Newcastle area that have penetrated the Fall River or older rocks are listed in table 3; the status of wells in the oil and gas producing areas is given in table 4; and some characteristics of crude oil from the Newcastle and adjacent areas are shown in table 5.

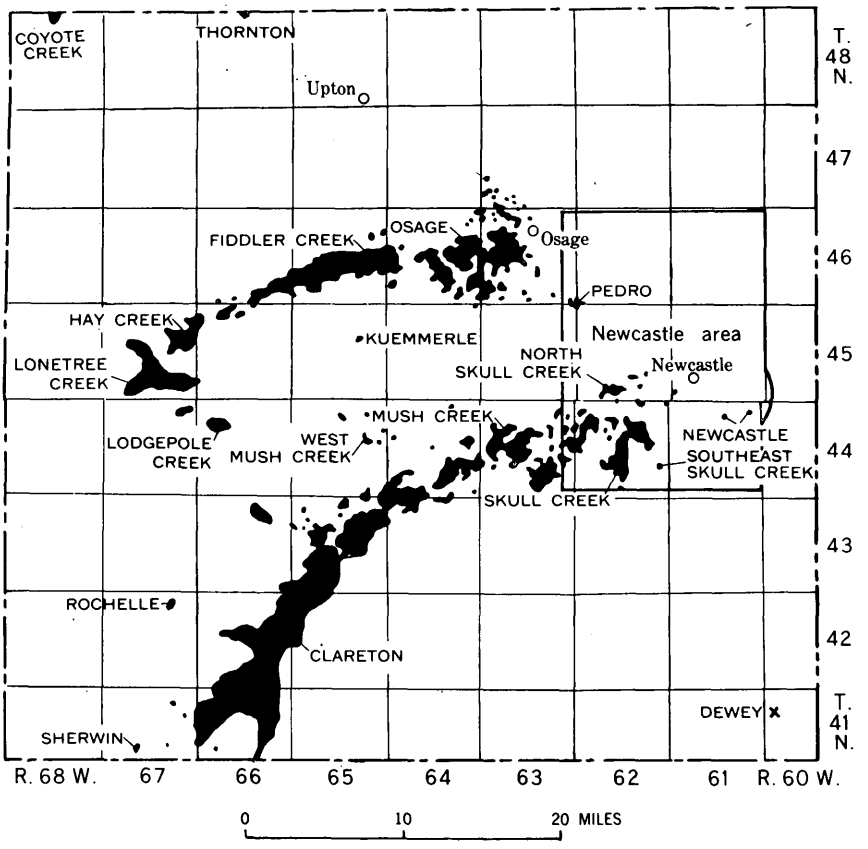

FIGURE 10.—Oil fields in Weston County, Wyo., January 1960.

Pedro oil field.—The Pedro oil field is about 2 miles northwest of Pedro at the corner common to Tps. 45 and 46 N., Rs. 62 and 63 W. As shown on figure 10 the field is at the east end of an oil-producing belt that farther west includes the Osage, Fiddler Creek, Lodgepole Creek, and Lonetree Creek fields. The Pedro field was discovered in 1922 by a well in the NW¼ NW¼ sec. 6, T. 45 N., R. 62. W. From 1922 until 1960 there were 58 wells drilled in and adjacent to the field. Of these, 25 were completed with initial productions that ranged from about 2 to 5 barrels of oil per day. The oil comes from fractures in

TABLE 3.—*Selected wells drilled in the Newcastle area*

Location in section	Operator and well	Year completed	Total depth (feet)	Oldest formation reached	Remarks
T. 44 N., R. 61 W.					
CSE¼SE¼ 4	W. F. Sheehan, Jr., Ertman 2	1957	1,368	Fall River	
NE¼SE¼SE¼ 6	E. T. Williams Oil Co., Henry Martin 1	1920	2,055	do	
NW¼NE¼SW¼ 6	L. W. Winkler and Son, Govt. 1	1960	3,142	do	
SW¼SE¼SW¼ 10	Stone and Ogle, Ertman 1	1949	2,875	do	
CSW¼SW¼ 12	Coronado Petroleum Co., LAK Ranch 1	1955	4,629	Minnelusa	Oil show, Belle Fourche.
SW¼NE¼/SE¼ 15	P. F. Smith, Govt. 1	1959	3,005	Morrison	
NW¼NW¼NW¼ 18	Parker-Simmons Drilling Co., Govt. 5	1950	4,050	Spearfish	
SW¼SW¼NW¼ 22	M. M. Newell, Govt. 1	1949	2,768	Fall River	
E½NE¼NW¼ 31	Mon-O-Co Oil Co., Aimonetto Estate 1	1948	3,760	Sundance	Converted to water well.
T. 44 N., R. 62 W.					
SW¼SW¼NE¼ 2	Thomas and Morton, Jake Kozel 1	1949	3,138	Fall River	
NE¼SW¼SE¼ 2	Black Hills Drilling Co., H. Graham 1	1955	6,227	Deadwood	Oil shows, Minnelusa and Pahasapa.
CNW¼NW¼ 2	Ackerman and Roberts, State of Wyoming, Jake Kozel 3.	1958	3,385	Morrison	Oil, Newcastle. Converted to water injection well; 1,250 bbls water per day from the Lakota.
NW¼NE¼NW¼ 13	John Brorby, L. B. Hanson 1	1942	3,568	Fall River	Gas show, Turner Sandy Member of the Carlile.
SW¼SW¼NW¼ 16	Morton Drilling Co., State of Wyo. 2	1948	3,558	do	
NE¼NE¼NW¼ 16	Skull Creek Syndicate and Midwest Refining Co., State of Wyo. 1.	1922	3,692	Lakota	Oil show, Fall River.
NW¼NW¼NW¼ 23	Brinkerhoff Drilling Co., H. D. Livingston 1.	1948	3,305	Fall River	
NW¼NE¼SW¼ 24	O. H. Parker, Govt. 2	1949	3,170	do	
CNE¼SE¼ 26	Summit Oil Co., Amerada-Govt. 1	1960	3,445	Lakota	
NE¼NW¼NE¼ 26	R. F. Six, Bedell 1	1950	3,264	Fall River	10.0 million cu ft gas per day, Newcastle.
CSW¼SE¼ 27	English Oil Co., Govt. 1A–27	1958	3,798	Lakota	
NW¼NW¼NW¼ 31	Galloway—Smith, Govt. 1	1948	3,934	Fall River	

