Stratigraphy and Structure of The Northern and Western Flanks of The Black Hills Uplift, Wyoming Montana, and South Dakota

GEOLOGICAL SURVEY PROFESSIONAL PAPER 404

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

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By CHARLES S. ROBINSON, WILLIAM J. MAPEL, *and* MAXIMILIAN H. BERGENDAHL

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STRATIGRAPHY AND STRUCTURE OF THE NORTHERN AND WESTERN FLANKS OF THE BLACK HILLS UPLIFT, WYOMING, MONTANA, AND SOUTH DAKOTA

By Charles S. Robinson, William J. Mapel, and Maximilian H. Bergendahl

ABSTRACT

This report describes the stratigraphy and structure of an area of about 5,000 square miles in northeastern Wyoming and adjacent parts of Montana and South Dakota. The area includes the northern end and part of the western side of the Black Hills uplift and the adjoining part of the Powder River Basin.

About 11,000 feet of sedimentary rocks ranging in age from Mississippian to early Tertiary are exposed in the area, not including surficial deposits of Tertiary(?) and Quaternary age. The oldest rocks crop out in the southeastern part of the area and consist of 500 to 600 feet of light-gray cherty limestone that makes up the Early Mississippian Pahasapa limestone. Unconformably overlying the Pahasapa limestone is the Minnelusa formation of Pennsylvanian and Permian age. It is 650 to 800 feet thick in drill holes and at outcrops in the southeastern part of the area, and it consists of interbedded light-gray and pink sandstone, gray sandy limestone and dolomite, some red shale and siltstone, and local beds of gypsum and anhydrite. The Permian Opeche formation overlies the Minnelusa formation unconformably and comprises 60 to 90 feet of red fine-grained sandstone, siltstone, and silty shale. Next in order is the Permian Minnekahta limestone, which is composed of light-gray and light purplish-gray thin-bedded limestone about 40 feet thick. The Spearfish formation, 450 to 825 feet thick, lies conformably on the Minnekahta limestone and is Permian and Triassic in age. Gypsum and red silty shale make up the lower part of the Spearfish, and red siltstone and silty sandstone the upper part.

An unconformity separates the Spearfish formation from the overlying Gypsum Spring formation of Middle Jurassic age. Beds of gypsum alternate with red claystone at the base of the Gypsum Spring formation; gray cherty limestone interbedded with red claystone makes up the upper part. The formation is 125 feet thick north of Hulett in northern Crook County, Wyo., but it thins southward owing to an unconformity at the top, and locally the formation is absent. Green shale, light yellowish-gray sandstone, red and yellowish-gray siltstone and gray limestone make up the overlying Sundance formation of Late Jurassic age. The average thickness of this formation is about 375 feet. It is divided into the Canyon Springs sandstone member at the base, overlain in ascending order by the Stockade Beaver shale member, the Hulett sandstone member, the Lak member, and the Redwater shale member.

The Morrison formation of Late Jurassic age is conformable with the Sundance formation and, at most places in the northern part of the Black Hills uplift, is between 80 and 120 feet thick. It consists of red and green claystone interbedded near the base with light-gray sandstone and limestone. Overlying the Morrison formation is a variable sequence of sandstone, shale, and claystone that makes up the Inyan Kara group of Early Cretaceous age. The lower 45 to 300 feet of this sequence is characterized by conspicuously crossbedded coarse-grained sandstone and variegated claystone and is assigned to the Lakota formation; the upper part, 95 to 200 feet thick in outcrops, is characterized by even-bedded brownish-gray sandstone and gray shale and is assigned to the Fall River formation. An unconformity separates the Lakota and Fall River formations. The contact between the Lakota and underlying Morrison formation is unconformable at some places and conformable at others.

Lower Cretaceous rocks younger than the Fall River formation include the Skull Creek shale, which is 180 to 270 feet thick and consists of grayish-black shale and a few thin beds of sandstone; the Newcastle sandstone, which averages about 40 feet in thickness and consists of sandstone, gray and brown shale, and some bentonite and shaly coal; and the Mowry shale, which is 180 to 230 feet thick and consists chiefly of gray siliceous shale and many thin bentonite beds.

The Belle Fourche shale, 350 to 850 feet thick, overlies the Mowry shale and is of Late Cretaceous age. It is composed of dark-gray shale, slightly sandy in the middle part, and several persistent beds of bentonite. Overlying the Belle Fourche is the Greenhorn formation, which is 70 to 100 feet thick at most places along the western flank of the Black Hills uplift but which thickens eastward to 370 feet across the northern end and to about 270 feet near Newcastle in Weston County, Wyo., at the southern end. Where thick, the Greenhorn consists of dark-gray alternately calcareous and noncalcareous shale, marl, and thin beds of light-gray limestone; in northern Weston County and western Crook County, where the formation is thin, it consists of gray to brownish-gray mostly noncalcareous shale containing large gray septarian limestone concretions.

The Carlile shale, 500 to 600 feet thick, conformably overlies the Greenhorn formation and is divided into three members. The lower unnamed member at the base is 40 to 125 feet thick and consists of gray shale, locally sandy and calcareous. The Turner sandy member, 150 to 260 feet thick, consists of gray shale and sandy shale, a few thin beds of sandstone, and numerous beds of septarian limestone concretions that weather yellow. The Sage Breaks member at the top is 200 to 300 feet thick, and consists of dark-gray shale and numerous septarian limestone concretions that weather light gray. Overlying the Carlile is the Niobrara formation, which is composed of 150 to 225 feet of gray calcareous shale and marl with thin beds of bentonite.

The Pierre shale is the next younger formation in the Upper Cretaceous sequence. It is 2,050 feet thick in northern Campbell County, Wyo., but thickness southward to about 2,700 feet in

Weston County. It is composed of dark-gray shale, at places sandy and silty, interbedded with bentonite and numerous limestone and siderite concretions. The formation is divided into several members, which from base to top are the Gammon ferruginous member, 0 to about 1,000 feet thick; the Mitten black shale member, 145 to about 870 feet thick; and the upper part of the Pierre shale including the Monument Hill bentonitic member 150 to about 220 feet thick, and the somewhat younger Kara bentonitic member about 100 feet thick. In the northern part of the area, the Gammon ferruginous member contains a zone of sandstone and sandy shale about 100 feet thick known as the Groat sandstone bed.

The Fox Hills sandstone overlies the Pierre shale and is 150 to 200 feet thick. Yellowish-gray sandstone and gray shale make up the Fox Hills sandstone at most places except in Carter County, Mont., where as much as 100 feet of very light gray cliff-forming sandstone crops out at the top of the formation and is mapped separately as the Colgate member.

Nonmarine sedimentary rocks overlie the Fox Hills sandstone and make up an essentially conformable sequence of sandstone, shale, and coal beds that includes the Lance formation of Late Cretaceous age, the Fort Union formation of Paleocene age, and the Wasatch formation of Eocene age. The Lance formation is 1,600 feet thick in northern Weston County, Wyo., but thins northward to about 500 feet in Carter County, Mont. The overlying Fort Union formation, 1,500 to about 2,100 feet thick, also thins northward. It is divided into the Tullock member at the base, 500 to 1,100 feet thick, characterized by numerous coal beds; the Lebo shale member in the middle, 200 to 250 feet thick, with little or no coal; and the Tongue River member at the top, about 800 feet thick, characterized by several thick persistent coal beds. The contact between the Fort Union and overlying Wasatch formation is the base of a thick coal bed tentatively correlated with the Roland coal bed of nearby areas. Only the basal 300 feet of the Wasatch formation crops out in the mapped area.

Remnants of the White River formation of Oligocene age uncomformably overlie rocks as old as the Spearfish formation of Permian and Triassic age. These deposits, which consist of as much as 150 feet of coarse-grained light-gray sandstone and light-gray to brownish-gray silty claystone, cap a few high divides.

Stream terrace deposits, landslide material, talus, and alluvium cover the older rocks locally.

Igneous rocks, mainly nepheline syenite, make up small plugs, sills, and dikes at Missouri Buttes, Devils Tower, Barlow Canyon, near the heads of Lytle and Miller Creeks, and at Inyan Kara Mountain. Small amounts of agglomerate crop out also at Missouri Buttes. The youngest formation intruded is the Mowry shale of Early Cretaceous age at Missouri Buttes.

A steep monocline bounds the Black Hills uplift on the west in Weston and Crook Counties, Wyo., and is the major structural feature. Stratigraphic units east of the monocline are warped upward a maximum of 4,000 feet above the same units west of it in a horizontal distance of 2 to 6 miles. The Pump Creek anticline, Thornton dome, and Oil Buttes-Pine Ridge anticline, and several smaller folds border the monocline on its upthrown side. A belt of northwesterly trending folds, including the Colony-Albion, Bull Creek, Chicago Creek, and La Flamme anticlines, borders the Black Hills uplift at its northeastern end. The northern end of the uplift plunges gently northward between the two folded belts. West of the monocline, the sedimentary rocks dip gently westward toward the axis of the Powder River Basin. Normal faults cut the sedimentary rocks locally, but most of the faults have displacements of less than 100 feet, and few of them could be traced more than a mile. The main deformation in the Black Hills and the intrusion of the igneous rocks were early Tertiary, or possibly Late Cretaceous in age.

Oil is produced from several fields on the west side of the Black Hills uplift in Wyoming, principally near Newcastle in Weston County and near Moorcroft in Crook County. Bentonite is mined at many places in Weston and Crook Counties, and these mines produce much of the bentonite used in the United States. Uranium occurs in the Lakota and Fall River formations and is an important product of northern Crook County, Wyo. The Fort Union and Wasatch formations contain large reserves of subbituminous coal, and the Lakota formation contains some bituminous coal.

INTRODUCTION

Purpose and scope of the report.—This report makes available reconnaissance geologic mapping and stratigraphic studies made from 1922 to 1924 in the northern Black Hills and adjacent parts of the Powder River Basin, modified and extended by the subsequent work of various Geological Survey field parties that have mapped in the area, mostly from 1954 to 1958, and by the mapping and stratigraphic studies of other persons whose work is published. The report presents fairly brief summary descriptions of the outcropping sedimentary and igneous rocks, and a résumé of the more important mineral resources of the region investigated. Information on the subsurface geology, or details of the geology of smaller areas within the region described, can be found in the publications cited at the end of the report.

Location and geographic features.—The area of this investigation includes about 5,000 square miles in the northeastern corner of Wyoming and the adjacent southeastern part of Montana and western part of South Dakota, as shown on figure 1. It includes parts of the Black Hills on the east and south and the Powder River Basin on the west. For the purpose of this report, the area is referred to as the northern and western flanks of the Black Hills uplift.

The main part of the Black Hills uplift lies southeast of the mapped area in South Dakota. The northwestern end of the Black Hills extends into the east-central part of the area as a subsidiary range of tree- and grass-covered peaks and dissected plateaus known as the Bear Lodge Mountains. A large area surrounding the Bear Lodge Mountains and extending south along the flank of the Black Hills is characterized by broad tree- and grass-covered divides and steep-walled canyons. This area merges northward and westward with low, rolling grass- and sage-covered hills and broad valleys, which farther west, in the eastern part of the Powder River Basin, includes locally steep escarpments, high isolated buttes, and areas of subdued badlands.

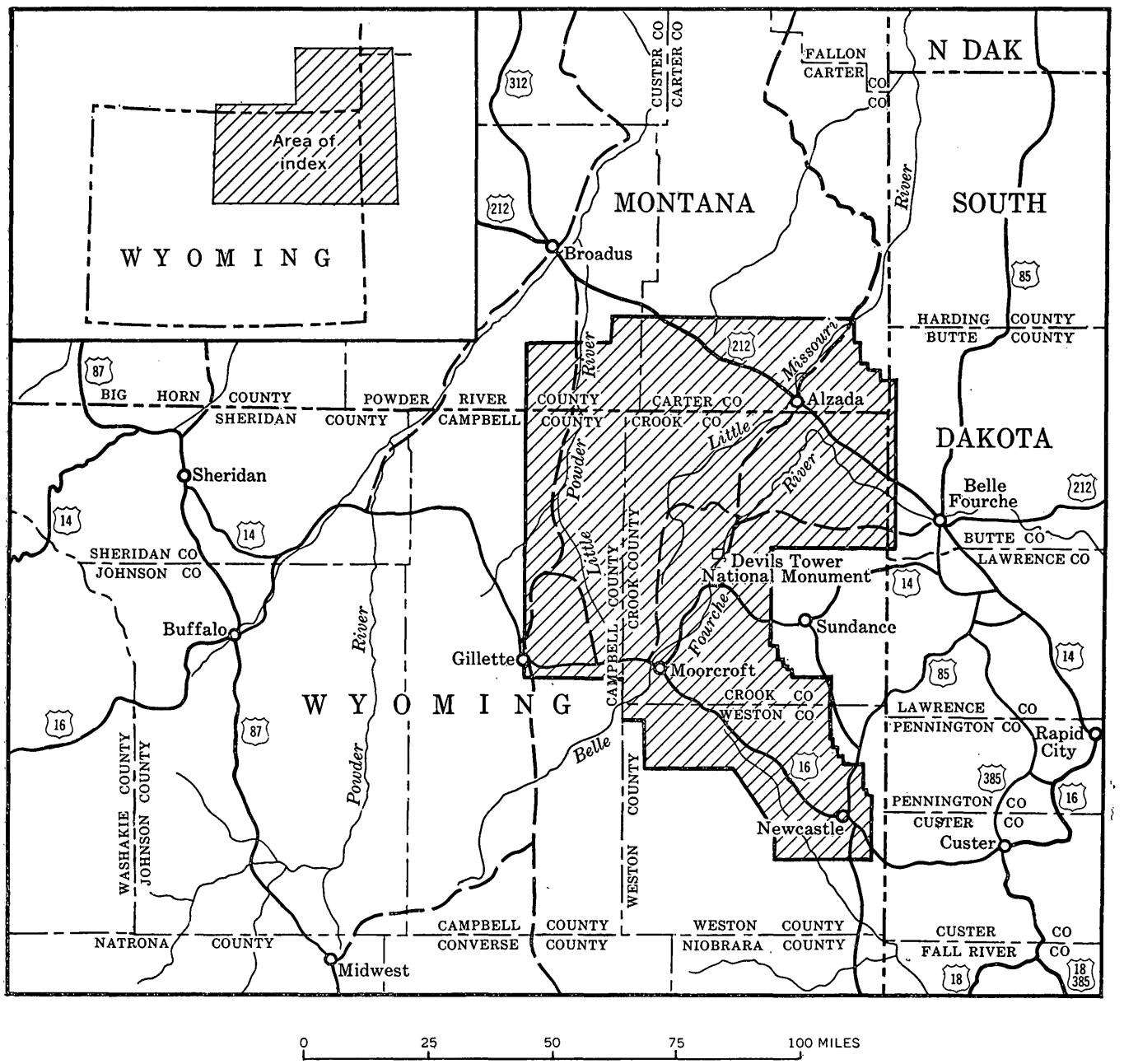

FIGURE 1.—Index map showing location of mapped area.

Altitudes range from 5,800 feet in the Bear Lodge Mountains at the eastern edge of the area to about 3,300 feet along the Little Powder River near the northwestern corner.