TABLE 3.—*Selected wells drilled in the Newcastle area*—Continued

Location in section	Operator and well	Year completed	Total depth (feet)	Oldest formation reached	Remarks
	T. 44 N., R. 63 W.				
SW¼NW¼SE¼ 12	Brinkerhoff Drilling Co., Elliot 1	1948	3,816	Fall River	
SE¼SW¼NW¼ 24	Mush Creek Producing Co., Govt. 1	1945	4,912	Spearfish	Oil show, Newcastle.
	T. 45 N., R. 61 W.				
CSE¼SE¼ 10	Leuthart and Briggs, 1	1926	850	Minnelusa	
NE¼NW¼NE¼ 29	City of Newcastle, City of Newcastle 1	1949	2,638	Pahasapa	Flowed 1,600 gpm water from the Pahasapa.
NW¼NW¼SW¼ 29	Sioux Oil Co., Sioux Oil Co. 1	1960	3,073	do	Oil show, Newcastle. Flowed about 20 gpm water from the Pahasapa.
NW¼NE¼NW¼ 32	Oil City Supply Co., Wyo. Farm 1	1960	680	Fall River	2½ bbls oil per day, Newcastle.
	T. 45 N., R. 62 W.				
NW¼NW¼NW¼ 16	R. B. Miller, Trustee, 1	1921	2,975	Sundance	
CSW¼SW¼ 22	Shaw Oil Co., Holst 1	1925	3,450	Lakota	
SW¼NE¼SW¼ 28	Brinkerhoff Drilling Co., Horton 1	1948	3,358	Fall River	
SW¼NW¼NE¼ 35	Coronado Petroleum Co., Boggs 1	1960	4,654	Minnelusa	Oil show, Newcastle.
SW¼SW¼NE¼ 36	Coronado Petroleum Co., State of Wyo.—J. F. Dougherty 1.	1960	2,998	Morrison	

T. 46 N., R. 63 W.					
CSE¼SW¼ 1	McAlester Fuel Co., Govt. E–1	1960	2,072	Morrison	
CNE¼SE¼ 12	M.K.M. Oil Co., Govt. 2	1958	2,740	Fall River	
T. 46 N., R. 61 W.					
NW¼ 29	North Pacific Oil and Development Co., 1.	1900	2,345	Pahasapa	Flowed 200 gpm water from Pahasapa.
T. 46 N., R. 62 W.					
SW¼SE¼NW¼ 18	J. K. Wadley, System Terminal Corp. 1	1957	2,737	Pahasapa	Flows water from Pahasapa(?).
T. 46 N., R. 63 W.					
CNE¼NW¼ 1	Webster Oil Co., Bock 1	1921	1,687	Minnelusa	Water from Minnelusa.

TABLE 4.—*Well status, December 31, 1959*

Oil field	Producing				Drilling or suspended	Injection	Abandoned	Total
	Active		Shut in					
	Oil	Gas	Oil	Gas				
Skull Creek	116	1	5	0	3	2	158	285
North Skull Creek	20	0	0	0	6	0	39	65
Pedro	8	0	17	0	0	0	33	58
Newcastle	3	0	1	0	3	0	13	20

TABLE 5.—*Analyses of crude oil from the Newcastle and nearby areas*

[From Biggs and Espach (1960, p. 447–460); analyses by U.S. Bur. Mines and U.S. Geol. Survey]