Fieldwork and acknowledgments.—Fieldwork leading to the present report was started by the U.S. Geological Survey in 1922 by C. R. Longwell and W. W. Rubey with the purpose of studying the stratigraphy and structure of outcropping Cretaceous and Tertiary rocks on the flanks of the Black Hills uplift. Mapping was continued in 1923 by W. W. Rubey, H. W. Hoots, and A. Stepanoff, and in 1924 by W. W. Rubey and M. N. Bramlette. Fieldwork was resumed in 1954 on behalf of the Division of Raw Materials of the U.S. Atomic Energy Commission because of the discovery of uranium deposits in the area. The writers, with P. K. Theobald in 1955, locally modified and extended the original mapping, compiled it on a more modern base, and measured additional stratigraphic sections. The mapping in the eastern part of the area was further modified as the result of detailed studies made from 1955 to 1958 by several geologists including M. H. Bergendahl, D. A. Brobst, R. E. Davis, G. A. Izett, W. J. Mapel, C. L. Pillmore, C. S. Robinson, and R. C. Vickers. The mapping of M. M. Knechtel and S. H. Patterson (1955) was used for a part of northern Crook County, Wyo., and southern Carter County, Mont. The areas for which different individuals are principally responsible are indicated on the map showing sources of geologic data on plate 1.

Important contributions to the work were made by several persons in addition to the ones mentioned above. K. M. Waagé, assisted in 1955 by Copeland MacClintock and in 1956 by Daniel Barker, made a special study of the Inyan Kara group which resulted in the redefinition of the Lakota and Fall River formations (Waagé, 1959). W. A. Cobban spent several days in the field with the writers in an examination of the Pierre shale and identified the invertebrate fossils collected from Cretaceous rocks by the writers and their associates. R. W. Imlay spent 3 days in the field with the writers in a review of the Jurassic stratigraphy, which resulted in some changes in the correlation of rocks of Middle Jurassic age (Mapel and Bergendahl, 1956). J. R. Gill clarified the stratigraphic relations of the lower part of the Pierre shale on the west side of the Black Hills in studies made in 1957 and 1958. I. G. Sohn in 1957 collected and identified ostracodes from many of the stratigraphic sections of Lower Cretaceous and Upper Jurassic rocks measured by the writers. J. B. Reeside, Jr., C. W. Gilmore, J. W. Gidley, E. W. Berry, F. H. Knowlton, and G. H. Girty identified fossils collected by W. W. Rubey and his associates during the early years of the investigation.

Special acknowledgment is due W. W. Rubey who made available the field notes, maps, and correspondence related to the earlier work, and who gave generously of his time in consultation during preparation and in a review of the report.

Planetable methods were used in the earlier mapping from 1922 to 1924, and aerial photographs were used in the subsequent work of the writers. Topographic maps at a scale of 1:24,000 or larger were used in the work done from 1955 to 1958. Altitudes used for structure contouring were determined from many sources including the planetable work, topographic maps, oil-well data, and traverses made with aneroid barometers. Stratigraphic sections were measured for the most part with hand level and 6-foot tape; a few were measured with 100-foot tape and Brunton compass or by planetable.

Previous work.—Several geologic maps published before 1957 cover areas within and adjacent to the area of this investigation, as shown by figure 2. The earliest comprehensive work was done by Darton and his associates who, from 1900 to 1910, mapped the Newcastle, Sundance, Devils Tower, and Aladdin 30-minute quadrangles, and made the first systematic study of the stratigraphy of the Black Hills.

Other important early work deals with the description and correlation of the sedimentary rocks exposed in the northern Black Hills. Dobbin and Reeside (1929) described the Fox Hills sandstone and its relation to the overlying Lance formation; Rubey (1929 and 1931) discussed the composition and origin of the Mowry shale and the lithology, structural behavior, and rate of deposition of some other marine shales of Cretaceous age; Imlay (1947) subdivided and described the Sun-

1. Barnett, 1915.
2. Collier, 1922.
3. Darton, 1901.
4. Darton, 1904.
5. Darton, 1905a.
6. Darton and O'Harra, 1905.
7. Darton and O'Harra, 1907.
8. Darton, 1909.
9. Darton and O'Harra, 1909.
10. Davis, 1912.
11. Dobbin and Barnett, 1927.
12. Dobbin, Miller, and Walter, 1935.
13. Dobbin and Horn, 1949.
14. Dobbin, Kramer, and Horn, 1957.
15. Hancock, 1920a.
16. Knechtel and Patterson, 1955.
17. Longwell and Rubey, 1923.
18. Robinson, 1956.
19. Rubey, 1924.
20. Stone and Lupton, 1910.
21. Stone, 1912.
22. Area described in this report.

FIGURE 2—Explanation.

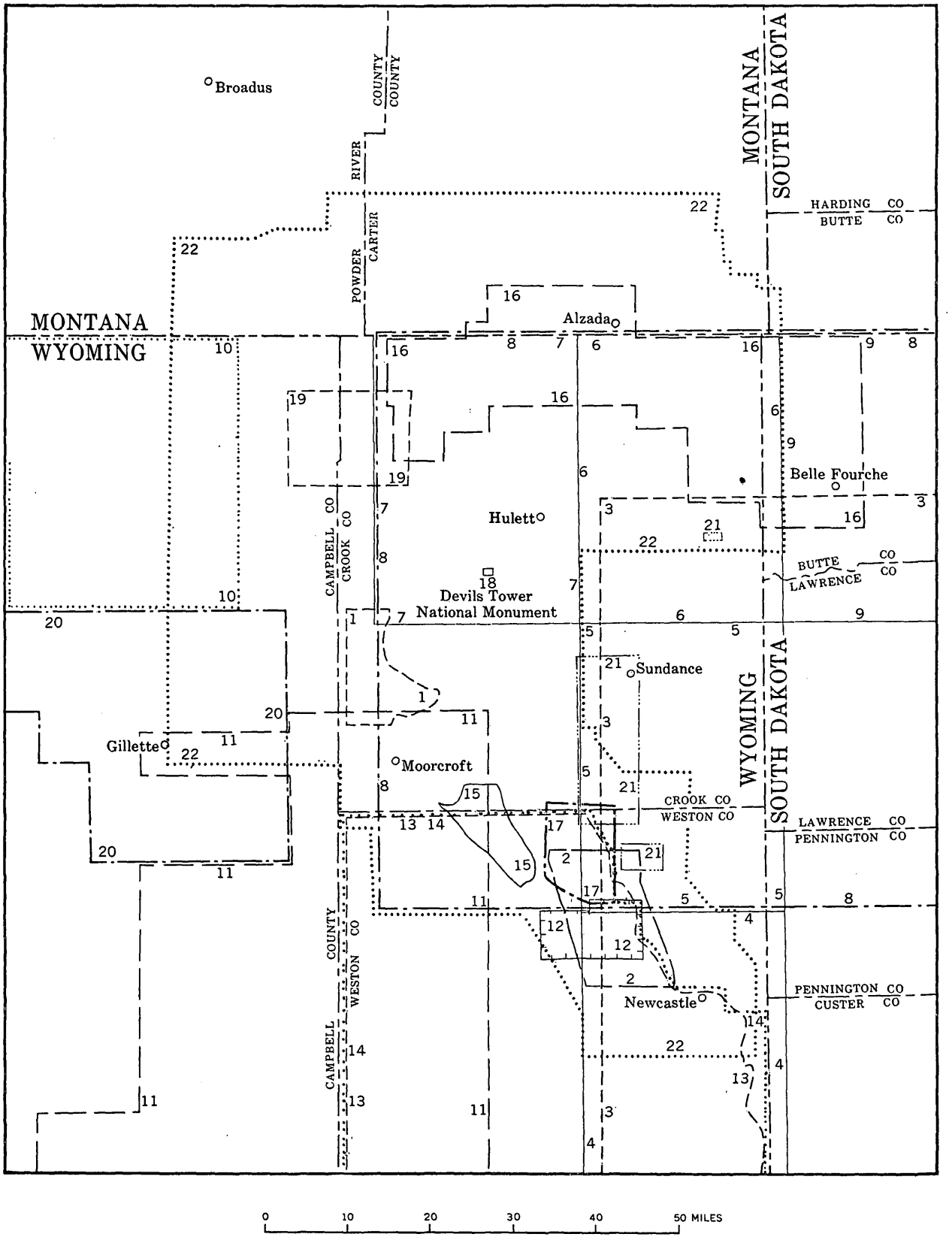

FIGURE 2.—Index of geologic mapping in the northern and western Black Hills.

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dance and Gypsum Spring formations of Jurassic age; and Cobban (1951) discussed the Cretaceous formations of the Colorado group in the northern Black Hills and their correlation with equivalent rocks in central and northwestern Montana. Some preliminary results of the present investigation have been published separately including a report on the correlation of lithologic units in the Pierre shale (Robinson, Mapel, and Cobban, 1959), and a slightly simplified map of the area investigated, excluding the part in Weston County, Wyo. (Mapel, Robinson, and Theobald, 1959). Many other reports have been published on the geology of small areas or on special phases of the stratigraphy, and these are referred to at the appropriate places in the following pages and listed at the end of the report.

STRATIGRAPHY

Sedimentary rocks exposed on the northern and western flanks of the Black Hills in the area mapped have an aggregate thickness of about 11,000 feet and range in age from Mississippian to Quaternary. These rocks may be diveded into 23 formations, exclusive of the surficial deposits of Tertiary(?) and Quaternary ages. The distribution of the formations is shown by the geologic map, plate 1 and a summary of their thickness and lithology is given in the following table.

Generalized section of the exposed sedimentary rocks on the northern and western flanks of the Black Hills uplift

System	Series	Stratigraphic unit				Thickness (feet)	Description
Quaternary	Recent and Pleistocene	Alluvium and stream terraces					Silt, sand, and gravel.
		—Unconformity—					
Tertiary	Oligocene	White River formation				0- 150	Light-gray medium- to coarse-grained sandstone at base overlain by light brownish-gray claystone and siltstone.
		—Unconformity—					
	Eocene	Wasatch formation				300+	Grayish-yellow sandstones and gray shale, numerous coal beds; thick extensively burned coal bed (Roland bed of U.S. Geol. Survey Bull. 796-A) at base.
	Paleocene	Fort Union formation	Tongue River member			500- 800±	Yellowish-gray massive sandstone and light-gray shale; numerous coal beds: thickest in Montana; thins southward.
			Lebo shale member			200- 250	Medium- to dark-gray shale, light-gray sandstone, and a few thin coal beds.
			Tullock member			500-1,100	Light-gray and light-brown sandstone, gray shale, and numerous thin coal beds: thinnest in Montana; thickens southward.
Cretaceous	Upper Cretaceous?	Lance formation				500-1,600	Gray to yellowish-gray sandstone and gray shale; a few thin beds of carbonaceous shale; thinnest in Montana; thickens southward.
		Montana group	Fox Hills sandstone	Colgate member, 50-100 ft.		125- 200	Brown sandy shale and siltstone, light-gray sandstone, and brown ferruginous sandstone concretions; the Colgate member, a prominent massive white sandstone, at top in Montana.
			Pierre shale	Upper part	Kara bentonitic member, 100±ft.	800-1,500	Dark-gray shale and claystone; locally beds of siltstone; abundant limestone concretions some fossiliferous in upper and lower parts; thickens southward from Montana. Kara and Monument Hill bentonitic members, gray bentonitic shale and impure bentonite with a few limestone concretions and small barite concretions.
					Monument Hill bentonitic member, 150-220 ft.		
				Mitten black shale member.		145-1,000	Dark-gray to black shale with beds of yellowish-gray bentonite at base and numerous large yellowish-brown-weathering fossiliferous septarian limestone concretions in upper part; thickens southward from Montana.
				Gammon ferruginous member	Groat sandstone bed, 0-125 ft.	0-1,000	Light-gray claystone and shale with abundant reddish-brown iron-stained concretions and thin lenses of siderite. Groat sandstone bed, mapped north of T. 55 N., consists of gray fine-grained glauconitic and ferruginous sandstone.
		Colorado group	Niobrara formation			150- 225	Chalk marl and calcareous shale; numerous thin beds of bentonite, dark gray when fresh, weathers light yellow.
			Carlile shale	Sage Breaks member		200- 300	Grayish-black noncalcareous shale with numerous beds of septarian limestone concretions that weather light gray.
				Turner sandy member		150- 260	Dark-gray shale, locally sandy and silty, with numerous beds of light-yellow and red silty limestone concretions; commonly a thin bed of light-gray medium-grained sandstone at the base.
				Lower unnamed number		40- 130	Dark-gray shale with a few limestone concretions; locally slightly silty and sandy; thickest in Montana.
			Greenhorn formation			70- 370	In northeastern and southeastern parts; gray calcareous shale and marl with some light-gray, thin-bedded limestone; in central part; gray noncalcareous shale containing prominent light-gray weathering septarian limestone concretions; thins westward.
			Belle Fourche shale			350- 850	Dark-gray to black shale with numerous dark purplish-red weathering siderite concretions in lower part, and several beds of light-gray and yellow-weathering limestone concretions in middle and upper parts; thickens westward.

Generalized section of the exposed sedimentary rocks on the northern and western flanks of the Black Hills uplift—Continued

System	Series	Stratigraphic unit		Thickness (feet)	Description
Cretaceous	Lower Cretaceous	Colorado group	Mowry shale	180- 230	Dark-gray siliceous shale, weathers light gray; numerous fish scales along partings; many thin bentonite beds; Clay Spur bentonite bed at top.
			Newcastle sandstone	0- 95	Lenticular beds of light-gray sandstone and siltstone and dark-gray shale and claystone; a few beds of impure coal and bentonite; thickness varies within short distances, but averages about 40 feet.
			Skull Creek shale	180- 270	Black shale with a few dark-red ferruginous concretions.
		Inyan Kara group	Fall River formation	95- 200	Fine- to medium-grained light yellowish-brown to brown sandstone with interbedded gray and black shale and gray siltstone; averages about 135 feet in thickness near its outcrop.
			—Unconformity—		
			Lakota formation	45- 300	Light yellowish-gray to white fine- to coarse-grained sandstone and conglomeratic sandstone irregularly interbedded with red, green, yellow, gray, and black claystone; coal beds near base locally; thickness varies within short distances.
Jurassic	Upper Jurassic	Morrison formation		0- 150	Greenish-gray, green, and grayish-red claystone with a few thin discontinuous beds of light-gray sandstone and limestone; thickness at most places between 80 and 120 feet.
		Sundance formation	Redwater shale member	30- 195	Greenish-gray soft fissile sandy and silty shale; includes some thin beds of glauconitic sandstone and oolitic and coquinoid limestone; thickness at most places between 160 and 190 feet.
			Lak member	40- 80	Yellow and pink crudely bedded fine-grained sandstone and siltstone.
			Hulett sandstone member	55- 90	Yellowish-gray fine-grained thin-bedded to massive calcareous sandstone; locally pink northeast of Devils Tower.
			Stockade Beaver shale member	50- 90	Soft gray calcareous shale with some thin beds of yellowish-gray sandstone.
			Canyon Springs sandstone member	0- 40	Friable yellowish-gray or pink sandstone, some light greenish-gray siltstone.
		—Unconformity—			
	Middle Jurassic	Gypsum Spring formation		0- 125	At base, massive white gypsum with interbedded red gypsiferous claystone; overlain near Hulett by interbedded gray cherty limestone and red claystone; thins southward from a maximum observed thickness of 125 feet near the junction of Deer Creek and the Belle Fourche River (SW¼ sec. 13, T. 55 N., R. 64 W.).
		—Unconformity—			
Triassic and Permian		Spearfish formation		450- 825	Red sandy shale, siltstone, and sandstone; beds of massive white gypsum in lower half.
Permian		Minnekahta limestone		40±	Light-gray thin-bedded limestone, pink on outcrop.
		Opeche formation		60- 90	Reddish-brown and maroon fine-grained sandstone, siltstone, and shale.
		—Unconformity—			
Permian and Pennsylvanian		Minnelusa formation		650- 800	Light-gray and red sandstone, gray limestone and dolomite, red shale, local gypsum and anhydrite.
		—Unconformity—			
Carboniferous: Mississippian		Pahasapa limestone		500- 600	Light-gray limestone, locally dolomitic.