Sample	Location (Sec., T., R.)	Depth (feet)	Formation	Specific gravity	A.P.I. gravity (°Baumé)	Sulfur (percent)	Saybolt universal viscosity, 100°F (seconds)	Pour point (°Fahrenheit)	Nitrogen (percent)	Color
Pedro field										
34–010	SW¼SW¼ 31, 44 N., 62 W.	270	Belle Fourche	0. 879	29. 5	0. 22	95	<5	-------	Brownish-green.
Mush Creek-Skull Creek area										
PC–52–324	SW¼SE¼ 26, 44 N., 63 W.	3, 940–3, 966	Newcastle	0. 850	35. 0	0. 06	44	<5	0. 044	Green.
PC–52–50	SW¼NW¼SW¼ 11, 44 N., 62 W.	2, 965–3, 030	do	. 855	34. 0	. 09	49	50	. 043	Do.
PC–54–49	NW¼SE¼SW¼ 27, 45 N., 62 W.	2, 980–2, 990	do	. 877	29. 9	. 09	81	50	. 056	Do.
Newcastle field										
PC–57–157	NW¼SW¼ 1, 44 N., 61 W.	175	Newcastle	0. 922	22. 0	0. 28	390	<5	0. 141	Brownish-green.
PC–57–160	SE¼SE¼ 3, 44 N., 61 W.	1, 234–1, 240	do	. 932	20. 3	. 27	710	<5	. 160	Do.

the Belle Fourche Shale at depths mostly between 120 and 500 feet.

Only 95 barrels of oil was produced from the Pedro field in 1959.

Skull Creek field.—The Skull Creek oil field is in T. 44 N., R. 62 W., about 2 to 8 miles southwest of Newcastle. It includes the east end of a chain of oil fields that farther to the west in Weston County comprises the Mush Creek, West Mush Creek, and Clareton fields (fig. 10). The Skull Creek field was discovered in April 1946 when the Morton and Siegel 1 well was drilled in the NE¼ sec. 16. This well initially produced 3 barrels of oil and 7 barrels of water per day from the Newcastle Sandstone at a depth of 3,330 of 3,364 feet (Dobbin and Horn, 1949). After a period of inactivity, drilling was greatly spurred by the completion, in June 1948 of the Brinkerhoff Drilling Co., Oil Creek Ranch Co. 1 well in the SW¼ sec. 3, whose initial production was 310 barrels of oil per day.

Oil in the Skull Creek field comes mainly from sandstone at the base of the Newcastle Sandstone in a zone ranging from 5 to about 25 feet in thickness. A second producing zone at the top of the Newcastle is locally important, chiefly in the southern part of the field. The depth to the producing zones ranges from about 2,900 to 3,400 feet. Initial daily production of wells in the Skull Creek field to the end of 1960 averaged about 125 barrels, although as much as 1,000 barrels per day was reported from the Dittus-Dakota and others Bock 2 well in the NE¼ sec. 7, and 900 barrels per day was reported from the Keith Railway Equipment Co. Govt. 1–A well in the SW¼ sec. 5. Four other wells in the field have produced initially between 500 and 600 barrels of oil per day.

Some dry gas has been produced from the base of the Newcastle Sandstone in sec. 11, and a show of gas was reported from the Turner Sandy Member of the Carlile Shale in a well in sec. 13.

North Skull Creek field.—The North Skull Creek field is adjacent to the Skull Creek field on the north in the south-central part of T. 45 N., R. 62 W. The discovery well in this area was the H. O. English Associates Engle 1 well in the NE¼ sec. 32, completed in December 1948 in the Newcastle Sandstone. This well had an initial daily production of 50 barrels of oil per day. The oil occurs mostly at the base of the Newcastle Sandstone in a zone about 7 to 25 feet thick and at a depth of about 2,875 to 3,325 feet. Wells in the North Skull Creek field have had initial daily oil productions ranging from about 10 to 200 barrels and averaging about 70 barrels.

Southeast Skull Creek field.—The Southeast Skull Creek field is a small producing area in secs. 23, 24, and 26, T. 44 N., R. 62 W., less than a mile southeast of the main Skull Creek field. The field consisted in 1960 of 2 oil wells in sec. 24, one of which initially produced 271 barrels of 40.6° API gravity oil per day from the top of the

Newcastle Sandstone, and 2 gas wells in secs. 23 and 26, respectively, that initially produced 19.8 and 10 million cubic feet of dry gas per day from the Newcastle. The producing zones in these wells range from 16 to 28 feet in thickness.

Mush Creek field.—The east end of the Mush Creek oil field extends into the southwestern part of the Newcastle area and connects with the Skull Creek field in the eastern part of sec. 7, T. 44 N., R. 62 W. The Mush Creek field was discovered when the Western Oil and Gas Co. A. E. Milhouse 1 well in the SW¼ sec. 24, T. 44 N., R. 63 W., was drilled, in May 1944. This well had an initial daily production of 40 barrels of 37.6° API gravity oil from the Newcastle Sandstone. In 1960, the part of the field that lies inside the Newcastle area included 48 oil wells and 2 gas wells completed for production.