All the sedimentary rocks, from the Pahasapa limestone of Mississippian age to the Wasatch formation of Eocene age, are about concordant in dip, although deposition was not continuous as shown by unconformities at the base of the Minnelusa formation of Pennsylvanian and Permian age; the Opeche formation of Permian age; the Gypsum Spring formation of Middle Jurassic age; the Sundance formation of Late Jurassic age, and the Fall River formation of Early Cretaceous age. The Wasatch formation and older rocks were deformed and eroded during early Tertiary time and the White River formation of Oligocene age was deposited unconformably on the uplifted older beds.

Rocks of marine and nonmarine origin are represented about equally. The Mississippian Pahasapa limestone is marine. Pennsylvania, Permian, and Triassic rocks probably were deposited mostly in shallow marine embayments. Marine sediments were deposited over the area during parts of Middle and Late Jurassic time, followed by nonmarine deposits in Late Jurassic and part of Early Cretaceous time. Much of the Cretaceous is represented by a thick marine sequence beginning with the Skull Creek shale and ending with the Fox Hills sandstone. Younger Cretaceous and Tertiary rocks are nonmarine.

As much as 600 feet of sedimentary rocks older than Mississippian crop out in parts of the Black Hills uplift east and southeast of the mapped area. The thicknesses and lithologies of these rocks are summarized in the following table. They include strata of Late Cambrian, Early and Middle Ordovician, and Early Mississippian age. In addition, sedimentary rocks of Silurian, Devonian, and Late Mississippian age are found by drilling in the Williston basin north of the Black Hills, and equivalent strata may extend varying distances southward in the subsurface into southern Carter and Powder River Counties, Mont., and perhaps into northern Crook County, Wyo.

Older sedimentary rocks exposed east of the mapped area in the northern part of the Black Hills (modified from Darton, 1909)

System		Series	Formation	Thickness (in feet)	Description
Carboniferous	Mississippian	Lower Mississippian	Englewood limestone	50- 60	Pink or purplish-gray thin-bedded limestone; locally shaly.
			—Unconformity—		
Ordovician		Upper Ordovician	Whitewood dolomite	50- 60	Mottled grayish-yellow massively bedded dolomite, locally cherty near top.
		Middle Ordovician	Winnipeg formation	60- 70	Upper part greenish-gray siltstone, lower part greenish-gray shale (Furnish, Barragy, and Miller, 1936; Carlson, 1958).
			—Unconformity—		
Cambrian and Ordovician		Upper Cambrian and Lower Ordovician	Deadwood formation	300-500	Brown sandstone, gray glauconitic limestone and edgewise limestone conglomerate, and green shale.
			—Unconformity—		
Precambrian					Metamorphic and igneous rocks.

MISSISSIPPIAN SYSTEM

PAHASAPA LIMESTONE

The oldest formation exposed in the mapped area is the Pahasapa limestone, which crops out locally in jagged ledges and cliffs at Inyan Kara Mountain (T. 49 N., Rs. 62 and 63 W.). The lower part of the formation is cut out by an igneous intrusive body at these exposures, but in complete sections nearby, the Pahasapa is 500 to 600 feet thick (Darton, 1905a, p. 2; Andrichuk, 1955, fig. 5). As described by Darton (1909, p. 21), the Pahasapa is massive fine-grained white to pale-cream limestone that weathers light gray and contains black chert in egg-shaped masses or in lenses parallel to the bedding. Marine fossils consisting mostly of brachiopods and corals have been reported from the formation at various places and indicate its age is Early Mississippian (Darton, 1909, p. 21–22; Gries, 1952, p. 71).

PENNSYLVANIAN AND PERMIAN SYSTEMS

MINNELUSA FORMATION

The Minnelusa formation crops out on the north side of Inyan Kara Mountain and in the center of a small dome at Strawberry Mountain (Tps. 48 and 49 N., Rs. 62 and 63 W.). The top of the formation crops out also in a few canyons along the southeastern edge of the mapped area. The topmost 20 to 50 feet of the Minnelusa at all these places is resistant light-gray to light yellowish-gray fine-grained calcareous sandstone that makes cavernous ledges and cliffs. The remainder of the formation was not examined in detail because of poor exposures.

In drill holes and in outcrops near the mapped area, the Minnelusa ranges from 650 to 800 feet in thickness and consists of interbedded light-gray to locally pink sandstone, gray sandy dolomite and limestone, some red shale and siltstone, and local beds of gypsum and anhydrite. Descriptions of the formation at various places on the west side of the Black Hills were given by Darton (1909, p. 22–24), Brady (1931, 1958), Foster (1958), and Bowles and Wolcott (1958). The Minnelusa rests unconformably on the Pahasapa limestone.

The upper 250 to 300 feet of the Minnelusa formation has been assigned to the Permian system on the basis of correlations with the Hartville formation south of the Black Hills (Foster, 1958, p. 39–40); the remainder of the Minnelusa is considered Pennsylvanian in age.

PERMIAN SYSTEM

OPECHE FORMATION

The Opeche crops out on the east side of Stockade Beaver Creek (T. 45 N., R. 60 W.) in the southeast corner of the mapped area and at a few other places farther to the north at and near Inyan Kara and Strawberry Mountains. At most of these places it is exposed in stream valleys cut through dip slopes on the overlying Minnekahta limestone. The formation is about 75 feet thick along Stockade Beaver Creek about 1 mile east of the mapped area (Darton, 1904, p. 3) and ranges from 60 to about 90 feet in thickness farther north. The Opeche formation consists mostly of soft reddish-brown siltstone and reddish-brown silty shale in beds about 1 to 4 inches thick. In the upper 3 to 5 feet, just below the contact with the Minnekahta limestone, the rock is characteristically a dark-purple or maroon silty shale. A few nodules and thin seams of gypsum occur near the middle of the formation locally.

No fossils have been reported from the Opeche formation, however the adjacent rocks above and below the Opeche are Permian. Equivalent beds in the Casper area of east-central Wyoming are placed by Burk and Thomas (1956, p. 8–10) in the basal part of the Goose Egg formation.

MINNEKAHTA LIMESTONE

The Minnekahta limestone of Permian age crops out along the east side of Stockade Beaver Creek (T. 45 N., R. 60 W.) at the southeastern edge of the mapped area, and near Inyan Kara and Strawberry Mountains a few miles to the north where it forms dip slopes almost barren of soil and vegetation.

The formation is about 40 feet thick and consists of light-gray limestone with purplish laminae; it locally

appears red in outcrop because of staining by overlying red beds of the Spearfish formation. Beds range in thickness from less than 1 inch to 3 feet. The lower part is silty and grades downwards within a few inches into red sandy and silty shale of the underlying Opeche formation. The rock has a strong petroliferous odor when freshly broken. Three chemical analyses of samples of the Minnekahta limestone collected in and near the mapped area are given below:

Chemical analyses of the Minnekahta limestone

[Analysts, J. G. Fairchild and J. A. Thomas, U.S. Geol. Survey]

	A [1]	*B*	*C*
Insoluble in HCl		1.37	2.5
MgO	0.36	[1] 20.46	Trace
CaO	54.54	[1] 31.28	54.6
CO_2	----	[1] 45.68	---
SO_3	Negligible	[1] .71	---
H_2O^+	----	.64	---
H_2O^-	----	.22	---
		100.36	

[1] Previously published by Wells (1937, p. 62).

A. SE¼ sec. 4, T. 52 N., R. 61 W.; banded gray and dull lavender in layers ¼ to 18 mm thick, sample collected by W. W. Rubey.

B. Center S½ sec. 18, T. 52 N., R. 61 W.; dolomite at top of Minnekahta limestone, gradational upward into prominent gypsum bed at base of overlying Spearfish formation; sample collected by W. W. Rubey.

C. SW¼ sec. 9, T. 49 N., R. 62 W.; laminated gray and purplish-gray limestone, top of formation.

Fossils are rare in the Minnekahta limestone. Rubey collected *Naiadites*? sp. from the lower 5 feet of the Minnekahta limestone in the N½ sec. 28, T. 50 N., R. 62 W., (loc. 5705) a few miles east of the mapped area near Sundance, Wyo., and *Naiadites*? sp. and *Bulimorpha*? sp. from Rapid Creek Canyon 3½ miles west of Rapid City, S. Dak., on the eastern side of the Black Hills (loc. 5706). The fossils were identified by G. H. Girty. Darton (1909, p. 26) reported marine invertebrates that suggest a Permian age. Denson and Botinelly (1949) recognized the Minnekahta limestone in the Hartville uplift of southeastern Wyoming and suggested that it correlates with some part of the Phosphoria formation, of Permian age, in central Wyoming. Burk and Thomas (1956, p. 9) considered the Minnekahta of the Hartville uplift as a member of the Goose Egg formation and correlated this formation with part of the Phosphoria formation in the Wind River Mountains of central Wyoming. As a result of the work of Burk and Thomas, the Wyoming Geological Association (1956) considered the Minnekahta limestone of the Black Hills as a member of the Goose Egg formation, and of Permian age.

PERMIAN AND TRIASSIC SYSTEMS

SPEARFISH FORMATION

The Spearfish formation of Permian and Triassic age consists of red shale, siltstone, and sandstone, and thick beds of white gypsum near the base. It crops out along the valley of the Belle Fourche River and its tributaries in the central part of the mapped area, near the head of Lytle Creek along the eastern edge of the area, and along the valley of Stockade Beaver Creek and in nearby areas in the southeastern part of the area.

The Spearfish formation rests with sharp contact but with no apparent unconformity on the underlying Minnekahta limestone of Permian age, and it is overlain unconformably by the Gypsum Spring formation of Middle Jurassic age or, where the Gypsum Spring formation is absent, by the Sundance formation of Late Jurassic age.

Logs of wells drilled in many parts of the area indicate that the Spearfish formation ranges in thickness from about 450 to 825 feet, averaging about 600 feet. Darton (1904, p. 3) reported its thickness as 450 feet along Stockade Beaver Creek; this measurement includes a few feet of gypsum that belong in the overlying Gypsum Spring formation. The thickness is about 645 feet between Miller and Lytle Creeks in 2 wells in Tps. 52 and 53 N., R. 65 W., and it is about 650 feet thick at Government Canyon in the Vickers Petroleum Corp. Duncan and Lobban 1 (well 29, pl. 1). The thickest section of the Spearfish is at Barlow Canyon in sec. 13, T. 54 N., R. 66 W. The Petroleum Inc. Holmes 1 (well 54, pl. 1) began an estimated 50 to 60 feet below the top of the Spearfish and penetrated an additional 768 feet in the formation giving a total thickness of about 825 feet.

The lowermost 250 to 300 feet of the formation consists of interbedded massive white gypsum in beds a few inches to 20 feet thick separated by partings of red silty mudstone and siltstone. The upper part of the formation consists of interbedded dark reddish-brown fine-grained sandstone, siltstone, and sandy shale or mudstone. Sandstone and siltstone in the Spearfish is crudely thin-bedded, commonly crosslaminated, and locally ripple-marked. Thin stringers of gypsum occur along bedding-planes and in fractures in the upper part of the formation, but they appear to be mostly secondary deposits leached from the thick beds of gypsum in the basal part of the overlying Gypsum Spring formation.

Fossils have not been reported from the Spearfish formation. The upper part, however, has the same stratigraphic position and lithology as the Red Peak member of the Chugwater formation of Triassic age in central and southeastern Wyoming. The lower gypsiferous sequence is lithologically similar to and occupies the same stratigraphic position as a gypsum and red shale unit of Permian(?) age mapped by Denson and Botinelly (1949) in the Hartville uplift to the south, and by Hose (1954) along the eastern flank of the Bighorn Mountains to the east. Burk and

Thomas (1956, p. 8) and Privrasky and others (1958, p. 49–50) include the lower gypsiferous sequence of the Spearfish formation, and underlying Minnekahta and Opeche formations, in the Goose Egg formation of "Permo-Triassic" age.

The following section shows the lithology of the upper part of the formation along the valley of the Belle Fourche River.

Section of the Spearfish formation on the south side of Devils Tower in the NW¼ sec. 18, T. 53 N., R. 65 W., Crook County, Wyo.

	Feet
Gypsum Spring formation (part):	
8. Gypsum, white, massive, stained pink on weathered surface	10+
Unconformity.	
Spearfish formation (part):	
7. Claystone, dark brownish-red, silty to sandy	11
6. Sandstone and siltstone, dark brownish-red; sandstone is fine grained	48
5. Shale, dark brownish-red; some interlaminated brownish-red siltstone	11
4. Siltstone, dark brownish-red; some interbedded fine-grained sandstone	18
3. Shale, dark reddish-brown, sandy; interbedded reddish-brown siltstone and fine-grained sandstone	22
2. Siltstone, dark reddish-brown	2
1. Mudstone, dark reddish-brown, sandy; some interbedded reddish-brown siltstone in beds as much as 6 in. thick	16
Partial thickness Spearfish formation	128

A partial section of the lower gypsiferous part of the Spearfish southeast of Strawberry Mountain, about half a mile east of the area, is given as follows:

Lower part of the Spearfish formation in the SE¼ sec. 24, T. 48 N., R. 62 W., Weston County, Wyo.

	Feet
Top of hill.	
Spearfish formation (part):	
16. Gypsum, white	1
15. Partly covered; mostly red siltstone containing gypsum stringers	6
14. Gypsum, white, lenticular	1
13. Partly covered; mostly red siltstone	3
12. Gypsum, white; a few partings of red siltstone in the bottom half; forms ledges	22
11. Siltstone and silty claystone, red; a few thin gypsum stringers	11
10. Gypsum, white, lenticular	1½
9. Siltstone and silty claystone, red; a few thin gypsum stringers	9
8. Gypsum, white; forms ledge	1½
7. Siltstone and silty claystone, red; a few thin gypsum stringers	23
6. Gypsum, white; forms lenticular ledge	2
5. Siltstone, red, slightly calcareous	4
4. Gypsum, white; forms ledge	9
3. Siltstone, red with a few green streaks, clayey, calcareous, massive	101

Lower part of the Spearfish formation in the SE¼ sec. 24, T. 48 N., R. 62 W., Weston County, Wyo.—Continued

	Feet
Spearfish formation (part)—Continued	
2. Siltstone, red; thin seams of light-gray limestone	1
Measured thickness Spearfish formation	196
Minnekahata limestone (part):	
1. Limestone, light- to medium-gray, finely crystalline; forms hard ledges in stream bank	3
Base of exposure.	

JURASSIC SYSTEM

MIDDLE JURASSIC SERIES

GYPSUM SPRING FORMATION

The Gypsum Spring formation of Middle Jurassic age, which consists of massive white gypsum, red claystone, and gray limestone, underlies the Sudance formation of Late Jurassic age and overlies the Spearfish formation of Permian and Triassic age. It crops out in almost continuous exposures along the valley of the Belle Fourche River and its tributaries from Beaver Creek southward for about 25 miles to the vicinity of Left Creek. Farther to the east, the basal part crops out from the vicinity of Inyan Kara Mountain southward almost to the edge of the area.

The formation is about 125 feet thick at its northernmost exposure near Beaver Creek, about 8 miles northeast of Hulett (sec. 13, T. 55 N., R. 64 W.). From this point southward it thins irregularly owing to truncation by the overlying Sundance formation. The Gypsum Spring formation is absent, and the Sundance formation rests directly on the Spearfish formation at Sawmill Gulch in T. 54 N., R. 66 W., and along the western edge of the Bear Lodge Mountains in Tps. 52 and 53 N., R. 64 W. Plate 2 shows the lithology of the formation and the correlation of beds from place to place.

The base of the Gypsum Spring formation at most places is a ledge- or cliff-forming unit as much as 30 feet thick made up mostly of gypsum in beds 1 to 10 feet thick separated by lenticular partings of red claystone. Usually the gypsiferous unit is all that is present where the formation is thin. About a mile south of Left Creek in the NE¼ sec. 35, T. 53 N., R. 66 W., beds of massive gypsum at the base of the formation grade laterally within a few feet into thinner beds of highly brecciated porous dark-brown limestone that may be the residue of impure gypsum leached by ground water. A few thin lenses of porous brown limestone breccia were found at the Spearfish-Sundance contact near the head of Lytle Creek in the SW¼ sec. 2, T. 52 N., R. 64 W., and these beds may be the altered remnants of gypsum beds in the Gypsum Spring formation at that locality. The basal gypsum beds rest sharply on under-

lying red siltstone, sandstone, or claystone of the Spearfish formation, and regional correlations suggest that the contact may be an unconformity representing most or all of Early Jurassic time (Imlay, 1947, p. 259; 1952, p. 1747–1749).

Overlying the basal gypsum sequence along the valley of the Belle Fourche River is a slope-forming unit as much as 45 feet thick consisting mostly of red claystone with some gypsum in thin lenticular beds and pods. The upper 2 to 4 feet of this sequence is generally bleached light greenish gray.

The remaining part of the formation, which crops out only in the vicinity of Hulett and northward, consists of beds of light-gray limestone that range in thickness from 1 to 4 feet, separated by beds of gray or red claystone. This part of the formation has a maximum exposed thickness of about 50 feet near the mouth of Beaver Creek about 8 miles northeast of Hulett. The limestone is earthy to sublithographic and locally gypsiferous. Beds of limestone at the base of the sequence characteristically contain gray and brown chert in thin wavy lenses and small irregular pods. The basal bed of limestone rests on the underlying part of the formation with a sharp slightly undulating contact. Five beds of limestone separated by intervals of claystone make up this unit near Beaver Creek; two beds of limestone are present at Hulett; and the entire unit is missing 5 miles south of Hulett in sec. 34, T. 54 N., R. 65 W.

The only fossils found in the Gypsum Spring formation were ostracodes of the genus *Cytherella*, which occur in red claystone in the upper part of the formation in the SW¼ sec. 13, T. 55 N., R. 64 W. As shown on figure 3, similarities in lithology and stratigraphic position suggests that the beds assigned to the Gypsum Spring formation in the Black Hills region are equivalent to the Gypsum Spring formation of central Wyoming as described by Love and others (1945), and to the lower and middle parts of the Piper formation of south-central Montana. Love (written communication,

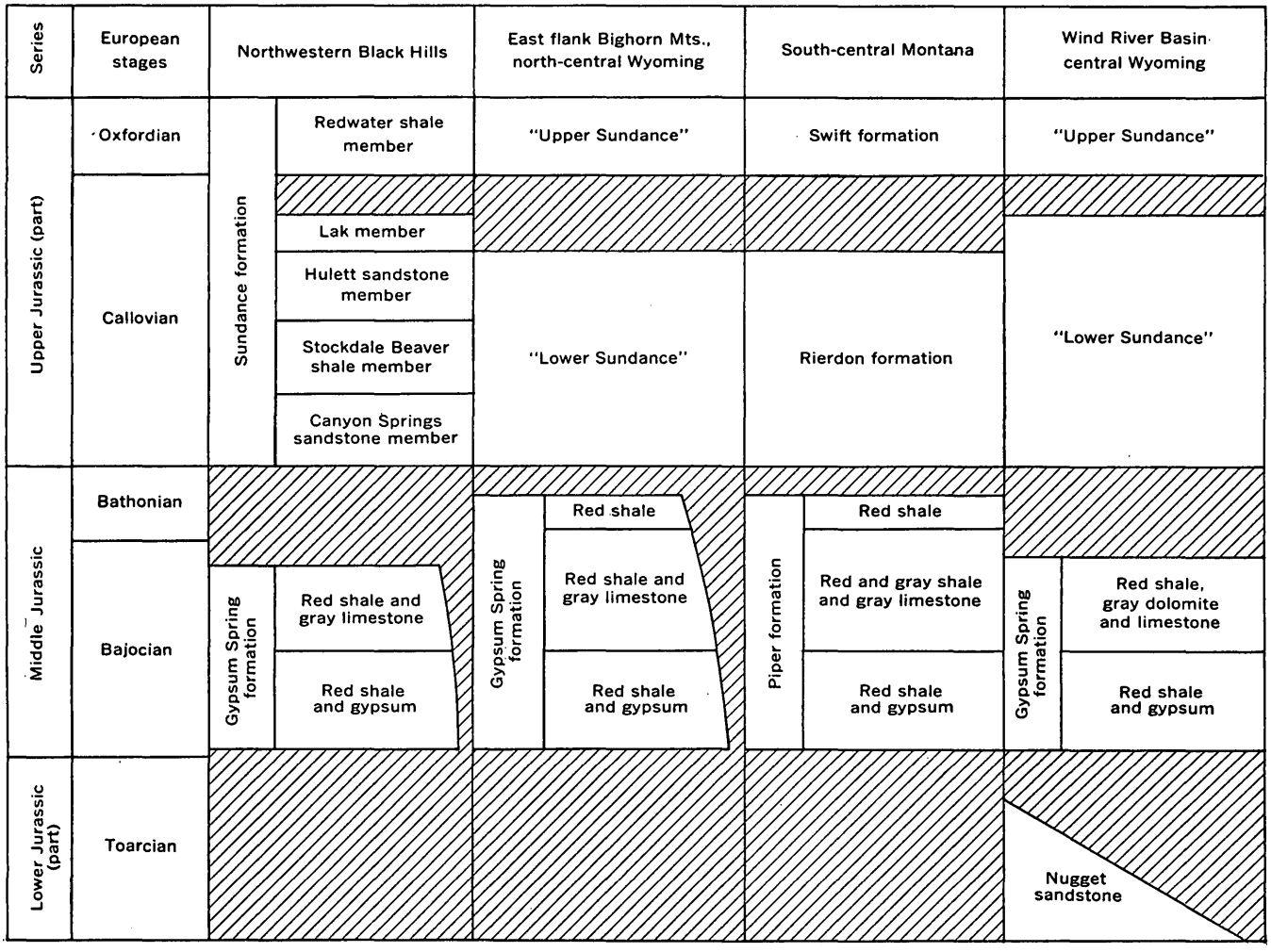


FIGURE 3.—Correlation of some Jurassic formations in parts of Wyoming and Montana. (Modified after Imlay, 1947, table 1.)

1957) has stated that the Gypsum Spring formation in the Black Hills is possibly not equivalent to the type Gypsum Spring but is equivalent to the Piper formation of Montana, which Love considered younger than his Gypsum Spring. The Wyoming Geological Association (1956, p. 45) considered, as did Imlay (1947, table 1), that the Piper and Gypsum Spring formations are equivalent, and, in their correlation chart for the eastern margin of the Powder River Basin, they used the term Piper.

The following sections, which are shown graphically on plate 2, illustrate the lithology of the Gypsum Spring formation on the northern and western flanks of the Black Hills:

Gypsum Spring formation and part of the Sundance and Spearfish formations on the east side of the Belle Fourche River in the SW¼ sec. 13, T. 55 N., R. 64 W., Crook County, Wyo. section 1, pl. 2)

	Feet
Sundance formation (part):	
Stockade Beaver shale member (part):	
19. Shale, greenish-gray, noncalcareous; contains thin laminae of light-gray fine-grained sandstone	22
18. Sandstone, very light gray, fine-grained, very friable and porous, well-sorted, massive	26
17. Shale, greenish-gray; calcareous in lower 2 ft; contains a few laminae of light-gray fine-grained sandstone	9
16. Limestone, medium-gray, abundantly fossiliferous; forms ledge	½
15. Sandstone, very light gray, fine-grained, calcareous	½
Partial thickness of Sundance formation	58
Unconformity.	
Gypsum Spring formation:	
14. Shale, dark reddish-brown, slightly silty; noncalcareous in lower part becoming calcareous in upper 2 ft; contains ostracodes identified by I. G. Sohn as *Cytherella* sp. in upper part	8
13. Shale and interbedded shaly limestone; shale is moderate reddish brown and very calcareous; limestone is dark yellowish orange and thin bedded and weathers to papery fragments that form a yellow band on the slope	2
12. Claystone, moderate reddish brown, calcareous	6½
11. Claystone, mottled red, yellow, and green, very calcareous; scattered rounded grains of chert and quartz as much as 1/16 in. in diameter in lower 2 ft; upper 2 ft contains *Cytherella* sp. identified by I. G. Sohn; nodules of pale-orange gypsum as much as 1 in. in diameter weathering from top of unit	4

Gypsum Spring formation and part of the Sundance and Spearfish formations on the east side of the Belle Fourche River in the SW¼ sec. 13, T. 55 N., R. 64 W., Crook County, Wyo. section 1, pl. 2)—Continued

	Feet
Gypsum Spring formation—Continued	
10. Limestone, very light gray, vuggy, faintly laminated; gypsiferous in middle part; forms ledge	2
9. Shale, grayish-red in lower part, greenish-gray in upper part, very calcareous	5½
8. Limestone, very light gray with dark-gray laminae, earthy; gypsiferous in lower part; contains abundant gray and brown chert in thin lenses and small irregular masses; forms ledge	4
7. Shale, dark greenish-gray to black, slightly calcareous	1
6. Limestone and gypsum, interbedded; limestone is very light gray, earthy, and thin bedded; gypsum is white, in beds as much as 1 ft thick	3
5. Limestone, very light gray, earthy, thin bedded; contains thin stringers of gray and brown chert; contact with underlying unit is sharp and slightly undulating; forms ledge	3
4. Claystone and interbedded gypsum; claystone is dark reddish brown and noncalcareous; gypsum is white and occurs as a branching network of lenses and pods; unit becomes grayish green in top 1 ft	47
3. Gypsum, white; in beds 2 to 6 ft thick separated by partings and thin beds of moderate reddish-brown claystone; forms cliff	28
Thickness of Gypsum Spring formation	114
Unconformity.	
Spearfish formation (part):	
2. Claystone, moderate reddish-brown, slightly silty; contains seams and stringers of white gypsum	0–10
1. Sandstone and siltstone, interbedded, moderate reddish-brown to moderate reddish-orange; sandstone is very fine grained, crossbedded; forms ledges and reentrants	25
Partial thickness of Spearfish formation	35

Gypsum Spring and parts of the Sundance and Spearfish formations on a bluff east of Hulett in the SW¼ sec. 7, T. 54 N., R. 64 W., Crook County, Wyo. (section 3, pl. 2)

	Feet
Terrace gravel.	
Sundance formation (part):	
Stockade Beaver shale member (part):	
10. Shale, greenish-gray, crumbly	2
9. Sandstone, light yellowish-gray, thin-bedded, calcareous; some interbedded light yellowish-gray sandy thin-bedded limestone; uppermost bed is ledge 8 in. thick of slightly glauconitic gray limestone	4½

Gypsum Spring and parts of the Sundance and Spearfish formations on a bluff east of Hulett in the SW¼ sec. 7, T. 54 N., R. 64 W., Crook County, Wyo. (section 3, pl. 2)—Continued

	Feet
Sundance formation (part)—Continued	
8. Sandstone, light-gray, calcareous; contains scattered irregularly shaped dark-brown chert pebbles which are rounded, polished, and pitted; contact with underlying unit is sharp and slightly undulating	2½
Partial thickness of Stockade Beaver shale member	9
Unconformity.	
Gypsum Spring formation:	
7. Limestone, light-gray, slightly sandy; contains wavy lenses and nodules of dark grayish-brown chert; forms prominent bench	1
6. Claystone, yellowish-green, calcareous; some interbedded yellowish-gray blocky limestone in top 2 ft	6½
5. Limestone, light-gray with darker gray undulating laminae, slightly sandy, earthy, vuggy; middle 6 in. weathers to rough honeycombed surface; contact with underlying unit is sharp	1½
4. Claystone, grayish-red, noncalcareous; some gypsum in thin beds and stringers 1 to 4 in. thick; upper 3 to 4 in. is pale green	5
3. Claystone, moderate to dark reddish-brown, noncalcareous; interbedded white granular gypsum in beds as much as 1 ft thick; grades into underlying unit; lower contact picked arbitrarily	24
2. Gypsum, white, massive, granular; in beds 1 to 3 ft thick separated by partings and beds of dark reddish-brown silty claystone as much as 1 ft thick; forms moderately steep bluff; contact with underlying rocks is sharp	29
Thickness of Gypsum Spring formation	67
Unconformity.	
Spearfish formation (part):	
1. Sandstone and siltstone, interbedded, moderate reddish-orange, slightly calcareous; sandstone is fine grained, locally cross-bedded; some white gypsum in fractures and along bedding planes near the top of the unit	93

Gypsum Spring and parts of the Sundance and Spearfish formations on the south side of Devils Tower in the NW¼ sec. 18, T. 53 N., R. 65 W., Crook County, Wyo.

	Feet
Sundance formation (part):	
Stockade Beaver shale member (part):	
7. Shale, light-gray	10
6. Siltstone and fine-grained sandstone, grayish-white, friable	4
5. Shale, dark, greenish-gray, noncalcareous	14

Gypsum Spring and parts of the Sundance and Spearfish formations on the south side of Devils Tower in the NW¼ sec. 18, T. 53 N., R. 65 W., Crook County, Wyo.—Continued

	Feet
Sundance formation (part)—Continued	
Stockade Beaver shale member (part)—Continued	
4. Sandstone yellowish-gray, fine-grained, calcareous; contains a few chert pebbles that average about ½ in. in maximum dimension	1
Partial thickness of Stockade Beaver shale member	29
Unconformity.	
Gypsum Spring formation:	
3. Claystone, dark reddish brown at base, grades to light purplish gray at top	3
2. Gypsum, white; contains a few partings of dark-red claystone 1 to 6 in. thick	12
Thickness of Gypsum Spring formation	15
Unconformity.	
Spearfish formation (part):	
1. Claystone, dark brownish-red, silty to sandy	10+

Gypsum Spring and parts of the Sundance and Spearfish formations on the north side of Left Creek in the SE¼ sec. 22, T. 53 N., R. 66 W., Crook County, Wyo. (section 8, pl. 2)

	Feet
Sundance formation (part):	
Hulett sandstone member (part):	
15. Sandstone, yellowish-gray to yellowish-brown fine- to medium-grained, calcareous, slightly glauconitic; massive in upper part grading to thin bedded at base; forms cliff	29+
14. Sandstone, yellowish-brown to yellowish-gray, fine-grained; in beds ½ to 8 in. thick, ripple-marked, calcareous; contains a few thin partings of grayish-green shale	7
Partial thickness of Hulett sandstone member	36+
Stockade Beaver shale member:	
13. Partly covered; mostly grayish-green shale with some interbedded yellowish-gray fine-grained sandstone	16
12. Sandstone, yellowish-gray, fine-grained, calcareous; sparse glauconite	2
11. Shale, greenish- to brownish-gray, noncalcareous	15
10. Sandstone, yellowish-gray, fine-grained, calcareous; sparse glauconite	3
9. Shale, greenish-gray, noncalcareous	40
8. Sandstone, yellowish-gray, fine-grained, locally shaly, friable; in beds as much as 4 in. thick	6
Thickness of Stockade Beaver shale member	82

Gypsum Spring and parts of the Sundance and Spearfish formations on the north side of Left Creek in the SE¼ sec. 22, T. 53 N., R. 66 W., Crook County, Wyo. (section 8, pl. 2)—Con.