The oil-producing zone of the field in the Newcastle area is at the base of the Newcastle Sandstone; it is 3 to 26 feet thick and at a depth of about 3,500 feet. Wells shown on the geologic map (pl. 1) had average initial daily productions of about 125 barrels of oil; however, the Silver Sage Oil and Mineral Co. Shostak 3 well in the SE¼ sec. 13, T. 44 N., R. 63 W. initially produced as much as 1,100 barrels of oil per day. Two gas wells in sec. 25, T. 44 N., R. 63 W. each initially produced about 600 million cubic feet of dry gas per day from the base of the Newcastle Sandstone.

Newcastle field.—Several wells have been drilled in the vicinity of Newcastle in the northeastern part of T. 44 N., R. 61 W., and some have produced small amounts of oil (Darton, 1904, p. 9; Biggs and Espach, 1960, p. 190). In sec. 1, two wells drilled in 1957 and one drilled in 1959 found oil in the Newcastle Sandstone at depths ranging from 25 to 175 feet. Two of the three wells initially produced ½ barrel of oil per day, and the remaining well produced 3 barrels of oil per day. The oil is 18.0° to 22.0° API gravity. A well in sec. 3, drilled in 1956, had an initial production of 13 barrels of 20.3° API gravity oil and 22 barrels of water from the Newcastle Sandstone at a depth of 1,234 to 1,240 feet.

Oil and gas possibilities.—The known producing area of the Newcastle Sandstone in the Skull Creek and Mush Creek fields was significantly enlarged by drilling during 1960. Further increases seem assured, especially in the southern part of the Skull Creek field where, in the S½ T. 44 N., R. 62 W., 9 successful wells and 2 unsuccessful wells were drilled in 1959 and 1960. As shown on figure 4, the largest parts of the two fields coincide with a southwestward-trending belt of thick Newcastle Sandstone. Producing wells in the southern part of the Skull Creek field lie on subsidiary belts of relatively thick Newcastle sandstone that seem to trend southeastward. The possi-

bilities for new oil and gas production would be enhanced by drilling on the extensions of these belts.

The upper and lower parts of the Fall River Formation in the Newcastle area contain thick porouss and stone lenses (pl. 3). Oil is produced from sanstone lenses in the formation in southern Crook County, a few miles northwest of Newcastle, and some oil is produced from the Fall River Formation at the Lonetree Creek field about 30 miles west of Newcastle (fig. 10). The small Kuemmerle field, 20 miles west of Newcastle, also had some production of oil from the Fall River. The formation seems to offer good possibilities for oil and gas production near Newcastle, although information now available on the distribution of sandstone in the Fall River is insufficient to predict accurately the location of potentially productive sandstone lenses.

The Minnelusa Formation reportedly contains uncommercial amounts of oil in a well in sec. 2, T. 44 N., R. 62 W. (table 3); the upper part of the formation is oil bearing near Moorcroft, in Crook County, Wyo.; and the middle part contains oil at Dewey, in Weston County, Wyo. (fig. 10). The Minnelusa Formation, therefore, would seem to be a potential oil reservoir in the Newcastle area. No study was made of the Minnelusa during the present investigation, however, and no stratigraphic details bearing on its oil and gas possibilities can be given.

COAL

The lower part of the Lakota Formation contains coal at several places in the Newcastle area, notably in the vicinity of Cambria, about 6 miles north of Newcastle, where coal mining was once a major industry. The mines have been abandoned for many years, and mine workings and prospects are now inaccessible. Nevertheless, much information is available on the thickness and quality of the coal and on the history of mining from earlier reports by Darton (1904, p. 8–9), Stone (1912, p. 31–44, 48–64), and Connolly and O'Harra (1929, p. 381–386). Most of the information given below is summarized from these reports.

The coal in the Lakota Formation is interbedded with carbonaceous shale in a persistent zone that lies about 60 feet stratigraphically above the base of the formation. Coal beds within the zone are lenses that vary greatly in thickness; at many places the zone contains no coal. Correlation of the coal zone is shown on the columnar sections, plate 3.

Most of the coal is high-volatile *C* bituminous in rank. It is hard, banded in alternate dull and bright layers, and has well-developed prismatic cleavage. Also present are cannel and splint coal, and

felted masses of carbonized fibers called pine needle coal. Some of the coal has good coking qualities. An analysis of coal from mines at Cambria is shown in table 6; other analyses of coal from the same area were given by Stone (1912, p. 53–54) and by the U.S. Bureau of Mines (1931, p. 76–77.)

TABLE 6.—*Fuel analyses of a composite coal sample from the Antelope 4 mine, Cambria district, Weston County, Wyo.*

[From U.S. Bur. Mines, 1931, p. 76–77]

Sample		Proximate				Ultimate					Heat value (British thermal units)
Laboratory No.	Condition [1]	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	
16415	1	10.8	39.1	35.1	15.0	4.9	5.5	56.1	0.7	17.8	10,340
	2		43.8	39.4	16.8	5.5	4.8	62.9	.8	9.2	11,590
	3		52.7	47.3		6.6	5.7	75.6	1.0	11.1	13,940

[1] 1, sample as received; 2, dried at a temperature of 105°C; 3, moisture and ash free.