	Feet
Unconformity.	
Gypsum Spring formation:	
7. Claystone, dark-red grading to greenish-gray in upper 2 in., noncalcareous	3
6. Gypsum, white	1
5. Claystone, dark-red, noncalcareous	3
4. Gypsum, white	1
3. Claystone, dark-red; contains a few thin stringers of white gypsum	8
2. Gypsum, white; contains some interbedded dark-maroon claystone in beds as much as 1½ ft thick	18
Thickness of Gypsum Spring formation	34
Unconformity.	
Spearfish formation (part):	
1. Siltstone, dark-red, thin-bedded	17+

UPPER JURASSIC SERIES

SUNDANCE FORMATION

The Sundance formation crops out in the east-central part of the area along the Belle Fourche River and its tributaries and farther southward in the eastern third of the area. The formation consists of green shale, yellowish-gray and red very fine grained sandstone and siltstone, and, at some horizons, thin beds of gray limestone. At most places it is between 375 and 400 feet thick, but it is only about 230 feet thick at Sawmill Gulch in T. 54 N., R. 66 W., owing to a local unconformity at the top.

The formation contains five members, which, from oldest to youngest, were named by Imlay (1947, p. 246) the Canyon Springs sandstone, Stockade Beaver shale, Hulett sandstone, Lak, and Redwater shale members. The Canyon Springs sandstone and Stockade Beaver shale members were mapped together because they are relatively thin. From Devils Tower south, remnants of the underlying Gypsum Spring formation are included with these members. The Lak and Redwater shale members were also mapped (pl. 1) together, principally because the Lak is relatively thin, and because of poor exposures.

Marine invertebrate fossils have been found throughout the Sundance formation with the exception of the Lak member, and in addition, Rubey and others in 1922 found vertebrae of an ichthyosaurian reptile, probably *Baptanodon*, in the Redwater shale member is sec. 30, T. 51 N., R. 66 W., Crook County, Wyo. (identified by C. W. Gilmore). Imlay (1947, 1952, 1957), Schmitt (1953), and Peterson (1954, 1957, 1958), who have discussed the fossil content, age, and regional correlation of the Sundance formation in some detail, regarded the Stockade Beaver shale, Hulett sandstone, and Lak members as Callovian in age, and the Redwater shale member as Oxfordian in age. Imlay (1947, 1952) suggested that the contact between the Lak and Redwater shale members is a disconformity that represents some part of late Callovian time. Contacts between the other members are conformable. The Wyoming Geological Association (1956) has introduced the terms Rierdon and Swift formations for the Sundance formation of the Black Hills—the Rierdon formation being equivalent to the Canyon Spring, Stockade Beaver, Hulett, and Lak members, and the Swift to the Redwater shale member.

The Sundance formation rests unconformably on the Gypsum Spring formation or, where this formation is absent, on the Spearfish formation; the basal contact of the Sundance is marked by shallow channeling and by truncation of the underlying rocks. At most places the Sundance formation is overlain conformably by the Morrison formation, except at Sawmill Gulch where the Sundance is overlain unconformably by the Lakota formation.

Graphic sections of the Sundance formation are shown by plate 2.

CANYON SPRINGS SANDSTONE MEMBER

The Canyon Springs sandstone member of the Sundance formation ranges from a few inches to about 40 feet in thickness in the northwestern part of the Black Hills uplift. The member is thickest and most continuous from the vicinity of Inyan Kara Mountain southward for about 15 miles to Mount Pisgah. In this area it consists mostly of very fine grained friable calcareous sandstone that generally is nonresistant and poorly exposed. The sandstone is mostly light yellowish gray, but locally it is pink, or it is banded or mottled pink and yellow. In the Inyan Kara Mountain–Mount Pisgah region, the base of the member generally includes a few inches to several feet of light greenish-gray calcareous siltstone. A ledge-forming bed 5 feet thick of sandy oolitic fossiliferous limestone caps the member in sec. 12, T. 47 N., R. 62 W. (loc. 14, pl. 2).

Locally thick beds of friable light-gray sandstone in the basal part of the Sundance formation along the Belle Fourche River probably are equivalent to the Canyon Springs sandstone member of the Inyan Kara–Mount Pisgah region; however, the sandstone is less continuous in the Belle Fourche valley than farther south, and commonly it is interbedded with shale, siltstone, and limestone. In the Belle Fourche valley, beds correlated with the Canyon Springs member are about 37 feet thick at Bush Canyon near Hulett and are nearly the same thickness farther north opposite the mouth of Deer Creek.

Nearly everywhere in the Belle Fourche valley, the basal bed of the Sundance contains coarse grains and small pebbles of gray and brown chert concentrated in a thin layer at the base; other thin conglomeratic layers also may occur a few inches above the base. Most of the larger fragments in these conglomeratic layers are an inch or two in maximum dimension; however, at Beaver Creek in the S½ sec. 1, T. 55 N., R. 64 W., rounded fragments of chert and limestone at the base of the Sundance are as much as 1½ feet in diameter. The pebbles characteristically are pitted and grooved and most of them are highly polished.

STOCKADE BEAVER SHALE MEMBER

The Stockade Beaver shale member of the Sundance formation ranges in thickness from 50 to about 90 feet. The member is thin where the underlying Canyon Springs sandstone member is thick, and conversely is thick where the Canyon Springs is thin or missing. It consists mainly of dark greenish-gray fissile shale with some thin beds and laminae of very fine grained light-gray sandstone and siltstone, mostly in the upper part. The contact with the Canyon Springs is gradational through an interval of generally less than 1 foot.

HULETT SANDSTONE MEMBER

The Hulett sandstone member ranges in thickness from about 55 to 90 feet, averaging about 70 feet. It consists mostly of fine-grained calcareous thin- to thick-bedded firmly cemented sandstone. Commonly the beds are ripple marked, some are crossbedded, and a few are sparsely glauconitic. The rock at many places is light gray, weathering light yellowish gray; but for distances of several miles along Blacktail and Whitetail Creeks (Tps. 53 and 54 N., Rs. 64 and 65 W.), it is pink or grayish red. At most places the member forms a single high cliff that may be traced for many miles in continuous outcrops.

The lower 10 to 15 feet of the Hulett sandstone member generally contains a few thin partings of greenish-gray shale, and the member grades downward into the Stockade Beaver shale member by an increase in the thickness and number of these partings. The contact is chosen at the horizon where shale predominates over sandstone, and it generally can be picked within about 5 feet.

LAK MEMBER

The Lak member of the Sundance formation is 40 to 60 feet thick in outcrops near the Belle Fourche River, and 60 to 80 feet thick a few miles to the south along Oil and Stockade Beaver Creeks. With some exceptions, the Lak is thick where the underlying Hulett sandstone member of the Sundance is thin, and thin where the Hulett is thick.

The Lak consists of yellowish-gray and pink poorly sorted siltstone and very fine grained sandstone. At some places a few partings and thin beds of silty green shale occur in the uppermost 5 to 10 feet. The member differs from the underlying Hulett sandstone member by being somewhat finer grained, more crudely bedded, and much less firmly cemented. In the southern part of the area, the Lak member is pink in contrast to the yellowish-gray of the Hulett, but at some places farther north near Devils Tower, both the Hulett and Lak members are predominantly pink and at other places both are predominantly yellowish gray. The Lak member weathers readily to form gentle slopes and flats above steep cliffs made by the Hulett.

The contact of the Lak member with the Hulett member is gradational and is arbitrarily established at the change from soft massive sandstone or siltstone in the Lak to more evenly bedded ledge-forming sandstone in the Hulett. Where exposures are good, the contact may be picked within about 3 feet.

REDWATER SHALE MEMBER

The Redwater shale member of the Sundance formation thins southward from about 195 feet a short distance north of Hulett to about 165 feet in the area south of Inyan Kara Mountain. It is only about 30 feet thick at Sawmill Gulch in the eastern part of T. 54 N., R. 66 W., but here the upper part has been eroded locally and the Lakota formation rests unconformably on the Redwater. The Redwater member consists mainly of grayish-green shale with subordinate amounts of light-gray sandstone and gray sandy limestone. The sandstone is fine grained and calcareous and occurs as laminae and thin discontinuous beds mostly near the base and in the upper part of the member. The limestone is oolitic and abundantly fossiliferous. It crops out in the upper part of the member in beds 1 to 4 feet thick. Spherical gray limestone concretions as much as a foot long are also fairly common. Glauconite occurs throughout the member but is particularly abundant near the base. The member as a whole erodes easily, and it commonly forms gentle slopes and rolling grass-covered hills on which the more resistant beds of sandstone and limestone stand out in slabby ledges.

The top bed of the Redwater is a calcareous sandstone, 2 to 30 feet thick, that usually weathers yellow and forms a ledge or band of bright-yellow sandy soil. Calcite coats the sand grains, giving some of them the appearance of oolites. The sandstone contains discontinuous seams about half an inch thick of red and

white oolitic chert at places along Inyan Kara Creek and its tributaries, and it contains thin seams of light bluish-gray chert near Mona Butte in sec. 14, T. 56 N., R. 63 W. Beds of white gypsum a few inches to as much as 4 feet thick are interbedded with and overlie this sandstone in sec. 35, T. 52 N., R. 66 W., and a few seams of pink and white gypsum a few inches thick were noted in the top of the Redwater shale member 20 to 25 feet stratigraphically below the sandstone east of Newcastle in the southeastern part of T. 45 N., R. 61 W.

The base of the Redwater shale member is marked at most places by green shale or glauconitic light-gray sandstone that rests sharply on nonglauconitic red or yellowish-gray sandstone at the top of the Lak member. Locally, however, the Lak may contain a few thin partings of green shale in its upper 2 to 3 feet, and at these places the contact is picked at the base of the predominantly shaly sequence. The contact of the Redwater member with the overlying Morrison formation is gradational.

The following sections, which are also shown graphically on plate 2, illustrate the lithology of the Sundance formation on the northern and western flanks of the Black Hills. Additional sections have been given by Imlay (1947, p. 266–273).

Sundance and part of the Gypsum Spring formations along the Alzada road about 1 mile northwest of Hulett in the SE¼ sec. 2 and the NW¼ sec. 12, T. 54 N., R. 65 W., Crook County, Wyo. (section 4, pl. 2)

Top of ridge.

Sundance formation:

	Feet
Redwater shale member:	
14. Sandstone, grayish-yellow, very fine grained, calcareous; forms ledge. Top of bed is about the top of Redwater shale member	4
13. Poorly exposed; mostly grayish-green shale with some interbedded light-gray very fine grained sandstone; a few beds as much as 1½ ft thick of gray fossiliferous glauconitic limestone in upper part; forms grass-covered slopes	175±
12. Shale, greenish-gray	5
Thickness (rounded) of Redwater shale member	185±
Lak member:	
11. Sandstone, yellowish-gray, very fine grained, slightly calcareous, massive, friable; a few partings of grayish-green shale in upper 3 to 4 ft	9
10. Poorly exposed; mostly reddish-orange and yellowish-gray very fine grained sandstone and siltstone	16
9. Sandstone, yellowish-gray, very fine grained to silty, friable, thin-bedded to massive	33
Thickness of Lak member	58

Sundance and part of the Gypsum Spring formations along the Alzada road about 1 mile northwest of Hulett in the SE¼ sec. 2 and the NW¼ sec. 12, T. 54 N., R. 65 W., Crook County, Wyo. (section 4, pl. 2)—Continued

Sundance formation—Continued

	Feet
Hulett sandstone member:	
8. Sandstone, yellowish-gray, very fine grained, calcareous, firmly cemented; thin bedded in lower 20 ft and upper 15 ft; remainder medium to thick bedded, faintly cross laminated; a few partings of greenish-gray siltstone and shale in lower 6 ft; forms cliff	90
Stockade Beaver shale member:	
7. Shale, greenish-gray; interbedded light-gray very fine grained sandstone near base and top	48
Canyon Springs sandstone member:	
6. Sandstone, light yellowish-gray, very fine grained, calcareous, slightly glauconitic, friable	11
5. Poorly exposed; appears to be mostly greenish-gray sandy shale and siltstone	8
4. Sandstone, greenish-gray, very fine grained to silty, calcareous, thin-bedded, locally fossiliferous	5
3. Sandstone, light-gray, mostly fine-grained; abundant pebbles of brown chert in lower part; sharp slightly undulating contact at base	5
Thickness of Canyon Springs sandstone member	29
Thickness (rounded) of Sundance formation	410±
Unconformity.	
Gypsum Spring formation (part):	
2. Limestone, light-gray, dense, thin bedded; lenses of dark-brown chert abundant in upper part, shaly in middle part; upper and and lower parts form ledges	5
1. Claystone, dark reddish-brown; grades to greenish gray in top 1 ft; contains thin lenses and stringers of white gypsum	10
Partial thickness of Gypsum Spring formation	15

Sundance and parts of the Spearfish and Lakota formations at Sawmill Gulch, SW¼ sec. 13, T. 54 N., R. 66 W., Crook County, Wyo. (section 5, pl. 2)

Lakota formation (part):	Feet
11. Sandstone, light-brown, medium- to coarse-grained with many lenses as much as 4 ft thick of very coarse grained to pebbly friable conspicuously crossbedded sandstone; pebbles are mostly subrounded fragments of chert but include clay pellets and fragments of sandstone; unit forms massive cliff	50±

Sundance and parts of the Spearfish and Lakota formations at Sawmill Gulch, SW¼ sec. 13, T. 54 N., R. 66 W., Crook County, Wyo. (section 5, pl. 2)—Continued

Unconformity.

Sundance formation:

Redwater shale member: *Feet*

10. Grass-covered slope; probably mostly shale as in unit below 15
9. Shale, greenish-gray with a few pale-red beds, noncalcareous, soft; contains abundant belemnites 15

Thickness of Redwater shale member 30

Lak member:

8. Sandstone, light yellowish-gray to light-gray, very fine grained, calcareous, thin-bedded; grades downward into underlying unit; forms slabby ledge 3
7. Siltstone and very fine grained sandstone, light yellowish-gray to light-gray with pink bands 1 to 2 ft thick in top 6 ft; calcareous, thin bedded to massive, very friable; lower third is poorly exposed; forms slope 42

Thickness of Lak member 45

Hulett sandstone member:

6. Sandstone, light-gray; weathers light yellowish gray, fine to very fine grained, calcareous; thin bedded in bottom 4 ft and top 6 ft, remainder medium to thick bedded; locally ripple marked; forms cliff 63

Stockade Beaver shale member:

5. Poorly exposed; scattered outcrops of greenish-gray shale; top 10 ft covered; forms slope 84
4. Claystone, light-gray to pink, silty 2
3. Claystone, pink, calcareous 1

Thickness of Stockade Beaver shale member 87

Canyon Springs sandstone member:

2. Sandstone, light yellowish-gray, fine to very fine grained, very calcareous, thin bedded with contorted laminae, locally brecciated; forms prominent overhanging ledge; contact with underlying unit sharp and irregular 8

Thickness of Sundance formation 233

Unconformity.

Spearfish formation (part):

1. Sandstone, moderate reddish-brown, fine-grained, slightly calcareous, indistinctly crossbedded, firmly cemented 9

Sundance formation on the east side of Blacktail Creek in SW¼ sec. 3, T. 53 N., R. 64 W., Crook County, Wyo. (section 9, pl. 2)

Top of hill.