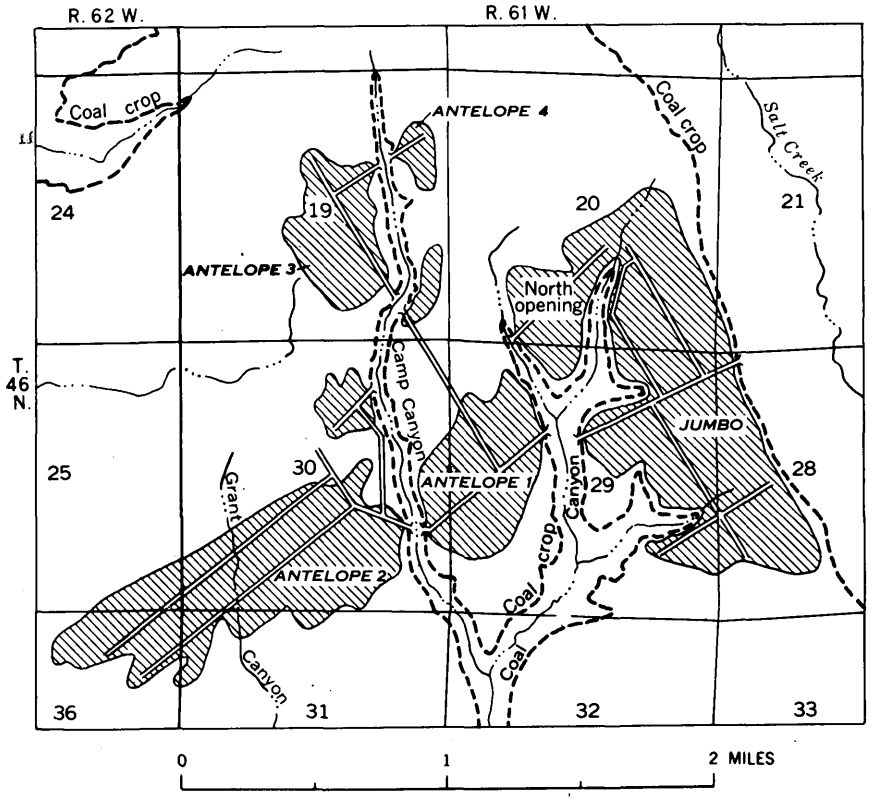

FIGURE 11.—Mine workings at Cambria, Wyo., 1908. From Stone (1912, fig. 5), modified to fit modern base.

Cambria.—Coal mining began at Cambria in 1889 and ceased in 1928. The total production of coal was given by Connolly and O'Harra (1929, p. 302) as 12,464,047 short tons. As much as 542,650 short tons were produced during the peak year, 1899. The mines are at the heads of Camp and Coal Canyons, 6 miles north of Newcastle and, as shown on the map of the mine workings, figure 11, covered parts of nine sections a few years after mining began. In the early 1900's, the industry supported a town at Cambria that had about 1,400 people and 150 houses (Lupton, *in* Stone, 1912, p. 38). Only the mine dumps and a few ruined shacks were left to mark the site in 1955.

The coal bed at Cambria ranged generally from 3 to 10 feet in thickness where mined and averaged about 5 feet. Connolly and O'Harra (1929, p. 383) stated that in the later period of mining, an area of about 200 acres was found in which the thickness of coal ranged from 8 to 18 feet. The thickness of the bed varies with the position of the floor, which is wavy, and with the thickness of sandstone, shale, and bone partings.

Most of the coal produced at Cambria was used for locomotive fuel on the Chicago, Burlington, and Quincy Railroad. Coke was made from the coal in the period 1891 to 1903 and sold to smelters in the Black Hills. From 1891 to 1900 inclusive, 106,880 tons of coke was produced from 224,750 tons of coal. Ash in the coke was reported by Stone (1912, p. 51) to average 22.40 percent.

Gold and silver has been reported from some of the coal from the Jumbo and Antelope 1 and 2 mines (fig. 11). Stone (1912, p. 63) stated:

> According to a verbal statement by W. E. Mouck, superintendent of the Cambria mines, an assay made by the company's chemist of ashes from the boiler house showed $10 per ton and of the sandstone roof of the bed $2 per ton in gold. This unexpected result led to further investigation, and soot from the furnace stack was assayed, with the result that it was found to contain $4 per ton in gold. The coal itself has shown from nothing up to $2 per ton in gold * * *. The samples from 31 cars of coke showed an average of $2.46 per ton in gold and $0.28 in silver.

At the time of the above report, gold was valued at $20 per ounce, and silver was valued at $0.65 per ounce.

Berryhill and others (1950, p. 11) estimated original coal reserves at Cambria, in beds more than 14 inches thick, at about 36 million short tons. They estimated that about 21 million tons have been mined or lost in mining, and they stated that most of the remaining reserves are probably in small pockets that would be difficult and expensive to mine. Most of the field is regarded as mined out.

Other areas.—No systematic large-scale mining has been done in the Newcastle area, except at Cambria, although small prospects

have been opened on coal at several places. One of these prospects was reported by Stone (1912, p. 43) to be in a ravine in sec. 11, T. 45 N., R. 62 W. about 4 miles southwest of Cambria. The bed is described as follows:

Section of coal bed at Mount Zion Ranch

[Stone, 1912, p. 43]

	Ft	in
Sandstone, white, massive	12	
Coal, bituminous		2–6
Sandstone, white, massive	3–4	
Coal, bituminous	3	4
Sandstone, gray, hard		6–20
Coal, bituminous, ashy	2	
Sandstone, gray, massive	50	

Other prospects have uncovered some coal near the mouth of Salt Creek, in Hilton Draw east of Newcastle, in Cambia Canyon between Camp Canyon and Newcastle, and at various places along Oil and East and West Plum Creeks; but at all these places the coal is too poor in quality or in beds too thin to be mined profitably. The thickest coal at any of these places was reported by Stone (1912, p. 31) to be on the west side of East Plum Creek in sec 12, T. 46 N., R. 62 W., where he measured the following section.

Section of coal bed on East Plum Creek

	Ft	in
Coal, impure		8
Coal, good		7½
Coal, bony	10	
Coal	6	
Shale, sandy	1	4
Coal		2½
Coal, bony	1	1
Total coal and shale	5	3

In Forelle Draw, near the above locality to the southeast, Stone (1912, p. 31) reported the coal bed to be 3 feet 1½ inches thick, including a sandstone parting 1 foot thick in the upper part.

URANIUM

Uranium was discovered in the southern part of the Black Hills in 1951, and since then valuable deposits have been found at many places along the south, west, and north sides of the Black Hills in the Lakota and Fall Fiver Formations. As recently as the end of 1960, the Newcastle area had no known workable deposits of uranium, although rocks that are uranium bearing in nearby areas are extensively exposed and have been prospected along their outcrops by many individuals. Robinson and Gott (1958) summarized information on uranium in the Black Hills and discussed the controls believed effective in localizing the deposits.

Carbonaceous material is believed to provide a reducing environment that favors the precipitation of uranium. Coal in the Lakota

Formation at Cambria contains a significantly greater concentration of uranium than the adjacent rocks and more than the average for coal. The following analyses of coal in the bed formerly mined at Cambria were made from samples collected by J. R. Gill in August 1952.

Analyses of coal in bed formerly mined at Cambia

[Audrey Pietsch, Mary Joslyn, and Ivan Barlow, analysts]

Laboratory No.	Equivalent uranium (percent)	Uranium (percent)	Ash (percent)	Uranium in the ash (percent)	Description
SE¼SE¼NE¼ sec. 20, T. 46 N., R. 61 W.					
72277	0.005	0.005	44.89	0.010	Top 1.2 ft of 4.8-ft coal.
72278	.002	.002	39.88	.005	Next 1.2 ft of 4.8-ft coal.
72279	.006	.004	36.84	.010	Do.
72280	.016	.005	65.45	.008	Bottom 1.2 ft of 4.8-coal.
SW¼ sec. 20, T. 46 N., R. 61 W.					
98536	0.005	0.007	34.0	0.022	Top 1.1 ft impure coal.
98537	.010	.010	37.6	.026	Next 1.1 ft impure coal.
98538	.008	.010	61.2	.017	Do.
Sec. 29, T. 46 N., R. 61 W.					
72276	0.009	0.003	30.91	0.009	Coke from dump at Cambria.

A channel sandstone in the Fall River Formation contains uranium deposits in the Dewey and Clifton quadrangles a short distance southeast of the Newcastle area (Brobst, 1956, p. 108), and the probable extension of the channel sandstone crops out at the base of the Fall River Formation in the area between Newcastle and Cambria (pl. 1 and fig. 3). The upper few feet of the sandstone is abundantly carbonaceous at locality 12 (pls. 1, 3) near Newcastle; the west edge trends northward beneath Antelope Flats. This sandstone would seem to be a favorable host for uranium and it is shallow enough to be inexpensively explored by drilling.

BENTONITE

Upper Cretaceous marine rocks in the Black Hills region contain many beds of bentonite, including the beds that elsewhere in the Black Hills supply much of the high-quality bentonite produced in the United States. Some bentonite has been strip mined in the northwestern part of the Newcastle area from a bed in the lower part of the Belle Fourche Shale (sec. 31, T. 46 N., R. 62 W.) and from the Pedro Bentonite Bed at the base of the Pierre Shale (secs. 8 and 9, T. 45 N., R. 62 W., and sec. 1 of the next township west). The amount of bentonite removed has been small, however, compared to the much

more extensively mined area near Osage and Upton nearby to the northwest. The steep dip (10°–70°) of the bentonite-bearing formations at most places in the area restricts the amount of bentonite that can be removed by stripping and undoubtedly has discouraged more extensive development of the deposits.