Sundance formation:

Redwater shale member: *Feet*

26. Sandstone, moderate reddish-organge, fine- to medium-grained, calcareous, thin- to medium-bedded; uppermost bed of Sundance formation ..... 2+
25. Shale and sandstone, interbedded and interlaminated; shale is greenish gray; sandstone is yellowish gray and very fine grained; contains thin bed of gray limestone in lower part; poorly exposed 24
24. Limestone, medium-gray, slabby, very fossiliferous; forms ledge 1
23. Shale, greenish-gray, sandy 1
22. Sandstone, light yellowish-gray, fine-grained, very calcareous, thin-bedded, slabby; sparse glauconite; forms ledge 3
21. Shale and sandstone, interbedded and interlaminated; shale is dark greenish gray and noncalcareous; sandstone is yellowish gray, very fine grained, calcareous, glauconitic, and friable 6
20. Limestone, medium-gray, very fossiliferous; forms ledge 1
19. Shale and sandstone, interbedded and interlaminated; shale is dark greenish gray and noncalcareous; sandstone is yellowish gray, very fine grained, calcareous, and glauconitic 18
18. Limestone, medium-gray, sandy, glauconitic, fossiliferous; forms blocky ledge 1
17. Shale and sandstone, interbedded and interlaminated; shale is greenish gray and noncalcareous; sandstone is yellowish gray, very fine grained, and calcareous; contains a few gray limestone concretions 40
16. Mostly covered; grayish-green sandy soil and fragments of green shale on slope 70
15. Sandstone, light yellowish-gray, very fine grained, calcareous, medium-bedded; abundant glauconite; forms rounded ledge; contact with underlying unit is sharp 2½

Thickness (rounded) of Redwater shale member 170

Lak member:

14. Siltstone, grayish-red, calcareous; a few thin beds of grayish-red, fine-grained sandstone near top; poorly exposed 42

Hulett sandstone member:

13. Sandstone, pale-red with a few light-gray laminae, calcareous, fine-grained to silty, thin-bedded; forms slope 18

Sundance formation on the east side of Blacktail Creek in SW¼ sec. 3, T. 53 N., R. 64 W., Crook County, Wyo. (section 9, pl. 2)—Continued

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

Part of the Sundance and underlying formations northwest of Oil Creek in the SW¼ sec. 35, T. 48 N., R. 62 W., Weston County, Wyo. (section 13, pl. 2)

	Feet
Top of exposure.	
Sundance formation (part):	
Redwater shale member (part):	
16. Poorly exposed; mostly dark greenish-gray shale	5
15. Sandstone, light-gray, very fine grained, calcareous, glauconitic, friable; some interlaminated greenish-gray shale; nonresistant	20
14. Shale, greenish-gray; much interlaminated light-gray very fine grained calcareous sandstone	14
13. Sandstone, light-gray, very fine grained, calcareous, very glauconitic, nonresistant	3
Partial thickness of Redwater shale member	42
Lak member:	
12. Siltstone, sandy; and silty very fine grained sandstone; pink to pale reddish-brown in upper part, banded pink and light-gray in lower 20 ft, massive in upper part becoming crudely thin bedded at base; slightly calcareous locally; nonresistant	80
Hulett sandstone member:	
11. Sandstone, light yellowish-gray, fine to very fine grained, calcareous; ripple marked at top and base; locally cross laminated; forms massive cliff	30
10. Sandstone, light yellowish-gray, very fine grained, calcareous, cross laminated; many thin laminae of green siltstone, nonresistant	6
9. Sandstone, light yellowish-gray, very fine grained, calcareous, cross laminated; forms resistant ledge	3
8. Shale, greenish-gray; interbedded and interlaminated light-gray siltstone and very fine grained sandstone; nonresistant	6
7. Sandstone, light-gray to light yellowish-gray, fine to very fine grained, calcareous, cross-laminated; in blocky beds ½ to 1 ft thick; forms ledges	10
Thickness of Hulett sandstone member	55
Stockade Beaver shale member:	
6. Siltstone, light greenish-gray, interlaminated light-gray very fine grained sandstone; calcareous; grades into units below and above	8
5. Shale, dark-greenish-gray, noncalcareous; a few silty laminae in top 6 to 8 ft	36
Thickness of Stockade Beaver shale member	44

Part of the Sundance and underlying formations northwest of Oil Creek in the SW¼ sec. 35, T. 48 N., R. 62 W., Weston County, Wyo. (section 13, pl. 2)—Continued

	Feet
Sundance formation (part)—Continued	
Canyon Springs sandstone member:	
4. Sandstone; light greenish-gray at base grading to light yellowish-gray at top; very fine grained, calcareous, massive, friable, nonresistant	23
3. Siltstone, greenish-gray, very calcareous, thin-bedded, locally fossiliferous	6
Thickness of Canyon Springs sandstone member	29
Partial thickness of Sundance formation	250
Unconformity.	
Gypsum Spring formation:	
2. Gypsum, white, granular; makes a single massive overhanging ledge	18
Unconformity.	
Spearfish formation (part):	
1. Siltstone, dark-red, locally sandy, crudely thin-bedded; a few discontinuous seams of gypsum as much as ½ in. thick in fractures in upper 20 ft; nonresistant	50

MORRISON FORMATION

The name Morrison formation was introduced in the Black Hills by Darton (1904), who correlated beds previously known as the Beulah clays (Jenney, 1899) with the Morrison formation of Colorado (Eldridge, 1896). The formation consists of claystone, sandstone, and limestone that crops out in the east-central and southeastern parts of the mapped area. The lower part of the formation forms small areas of badlands and is well exposed at many places; talus or landslide material from sandstone cliffs of the overlying Lakota formation commonly covers the upper few feet.

The formation is generally between 80 and 120 feet thick; however, it is only about 30 feet thick near Aladdin in sec. 34, T. 54 N., R. 61 W., and it is as little as 20 feet thick locally north of the Lytle Creek dome in sec. 22, T. 53 N., R. 64 W. The Morrison is absent and the Lakota formation rests directly on the Redwater shale member of the Sundance formation in Barlow Canyon, secs. 13, 24, and 25, T. 54 N., R. 66 W., and in Barnard Canyon, sec. 6, T. 54 N., R. 65 W.

The basal bed of the Morrison formation usually consists of light-gray sandstone or greenish-gray claystone or shale that rests conformably on a bed of yellow-weathering calcareous sandstone at the top of the Sundance formation. Beds at the contact appear to represent a thin transitional zone from marine rocks below to nonmarine rocks above.

Discontinuous beds of limestone or marl, a few inches to as much as 4 feet thick, are interbedded with claystone in the lower calcareous part of the formation at all exposures, and limestone is also abundant in the claystone as small concretions or nodules as much as 4 inches in diameter. The limestone is light gray to grayish white and characteristically is very finely crystalline to sublithographic. Some limestone beds are silty or sandy. Commonly, a ledge-forming bed of sandy limestone 1 to 2 feet thick with contorted gray laminae crops out within 10 feet stratigraphically of the base of the formation.

Small nodules of barite weather out from the claystone at a few places, most commonly from the upper part of the formation.

Most of the Morrison formation is made up of greenish-gray claystone. The claystone is calcareous in the lower 40 to 60 feet of the formation and noncalcareous in the remaining upper part. At most places the contact between the two parts is sharp, although locally beds of calcareous and noncalcareous claystone may alternate through an interval of 3 or 4 feet. The calcareous claystone weathers greenish gray and grayish red, and the noncalcareous claystone weathers mostly shades of green. Where the formation is relatively thick and is overlain by thick beds of sandstone in the Lakota formation, claystone in the top 10 to 30 feet of the Morrison formation is dark gray to dark brownish gray. Claystone in the lower part of the formation is locally sandy and silty becoming less sandy and silty in the upper part. The formation is unusually silty near Sourdough Creek in T. 55 N., R. 65 W., where it consists largely of greenish-gray siltstone interbedded with a few thin lenses of sandstone.

Tank (1956, p. 871–877) in a study of the mineralogy of the claystones of the Morrison formation of the Black Hills reported that illite is the predominant clay mineral, kaolinite is abundant, and montmorillonite is rare. Bergendahl, Davis, and Izett (1961, p. 627) found that near Carlile, chlorite, illite, or montmorillonite may be the major constituent, or the three minerals may be present in about equal amounts. They reported kaolinite in minor amounts.

Beds of sandstone are present in the lower part of the formation at nearly all exposures. The sandstone is light gray to grayish white, calcareous, and friable and at most places is very fine grained to silty, although a sandstone bed near the base of the formation at the north end of the Oil Butte-Pine Ridge anticline, sec. 14, T. 52 N., R. 67 W., contains coarse grains and a few granules of brown and gray chert and locally some small pyrite cubes 1 to 3 mm across. The sandstone beds generally range from a few inches to 10 feet in thickness,

are lenticular, and at many places are ripple marked and cross laminated. A bed of friable grayish-white sandstone 35 feet thick constitutes the basal part of the Morrison locally on the west side of Salt Creek in sec. 15, T. 45 N., R. 61 W. On the divide between Oil Creek and Black Canyon in secs. 28, 29, 32, and 33, T. 47 N., R. 62 W., the Morrison formation is as much as 155 feet thick and consists entirely of clean friable well-sorted fine to very fine grained light-gray sandstone locally mottled shades of pink and yellow. Similarly, a bed of friable sandstone as much as 60 feet thick completely replaces claystone and marl in the Morrison formation near the Barlow Canyon dome in the southeastern part of T. 54 N., R. 66 W., and in sec. 19 of the township to the east. A bed of sandstone 48 feet thick makes up nearly all the Morrison formation locally farther to the north near Mona Butte in the SE¼ sec. 9, T. 56 N., R. 63 W. The sandstones at all of these places appear to grade laterally into calcareous claystone and marl more typical of the Morrison, and resemble in lithology and stratigraphic relations the Unkpapa sandstone which replaces the Morrison in large areas in the southern Black Hills (Darton, 1909, p. 37; D. E. Wolcott and G. B. Gott, 1954, oral communication).

Lenticular beds and irregular masses of gray, red, and black chert are fairly common near the top of the formation, most notably on the north side of Barnard Canyon in sec. 9, T. 54 N., R. 65 W., and near Lytle and Whitetail Creeks in T. 53 N., Rs. 64 and 65 W. Chert fragments are common, also, in the float from the upper part of the formation at several places along Inyan Kara Creek and its tributaries farther to the south. Some of the chert makes up concentrically banded nodules cemented together by silicified claystone. Commonly the chert masses are brecciated and recemented by silica.

Fossils are locally abundant in the lower calcareous part of the Morrison formation. Saurian bones weather from the lower part along Lake and Left Creeks in T. 53 N., R. 66 W., east of Inyan Kara Creek in sec. 21, T. 51 N., R. 65 W., south of Mason Creek in sec. 2, T. 48 N., R. 63 W., and at several other places in the area. Mollusks are relatively rare, although *Unio nucalis* Meek and Hayden was found in a limestone lens about 60 feet above the base of the formation in the SE¼ sec. 3, T. 49 N., R. 64 W. (loc. D1157; identified by W. A. Cobban), and W. W. Rubey collected *Unio stewardi* White and *Neritina* sp. from green and maroon claystone near the base of the formation in the NE¼ sec. 16, T. 52 N., R. 66 W. (identified by J. B. Reeside, Jr.). Sohn (1957, 1958; Sohn and Peck, 1963) reports ostracodes from the Morrison representing species of *Darwinula* Brady and Robertson, species of the "*Metacypris*" "*Gomphocythere*" group, species of *Theriosynoecum* Branson, and species of at least three undescribed genera. Charophytes collected during the present investigation from beds of marl in the lower part of the formation include *Aclistochara bransoni* Peck, *A. jonesi* Peck, *A. latisulcata* Peck, *Echinochara spinosa* Peck, *Latochara concinna* Peck, *L. latitruncata* (Peck), *Sphaerochara cf. S. verticillata* (Peck), and *Stellatochara obovata* (Peck) (identified by R. E. Peck). Sohn and Peck (1963, p. A5) also report *Praechara voluta* (Peck) and *Stellatochara arguta* Peck from the Morrison formation near Mona Butte. Fossil wood weathers out of the upper noncalcareous part of the formation at several places, and wood from the upper part of the formation in the SW¼ sec. 27, T. 51 N., R. 65 W., was tentatively identified by R. A. Scott as *Cephalotaxus* sp. (a conifer).

The fossils from the Morrison formation indicate that the age of at least the lower calcareous part is Late Jurassic (Kimmeridgian and early Portlandian stages) (Reeside, 1952; Yen, 1952; Peck, 1957, p. 8; Sohn, 1958, p. 124; Sohn and Peck, 1963).

Stratigraphic sections of the Morrison formation are given below; additional sections of part or all of the formation are given with the descriptions of the overlying Lakota and Fall River formations on pages 36–40 and are shown graphically on plate 3.

Morrison and parts of the Lakota and Sundance formations near Mona Butte in SW¼ sec. 14, T. 56 N., R. 63 W., Crook County, Wyo. (section 29, pl. 3)

Top of hill.

Lakota formation (part):	Feet
22. Sandstone, light-gray, mottled yellow, fine to very fine grained, friable; slightly carbonaceous locally; forms ledge	3
21. Shale, brownish-gray, silty, very carbonaceous	2
20. Claystone, dark-gray to brownish-gray, sandy and silty; slightly carbonaceous locally	4½
19. Sandstone, light-gray, fine to very fine grained, lenticular; forms blocky ledge	1½
18. Claystone, browish-gray, sandy to silty, lenticular	2
17. Sandstone, light-gray, fine to very fine grained; bottom 2 to 3 ft calcareous; remainder noncalcareous; crossbedded; mostly in beds less than 3 ft thick; a few carbonaceous laminae in basal part; forms ledges	11
16. Sandstone, light-gray, fine to very fine grained, calcareous, thin-bedded; contains thin seams of brown and olive-gray carbonaceous shale	3
15. Claystone, greenish-gray, noncalcareous; sandy at base	3

Morrison and parts of the Lakota and Sundance formations near Mona Butte in SW¼ sec. 14, T. 56 N., R. 63 W., Crook County, Wyo. (section 29, pl. 3)—Continued

	Feet
Lakota formation (part)—Continued	
14. Sandstone, light-gray, very fine grained; a few laminae of green sandy claystone; mostly friable and nonresistant but contains a few slabby calcareous beds locally	7
Partial thickness of Lakota formation	37
Morrison formation:	
13. Claystone, greenish-gray, noncalcareous	4
12. Claystone, greenish-gray, calcareous; a few discontinuous lenses of grayish-white clayey limestone at top of unit; limestone contains scattered pyrite cubes	2
11. Limestone, light-gray, clayey, brecciated	3½
10. Claystone, greenish-gray with grayish-red band at top; calcareous; lenses and thin beds of grayish-white clayey limestone and at top of unit thin beds of claystone containing green clay pellets; contains the following ostracodes (identified by I. G. Sohn, locs. 26921, 26922, 26456, and 26457): *Theriosynoecum wyomingense* (Branson), "*Metacypris*" sp., *Darwinula* sp., a large smooth form gen. indet., and a small smooth form gen. indet.; and the following charophytes (identified by R. E. Peck): *Stellatochara obovata* (Peck), *Latochara latitruncata* (Peck), and *Praechara voluta* (Peck)	30½
9. Sandstone, light-gray to grayish-white, very fine grained calcareous, thin-bedded, ripple-marked; laminae of green claystone in top one-half ft; forms minor ledge	3
8. Claystone, greenish-gray, slightly sandy, calcareous	3½
7. Sandstone, light-gray, very fine grained, friable	2½
6. Sandstone, light yellowish-gray, very calcareous; forms lenticular ledge	1
5. Shale, dark greenish-gray, locally weathers yellowish gray, sandy	1
4. Sandstone, light-gray, very fine grained, very calcareous; grades locally into sandy limestone; thin and irregularly bedded; forms ledge	2
Thickness of Morrison formation	53
Sundance formation (part):	
Redwater shale member (part):	
3. Sandstone, moderate-yellow, very fine grained, friable; a few partings of dark greenish-gray sandy shale	2
2. Shale, dark greenish-gray, noncalcareous; laminae of light-gray very fine grained sandstone	2

Morrison and parts of the Lakota and Sundance formations near Mona Butte in SW¼ sec. 14, T. 56 N., R. 63 W., Crook County, Wyo. (section 29, pl. 3)—Continued

	Feet
Sundance formation (part)—Continued	
Redwater shale member (part)—Continued	
1. Sandstone, light-gray, very fine grained, calcareous; partings of dark greenish-gray shale	2
Partial thickness of Sundance formation	6

Morrison and parts of the Lakota and Sundance formations on an outlying hill at the south end of Dakota Divide in the NE¼SE¼ sec. 10, T. 51 N., R. 66 W., Crook County, Wyo.

	Feet
Top of small butte.	
Lakota formation (part):	
14. Sandstone, light-gray, fine-grained, crossbedded, friable; carbonaceous fragments in lower half and a few thin carbonaceous laminae about the middle; forms rounded ledges	20
13. Sandstone, medium- to light-gray, fine-grained, silicified, slightly carbonaceous; forms blocky ledge	2
12. Sandstone, light-gray to light brownish-gray; locally mottled and streaked yellow; mostly fine grained with a few irregular streaks and lenses of medium-grained to pebbly sandstone; crossbedded; forms cliff; grades into underlying unit	19
11. Sandstone, conglomeratic, light-gray, coarser fragments mostly granules of gray chert and quartzite, crossbedded, friable; rests on underlying unit with sharp uneven contact; forms cliff	10
Partial thickness of Lakota formation	51
Local unconformity.	
Morrison formation:	
10. Claystone, dark-gray, to grayish-black, noncalcareous	7½
9. Partly covered; appears to be mostly greenish-gray noncalcareous claystone	30
8. Claystone, greenish-gray with some grayish-red bands, calcareous; contains several thin beds of dense gray clayey limestone	57
7. Sandstone, grayish-white, very fine grained, very calcareous, ripple-marked; forms slabby ledge	1
6. Claystone, greenish-gray, calcareous; thin bed of light gray clayey limestone in upper part	6½
5. Limestone, light-gray, dense, clayey	1
4. Sandstone, light-gray, very fine grained; a few partings of grayish green shale that become more numerous upward	3½
Thickness (rounded) of Morrison formation	106

Morrison and parts of the Lakota and Sundance formations on an outlying hill at the south end of Dakota Divide in the NE¼SE¼ sec. 10, T. 51 N., R. 66 W., Crook County, Wyo.—Continued

Sundance formation (part):

Redwater shale member (part):

	Feet
3. Sandstone, moderate-yellow to grayish-yellow, calcareous, fine to very fine grained, medium- to thin-bedded; ripple marked at top; lenses of light-gray oolitic chert ¼ in. thick 2 ft above base and about ½ ft below top	9
2. Sandstone, light-gray, with dark greenish-gray laminae, very fine grained, micaceous, friable, shaly at top	2½
1. Shale, greenish-gray, noncalcareous	2
Partial thickness (rounded) of Sundance formation	13

Base of exposure.

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

Lakota formation (part):

	Feet
13. Sandstone, light-gray to light yellowish-gray, mostly fine- to medium-grained with lenses of coarse-grained to granule sandstone, crossbedded, friable; forms prominent cliff	70
12. Partly covered; mostly medium-gray claystone with some thin beds of yellowish-gray fine-grained sandstone	12
11. Claystone, medium-gray, silty and sandy; some interbedded grayish-yellow fine-grained sandstone in upper half	8
10. Sandstone, light-gray, fine-grained, firmly cemented, carbonaceous, lenticular; forms blocky ledge	4½
9. Claystone and sandstone, interbedded; claystone is dark gray, carbonaceous; sandstone is medium gray, very fine grained, carbonaceous, friable	12
8. Sandstone, medium-gray, very fine grained, carbonaceous, friable; a few partings of dark-gray shale	4½
7. Shale, dark-gray, carbonaceous; a few stringers of very fine grained carbonaceous sandstone	7
Partial thickness of Lakota formation	118

Morrison formation:

6. Sandstone, light-gray, fine to very fine grained, friable, clean, massive; forms rounded ledges	25
5. Sandstone, very light grayish-green mottled pale purple, some thin dark yellowish-orange bands, fine to very fine grained, very friable, clean, indistinctly thin bedded to massive; gradational with overlying and underlying units; forms slope	15

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

Morrison formation—Continued

	Feet
4. Sandstone, very light gray mottled light orange pink and grayish yellow, fine to very fine grained, clean, massive, friable; forms cliff	37
3. Sandstone, very light greenish-gray, very fine grained, clayey	2
2. Sandstone, very light gray, weathers very light gray to very light yellowish gray, fine to very fine grained, very friable, variably calcareous; a few fragments of green claystone in lower part; rests sharply on underlying unit; forms slope	75
Thickness of Morrison formation	154

Sundance formation (part):

Redwater shale member (part):

1. Shale, dark greenish-gray, noncalcareous; interlaminated light-gray calcareous very fine grained sandstone, at the base a few thin beds of gray sandy glauconitic limestone	25

Morrison and part of the Lakota formations west of Salt Creek in the SE¼ sec. 15, T. 45 N., R. 61 W., Weston County, Wyo.

Lakota formation (part):

	Feet
10. Sandstone, light-gray, weathers light grayish yellow, fine-grained, massive, friable; forms rounded ledges at top of ridge	20
9. Covered	3
8. Siltstone, greenish-gray, friable	3
7. Sandstone, light-gray, very fine grained, carbonaceous	3
6. Siltstone, light-gray, sandy, slightly carbonaceous	3
Partial thickness of Lakota formation	32

Morrison formation:

5. Claystone, dark-gray and dark greenish-gray, in alternating bands, noncalcareous	33
4. Claystone, greenish-gray, with some grayish-red bands, calcareous, silty, thin lenses and nodules of light-gray marl	62
3. Sandstone and shale, interlaminated; sandstone is light gray, very fine grained, calcareous; shale is greenish gray; a thin bed of gray marl 3 ft below top	7
2. Sandstone, light-gray, very fine grained, calcareous, friable; top 3 ft makes slabby ledges; remainder nonresistant	35
Thickness of Morrison formation	137

Sundance formation (part):

Redwater shale member (part):

1. Sandstone, grayish-yellow, very fine grained, calcareous, friable; a few partings of green siltstone; weathers to prominent yellow band	4

CRETACEOUS SYSTEM

The Cretaceous rocks have a maximum thickness of about 6,500 feet, or somewhat more than half of the total thickness of the sedimentary rocks exposed in the mapped area. They consist chiefly of shale with lesser amounts of sandstone, bentonite, limestone, and coal. Twenty mappable units, classified as formations or members, have been recognized. Of these, the Lakota formation at the base of the sequence, and the Lance formation at the top, are nonmarine; the remaining units—with a total thickness of nearly 5,000 feet—are marine or marginal marine. Figure 4 shows the relative age of the various formations and members and their correlation in areas near the Black Hills.

LOWER CRETACEOUS SERIES

INYAN KARA GROUP

The Inyan Kara group in the northern Black Hills consists of about 200 to 400 feet of Lower Cretaceous nonmarine and marginal-marine sedimentary rocks that lie between the nonmarine Morrison formation below and the marine Skull Creek shale above. These rocks crop out in the eastern half of the mapped area from about Newcastle, Wyo., northward for about 60 miles almost to the big bend in the Belle Fourche River in northern Crook County, Wyo. (pl. 1). In general, the group forms prominent cliffs and caps broad grass- or tree-covered divides.

Darton (1904, and later papers) subdivided the post-Morrison nonmarine sequence in the northern Black Hills, in ascending order, into the Lakota sandstone, Fuson shale, and Dakota sandstone. Russell (1928, p. 136) later proposed the name Fall River formation for the Dakota sandstone as used by Darton near Hot Springs, South Dakota, at the southern end of the Black Hills, and subsequently Rubey (1931, p. 5) proposed the name Inyan Kara group to include the Lakota, Fuson, and Fall River formations. The group was named for exposures along Inyan Kara Creek in Tps. 49 to 52 N., Rs. 64 to 66 W., Crook County, Wyo. (pl. 1).

Detailed geologic mapping of the Inyan Kara group by the Geological Survey was started in 1952, and the geologists engaged in this work experienced much difficulty in separating Darton's Dakota, Fuson, and Lakota formations. To help resolve the problems of nomenclature and regional correlation, K. M. Waagé, in cooperation with the authors and with the support of the field parties in the southern Black Hills,[1] undertook a study of the Inyan Kara group in 1955. The result of this work was a redefinition of the formations of the Inyan Kara group.

[1] Henry Bell 3d, D. A. Brobst, N. P. Cuppels, G. B. Gott, E. V. Post, and R. W. Schnabel.

The Inyan Kara group was found by Waagé (1959) to consist of two principal units of contrasting lithology separated by a regional disconformity. The lower unit changes thickness within short distances and is characterized by complexly interfingering beds of conspicuously crossbedded sandstone, conglomeratic sandstone, and variegated claystone. The upper unit has a fairly uniform thickness and is characterized by relatively persistent beds of evenly bedded sandstone, siltstone, and dark-gray shale. The upper and lower units are in sharp contact, and this contact can be mapped throughout the Black Hills (Mapel and Gott, 1959). Waagé (1959) proposed that the two principal units of the Inyan Kara group should be the basis for formal subdivision. He suggested that the upper unit be termed the Fall River formation as it corresponds very closely to the type Fall River as defined by Russell (1928), and that the term Lakota formation be redefined to include all of the complex series of sandstone and claystone beds of the lower unit of the Inyan Kara group.

Correlation of sandstone, siltstone, and mudstone units within the Inyan Kara group on the west side of the Black Hills was summarized by Mapel and Gott (1959) and later modified by Post and Bell (1961). Descriptions of about 50 stratigraphic sections and the correlation of beds in the Inyan Kara group in the Bear Lodge Mountains at the north end of the Black Hills were given by Mapel and Pillmore (1963b). The mineralogy of sandstone in the Inyan Kara group was described by Mapel, Chisholm, and Bergenback (1964).

Plate 3 shows the correlation of the Fall River and Lakota formations in the northwestern Black Hills.

LAKOTA FORMATION

The Lakota formation consists of lenticular beds of sandstone, conglomeratic sandstone, claystone, and siltstone, and a few thin beds of limestone and coal locally. It has the most varied composition of any formation in the area, and the composition changes rapidly both laterally and vertically.

The formation ranges in thickness from less than 100 to nearly 300 feet. It is 165 to about 200 feet thick near Aladdin in the northeastern part of the area (pl. 1). It thickens westward to about 300 feet in incomplete exposures at several places in the Bear Lodge Mountains between Alva and Mona. Drill holes show the formation to be about 100 feet thick at Government Canyon and Bronco John Creek. Southward along the west side of the Belle Fourche River, the Lakota is slightly more than 200 feet thick at Sourdough Creek, and 150 to 190 feet thick between Sourdough Creek and the Keyhole Reservoir. It averages about 120 feet in thickness along Inyan Kara and Houston Creeks,

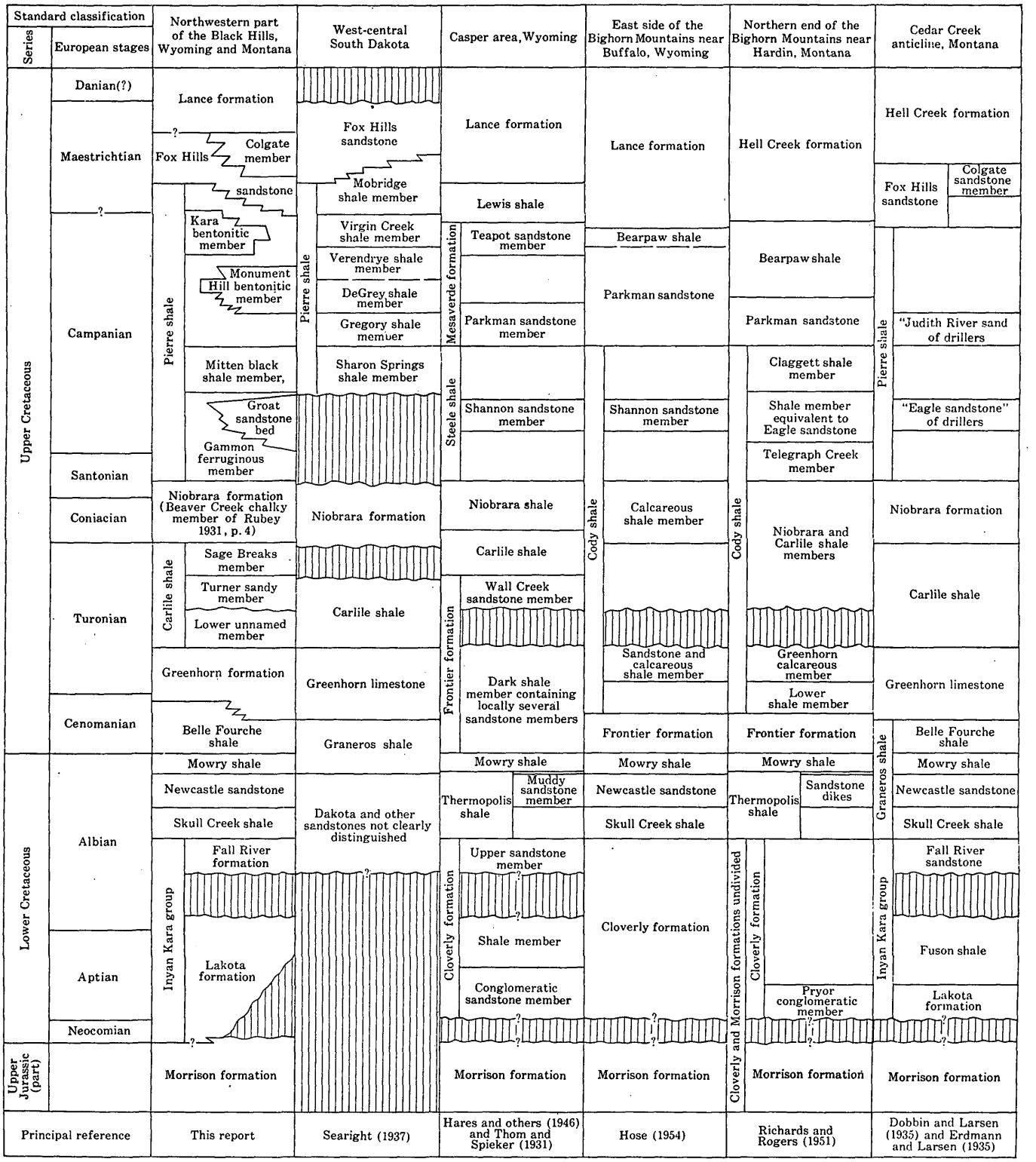


FIGURE 4.—Correlation of Cretaceous rocks in areas near the Black Hills (adapted from Cobban and Reeside, 1952, chart 10b).

thickens to about 175 feet at Mason Creek, and is between 175 and 250 feet thick at most places from Mason Creek southward to Newcastle. The Lakota thins locally to 45 feet on the west side of Oil Creek in sec. 32, T. 47 N., R. 62 W., owing to truncation by the overlying Fall River formation near the crest of a small dome (Mapel and Pillmore, 1963a).