Two samples of bentonite collected in and near the Newcastle area by W. W. Rubey have the following analyses, as reported by Wells (1937, p. 71).

Analyses of bentonite collected in and near Newcastle area

[J. G. Fairchild, analyst]

	A	B
SiO_2	53. 50	56. 93
Al_2O_3 (includes any P_2O_5)	21. 57	14. 75
Fe_2O_3 (FeO probably absent)	3. 28	2. 08
MgO	1. 89	1. 86
CaO	1. 25	6. 35
Na_2O	1. 94	2. 28
K_2O	1. 04	. 93
H_2O-	15. 20	10. 61
H_2O+		
TiO_2	. 11	----------
CO_2	None	4. 61
Total	99. 78	100. 40

A. Bentonite in the lower part of Belle Fourche Shale at Osage, about 20 ft above Clay Spur Bentonite Bed
B. Pedro Bed at mine near Pedro.

The bentonite bed mined near the base of the Belle Fourche Shale is correlated in this report with bed E (Knechtel and Patterson, 1955) of the northern Black Hills. Its thickness and stratigraphic relations are shown in the following partial section.

Bentonite beds in the SE¼ sec. 31, T. 46 N., R. 62 W.

	Feet
Belle Fourche Shale (part):	
Shale, grayish-black; scattered siderite; concretions about 1 ft in diameter that weather dark red	30
Bentonite (bed E Knechtel and Patterson, 1955), light-gray, swelling; stripmined along outcrop	4. 8
Siderite, dark-gray, dark-red-weathering; forms floor of bentonite pit	. 4
Poorly exposed; appears to be mostly grayish-black shale; some siderite concretions that weather dark red	30±
Mowry Shale (part):	
Bentonite (Clay Spur Bed), light-gray, swelling	1. 4
Shale, dark-gray, medium-gray-weathering, hard, brittle; forms bare slopes	10

The thin layer of siderite noted at the base of bentonite bed E in the above section is a characteristic feature of this unit for several miles along its outcrop between Newcastle and Upton. Bed E is 2 to 4 feet thick where examined at several places farther south in the Newcastle area.

The Pedro Bentonite Bed is locally as thick as 30 feet in pits near Pedro in secs. 8 and 9, T. 45 N., R. 62 W. (fig. 6). The following two sections show some details of the bed where it has been mined.

Bentonite beds at the base of the Pierre Shale east of Pedro in the NE¼ sec. 8, T. 45 N., R. 62 W., Weston County, Wyo.

[Measured by J. R. Gill and W. J. Mapel]

		Feet
Pierre Shale (part):		
Mitten Black Shale Member (part):		
40.	Shale, dark gray-brown; contains much organic material; weathers to hard platy chips; covered above this unit	2.0
39.	Bentonite and shale, interlaminated; laminae are about 2 mm thick	2.0
38.	Bentonite, light yellowish-gray; a few thin partings of black shale	3.6
37.	Shale, gray, silicified	.4
36.	Bentonite, light-yellow, nonswelling	.2
35.	Shale, dark gray-brown; much organic material; hard	1.6
34.	Bentonite, light-yellow, nonswelling	.3
33.	Shale, dark-gray; much organic material; hard	5.0
32.	Bentonite, light-yellow, nonswelling	.2
31.	Shale, dark gray-brown; much organic material; hard	.2
30.	Bentonite, orange, nonswelling	.1
29.	Shale, dark-gray, hard	2.6
28.	Bentonite, light yellowish-gray to orange; rests sharply on underlying unit; grades into overlying unit	.8
27.	Shale, dark-gray, soft; contains partings of bentonite; jarosite on bedding planes; silicified in upper 3 ft	3.4
26.	Bentonite, tan; partings of dark-gray shale	.4
25.	Shale, dark gray-brown; thin partings of bentonite	.8
24.	Bentonite, tan; lenses of silicified gray bentonite	.7
23.	Shale, dark reddish-brown, silicified	.1
22.	Bentonite, orange, nonswelling	.4
21.	Shale, light-gray, silicified	.2
20.	Bentonite, light yellowish-gray, nonswelling	2.8
19.	Shale, dark gray-brown; much organic material; hard; silicified in bottom 0.3 ft	.5
18.	Bentonite, orange, nonswelling	.1
17.	Shale, dark gray-brown; much organic material; many thin partings of bentonite	2.5
16.	Bentonite, light yellowish-gray, nonswelling	.3
15.	Shale, dark gray-brown; much organic material; hard; silicified in top 0.3 ft	3.3
14.	Bentonite, orange, nonswelling	.2
13.	Shale, dark gray-brown, hard	1.0
12.	Bentonite, tan, nonswelling	.1
11.	Shale, dark-gray, soft, bentonitic	1.0
10.	Bentonite, tan, nonswelling	.2
9.	Shale, dark-gray, soft, bentonitic	2.0
8.	Bentonite, tan, nonswelling	.1
7.	Shale, black, silicified	.5
6.	Bentonite, tan, nonswelling	.4
5.	Shale, dark gray-brown, silicified	.1
4.	Bentonite, light-gray, nonswelling	.1
3.	Shale, dark gray-brown; much organic material; hard	1.4
2.	Pedro Bentonite Bed as follows:	
	Bentonite, pale greenish-gray, swelling; fairly abundant flakes of biotite	3.0
	Bentonite, laminated light- and medium-gray, very hard; relict outlines of shards plainly visible in thin section; X-ray analysis shows a mixture of nonswelling clays and clinoptioite (L. G. Schultz, analyst)	5.9

Bentonite beds at the base of the Pierre Shale east of Pedro in the NE¼ sec. 8, T. 45 N., R. 62 W., Weston County, Wyo.—Continued

	Feet	Feet
Pierre Shale (part)—Continued		
Mitten Black Shale Member (part)—Continued		
2. Pedro Bentonite Bed as follows—Continued		
Bentonite, pale greenish-gray, swelling; fairly abundant flakes of biotite; hard claystone concretions in upper part 0.2 to 0.8 ft long	1. 4	
Shale, dark reddish-brown, hard; seams of clinoptiolite at top and base (L. G. Schultz, analyst)	. 5	
Bentonite, pale greenish-gray, swelling; fairly abundant flakes of biotite; about 12 ft above the base a very hard band of light-gray bentonite 1.3 ft thick	19. 5	
Thickness, Pedro Bentonite Bed		30. 3
Partial thickness rounded, Mitten Black Shale Member		72
Niobrara Formation (part):		
1. Marl, dark grayish-brown; top 1 to 2 ft hard and massive, lower part fissile		6

Pedro Bentonite Bed and underlying part of the Niobrara Formation west of Pedro in the SE¼ sec. 1, T. 45 N., R. 63 W., Weston County, Wyo.

[Measured by J. R. Gill, W. J. Mapel, and C. L. Pillmore]

	Feet
Pierre Shale (part):	
Pedro Bentonite Bed (part):	
13. Bentonite, light-gray; interbedded gray shale in the upper part; lenses of hard silicified(?) material in the lower part; top of the unit is the top of the exposure in an abandoned bentonite pit	5. 5
12. Bentonite, very light gray, swelling	8. 0
11. Shale, dark reddish-brown, silicified	. 3
Section below offset to opposite side of the pit.	
10. Bentonite, very light yellowish gray, swelling	10. 0
9. Bentonite, very light gray, swelling; contains flakes of biotite	3. 0
Partial thickness, Pedro Bentonite bed	26. 8
Section below offset about 200 yd east.	
Niobrara Formation (part):	
8. Shale, black, noncalcareous, hard	. 3
7. Marl, light grayish-brown, hard	7. 0
6. Bentonite, light-gray	. 1
5. Marl, as in unit 7 above	5. 0
4. Bentonite, light-gray	. 05
3. Marl, light-tan and yellowish-tan-banded; small concretions at the base that weather rusty brown	16
2. Shale, grayish-black, noncalcareous	4. 0
1. Shale, brown to yellowish-brown, calcareous	2
Partial thickness, rounded, Niobrara Formation	34

The Clay Spur Bed at the top of the Mowry Shale contains major reserves of bentonite elsewhere in the northern Black Hills, but in the Newcastle area it is thin and does not seem to contain large reserves. Other beds that may be thick and extensive enough to mine include a

bentonite that ranges from 1 foot to about 4 feet in thickness near the top of the Newcastle Sandstone, and bed F, about 3 feet thick, near the top of the Belle Fourche Shale.

GYPSUM

Beds of gypsum locally 30 feet thick crop out in the lower part of the Spearfish Formation, and a gypsum bed locally 15 feet thick makes up the Gypsum Spring Formation. The gypsum in the Gypsum Spring Formation generally crops out on the sides of steep cliffs and hence passes at most places under thick overburden a short distance back from the outcrop. Gypsum in the lower part of the Spearfish Formation, however, crops out in more rolling country in the northeast corner of the quadrangle and in the adjacent area to the east and could easily be strip mined at several places.

Analyses of the gypsum from the Spearfish Formation in the Inyan Kara Mountain quadrangle to the north indicate that impurities consisting mostly of calcium and magnesium carbonates constitute from less than 1 percent to as much as 12 percent of the beds (Mapel and Pillmore, 1963).

SAND AND GRAVEL

Sand and gravel for use as road-surfacing material has been dug from small pits in terrace deposits at several places in the area. The larger gravel pits are adjacent to sec. 1, T. 45 N., R. 63 W.; in and adjacent to sec. 33, T. 45 N., R. 62 W.; in sec. 22, T. 44 N., R. 62 W.; and in sec. 13, T. 44 N., R. 61 W. Deposits at these and other places in the area have a large proportion of structurally weak fragments of sandstone and siltstone cemented with iron oxides and therefore would probably have little value as concrete aggregate or in any other use requiring uniform physical properties.

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