A broad two-part subdivision of the Lakota formation can be made in the northern part of the Black Hills, corresponding in general with the Chilson and overlying Fuson members of the Lakota as these two names are used in the Black Hills farther south (Post and Bell, 1961). Stratigraphic correlations by Waagé (1959, p. 48), Post and Bell (1961, p. D178), and Mapel and Pillmore (1963b, fig. 2) indicate that the two subdivisions are about equal in thickness in the eastern part of the mapped area (pl. 1), but that rocks equivalent to the Chilson member thin westward and pinch out beneath rocks equivalent to the Fuson member west of a line that approximately bisects R. 63 W. in Crook and Weston Counties, Wyo.

Cliff-forming beds of sandstone characterize much of the Lakota formation at many places, and sandstone makes up almost all the formation locally, as along the north side of Miller Creek in sec. 2, T. 52 N., R. 65 W. and along Black Canyon in T. 47 N., R. 62 W. The sandstone beds range in thickness from a few inches to as much as 100 feet. Generally the sandstone is light gray to light yellowish gray, fine grained, well sorted, and friable. Rounded quartz grains make up most of the rock; chert grains and locally a few grains of feldspar are also generally present. Calcite cements a few of the sandstone beds in irregular patches and some beds contain calcite-cemented concretions as much as 10 feet in diameter. Calcite-cemented concretions ½ to 1 inch in diameter locally abound at the top of some sandstone beds and on weathering give the beds the appearance of being covered with marbles. Iron oxides impregnate the upper few inches of a few beds and sandstone concretions cemented with iron oxides, usually an inch or two long, are fairly abundant locally. Sandstone in the Lakota is highly silicified at places near Missouri Buttes in Tps. 53 and 54 N., R. 66 W., along Left Creek in T. 53 N., R. 66 W., and south of Whitetail Creek in T. 53 N., R. 64 W.

Many of the sandstone beds contain stringers and lenses composed of granule- and pebble-conglomerate made up mostly of rounded fragments of pink and gray quartzite, red, gray, and black chert, and gray sandstone and claystone in a matrix of fine- to coarse-grained quartz sand. At Dry Cabin Creek in sec. 16, T. 52 N., R. 66 W., the basal sandstone bed of the Lakota formation contains blocks as much as 2 feet long of calcareous claystone from the Morrison formation, and south of Barlow Canyon, in sec. 25, T. 54 N., R. 66 W., the basal sandstone bed of the Lakota formation, which here rests on the Redwater shale member of the Sundance formation, contains reworked fragments of belemnites from the Sundance. In the vicinity of Aladdin, in the northeastern part of the outcrop area and south of Corral Creek (T. 51 N., R. 65 W.) in the southeastern part, conglomeratic sandstone crops out in the upper half to two-thirds of the Lakota and beds of nonconglomeratic sandstone, siltstone, and claystone make up the remaining lower part. Elsewhere, conglomeratic layers are locally present in sandstone beds in all parts of the formation, and conglomeratic sandstone at the base of the Lakota makes massive cliffs as much as 70 feet high at places near the mouth of Inyan Kara Creek and along both sides of the Belle Fourche River valley from the Keyhole Reservoir northward to about Sourdough Creek.

The coarser grained sandstone in the Lakota generally is conspicuously crossbedded, and a few beds are ripple marked. The crossbeds occur in sets a few inches to about 3 feet thick and at places dip as steeply as 30°. Mapel and Pillmore (1962) have analyzed the directions of stream flow in the Lakota as shown by the dip directions of the crossbeds; they report a complicated local pattern of stream flow that can be resolved into a dominantly northwesterly direction of flow northwest of Inyan Kara Mountain, and a dominantly northeasterly direction of flow near Newcastle, Devils Tower, and Aladdin.

Green, red, gray, and grayish-purple noncalcareous claystone comprises most of the remainder of the Lakota formation. Most of the upper 150 feet of the formation is claystone at Sourdough Creek in sec. 12, T. 55 N., R. 65 W., and much of the lower 150 feet of the formation is claystone or sandy claystone at Deer Creek near the center of sec. 24, T. 56 N., R. 64 W., and near Devils Tower in sec. 36, T. 54 N., R. 66 W., and secs. 1, 2, and 11 of the township to the south. The formation contains fairly thick beds of claystone, also, along Inyan Kara Creek in T. 51 N., R. 65 W., at Government Canyon in T. 57 N., R. 64 W., and at many other places in the area. The claystone, in general, weathers to brighter colors than claystone in the underlying Morrison formation. Much of the claystone is silty and sandy with scattered fine to very fine rounded and frosted grains of quartz. Some beds of sandy claystone contain numerous granules and rounded polished pebbles as much as 6 inches long of red, brown, and gray chert and pink, gray, and white quartzite, the most common type being pink quartzite. Some of the chert pebbles contain fossils of Paleozoic

age. W. W. Rubey collected chert pebbles in sec 19, T. 51 N., R. 66 W., that contained *Chaetetes milleporaceus*, *Spiriferina*? sp., and numerous unidentifiable fragments of bryozoans, corals, brachiopods, and crinoid columnals (fossils identified by G. H. Girty). Henry Bell (oral communication, 1956), mapping in the southern end of the Black Hills, found chert pebbles that contained the fusulinids *Mineralla*? sp., *Nankinella plummeri* Thompson?, and *Stafella depressa*? Thompson, of Pennsylvanian age (identified by L. G. Henbest). These fossils are not diagnostic for any source area.

Commonly the topmost few inches to several feet of the formation is light-gray claystone or silty claystone, mottled shades of red and yellow, and containing numerous specks and tiny nodules of yellow or red iron oxide. This bed usually weathers to a distinctive band of red or yellow soil on steep slopes just below the top of the formation.

Light-gray siltstone that weathers to hard brittle chips comprises most of the lower half of the Lakota formation at Sourdough Creek in sec. 12, T. 55 N., R. 65 W.; and some siltstone, interbedded with claystone and sandstone, crops out at various other places in the area.

Thin beds of grayish-white argillaceous limestone crop out near the base of the formation along Inyan Kara Creek in sec. 27, T. 51 N., R. 65 W., near Houston Creek in sec. 9, T. 50 N., 64 W., and north of Left Creek in the SW¼ sec. 15, T. 53 N., R. 66 W. The bed of limestone north of Left Creek is about 5 feet thick; beds of limestone at the other places are about 1 foot thick. None of the limestone beds could be traced for more than a few hundred yards.

Coal is interbedded with claystone and sandstone at or near the base of the formation in the vicinity of Aladdin and Cambria, near the head of Houston Creek in T. 51 N., R. 64 W., and along Skull Creek in and near the southwest part of T. 48 N., R. 62 W., and beds of carbonaceous shale crop out in the lower part at many places along Skull, Oil, and Plum Creeks northwest of Cambria, along Salt Creek southeast of Cambria, and in the vicinity of Mona Butte in T. 56 N., R. 63 W. Some of the coal beds are thick and pure enough to have been mined for fuel. At some places, dark-brown or black carbonized woody fragments that range from small specks to pieces several inches long are concentrated along bedding planes or disseminated in the sandstone. Carbonaceous material seems to be most abundant in the lower part of the formation, although a lens of coaly shale 6 feet thick crops out about 130 feet above the base of the formation in sec. 19, T. 53 N., R. 64 W.; and claystone near the top of the formation is carbonaceous locally along Thorn Divide in T. 52 N., R. 66 W.

The Lakota formation is considered by most geologists to be Early Cretaceous in age on the basis of fossil ferns, cycads, and conifers that were collected from the formation in various parts of the Black Hills and identified by L. F. Ward and others (Ward, 1894, 1899). In the northern Black Hills, the formation also contains ostracodes (Sohn, 1958), charophytes (Peck, 1957), and a few remains of mollusks. The currently accepted age for the Lakota is Early Cretaceous (Aptian stage of European usage).

Sections of the Lakota formation are given on pages 28–41 and shown graphically on plate 3. Included in the sections are the fossil collections.

Morrison-Lakota Contact

The Lakota formation differs from the underlying Morrison formation mainly by having thick beds of sandstone and by having almost no calcareous claystone and limestone. The formations are easily distinguished in areas where greenish-gray and dark-brown claystone in the upper part of the Morrison are overlain by a thick cliff-forming bed of sandstone or conglomeratic sandstone. The contact at these places is an unconformity at the base of the sandstone. Elsewhere, the contact is conformable and locally obscure and must be defined arbitrarily.

In the vicinity of Cambria and Aladdin, and at other places mostly along the eastern edge of the area east of Inyan Kara Creek, dark-brown or greenish-gray claystone at the top of the Morrison formation is overlain conformably by a sequence several feet thick of interbedded sandstone, claystone, and carbonaceous shale or coal. Where carbonaceous beds are present, the contact between the Morrison and the Lakota is mapped at the base of the lowest bed of carbonaceous shale or at the base of the lowest bed of sandstone in the carbonaceous sequence.

Near the junction of Corral and Inyan Kara Creek and west of Devils Tower, ledge-forming beds of sandstone at the base of the Lakota formation appear to grade laterally into claystone or sandy claystone containing a few thin interbeds of sandstone and, locally, one or more beds of limestone or limy sandstone. No sharp lithologic break could be found between the two formations at such places, rather rocks characteristic of one formation appear to interfinger with rocks characteristic of the other through a transitional zone that locally is 50 feet thick. The contact at these places is mapped at the base of the stratigraphically lowest bed or lens of sandstone above the calcareous lower part of the Morrison.

At Sawmill Gulch in T. 54 N., R. 66 W., all of the Morrison formation and at least 100 feet of the Redwater shale member of the Sundance formation were removed prior to deposition of the Lakota formation, and a thick granule sandstone at the base of the Lakota rests unconformably on the lower part of the Redwater. The Lakota formation has a maximum thickness of about 200 feet here, which is about average for the formation nearby where all of the Morrison and Sundance formations are present. This seems to exclude the possibility of erosion of the Morrison and Sundance because of deep channeling at the base of the Lakota; rather, it indicates local uplift and erosion after most or all of the Morrison had been deposited (Izett, Pillmore, and Mapel, 1961).

FALL RIVER FORMATION

The Fall River formation is mostly 120 to 150 feet thick and averages about 135 feet in outcrops in the northern Black Hills. It is about 200 feet thick at Newcastle where sandstone in the basal part of the formation thickens locally and cuts downward into the underlying Lakota formation. The Fall River thins to about 95 feet in the subsurface near Moorcroft as indicated by cores from wells in the Donkey Creek oil field.

Interbedded light-gray to tan sandstone, gray siltstone, and dark-gray shale and carbonaceous shale make up most of the Fall River formation. Individual beds and groups of beds are fairly persistent over large areas in contrast to much more rapid lateral variations in the lithology of the underlying Lakota formation. In local areas, two or three ledge-forming units consisting mostly of sandstone with thin partings of siltstone and shale can be distinguished and mapped separately from intervening slope-forming units consisting of interbedded siltstone and shale with only minor amounts of sandstone. The lower part of the formation generally forms a grass-covered slope, except for a pair of sandstone ledges a few feet thick that crop out at many places in the basal 20 to 40 feet; the middle part typically forms cliffs at the crest of broad divides and long dip slopes; and the upper few feet is nonresistant and generally weathers back to a relatively narrow band adjacent to outcrops of the overlying Skull Creek shale.

Sandstone and siltstone make up most of the Fall River formation. The sandstone is light to yellowish gray, weathers light gray to brown, and is mostly fine to very fine grained. It is composed mostly of quartz, but contains some mica, minor amounts of feldspar, and locally a few small grains of clay. Thin seams an inch or two thick of coarse-grained to granule sandstone crop out locally about 40 feet above the base of the formation near the mouths of Mason Creek and Black Canyon and along Oil and Plum Creeks. Much of the sandstone is in beds less than an inch to about a foot thick, although thicker bedded sandstone units 30 to as much as 50 feet thick generally make massive rounded ledges in the upper half of the formation. A thick sandstone bed 70 to 90 feet above the base of the Fall River has been named the Keyhole sandstone member of the Fall River formation by Davis and Izett (1958). This bed has been traced from about the southern edge of Crook County northward along Inyan Kara Creek and the Belle Fourche River to the north end of the Black Hills at Government Canyon, and from there southeastward across Crook County to a point a few miles east of Aladdin. This bed is especially prominent in outcrops near the Keyhole Reservoir, and along the crest of the Bear Lodge Mountains. A similar sandstone bed at a slightly lower stratigraphic position makes prominent cliffs in Weston County north of Newcastle. A cliff-forming sandstone bed 50 to 70 feet thick replaces thinner bedded sandstone, siltstone, and shale at the base of the formation in the vicinity of Mona Butte (T. 56 N., Rs. 62–63 W., and T. 55 N., R. 62 W.), and in an area of several square miles north of Newcastle on the high divides that border Cambria Creek.

Sandstone in the Fall River formation is mostly friable, but at some localities a few thin beds are firmly cemented with calcite or silica. Where the sandstone beds are thick, they may contain spherical or ellipsoidal sandstone concretions as much as 5 feet in diameter cemented by calcite and silica. The upper part of some calcareous beds weather to nodules ½ to ¼ inch in diameter that are grouped in clusters and resemble popcorn balls. Resistant seams and thin layers firmly cemented by dark-brown or dark reddish-brown iron oxides are abundant in the thinner sandstone and siltstone beds, and small ferruginous concretions an inch or two in diameter are usually scattered in the thicker beds. Vertical tubelike structures that resemble worm borings extend from the top to bottom of some of the sandstone beds in the lower part of the formation, and fucoidal markings are very common on the bedding surfaces. Many of the thinner sandstone beds are ripple marked and cross laminated.

Light-to dark-gray siltstone and dark-gray silty shale are interbedded and interlaminated with the sandstone in nearly all parts of the formation. Locally as along the north side of Cabin Creek, secs. 5 and 6, T. 52 N., R. 66 W., the entire Fall River formation consists of thin silty and shaly beds with only a few beds of sandstone more than a foot thick. A bed about 5 feet thick of silty shale that weathers red to purplish red crops out near the middle of the formation along Sourdough Creek and at various other places to the

north and east, and locally makes a good marker for correlation. Near Missouri Buttes and at the head of Barnard Canyon in the central part of the area, the uppermost few feet of the Fall River formation is a sequence of interbedded silty sandstone and shale that weathers dark red to purplish red.

Carbonaceous material is common in the shale and siltstone, and locally it is abundant enough to form thin beds of shaly coal. Some of the sandstone and siltstone also contains abundant small dark-brown to black woody fragments that are concentrated along bedding planes and disseminated in the sandstone.

The contact of the Fall River formation with the underlying Lakota formation at most places is an even surface marked by a sharp change from variegated claystone or silty claystone below to laminated carbonaceous siltstone of silty shale above. The contact is believed by Waagé (1959) to mark a change in depositional environment from chiefly fluvial below to fluviomarine above. He suggested that the contact is a disconformity useful in making correlations over wide areas in the western interior.

W. W. Rubey and C. R. Longwell collected several specimens of fresh-water mollusks northeast of Osage from ferruginous beds they regarded as being doubtfully in the Fuson formation. The fossils probably were from the basal part of the Fall River formation as used in this report. They were identified by J. B. Reeside as *Unio* sp. (smooth oval form), *Unio* sp. (much elongated form with sculptured umbo), and *Viviparus*? sp. (fragment), collected on the east side of a tributary to Skull Creek in sec. 7, T. 46 N., R. 62 W. (loc. 11230); and *Corbicula*? n. sp. collected from the west side of Oil Creek in sec. 32, T. 47 N., R. 62 W. (loc. 11232). The fresh-water pelecypod *Protelliptio douglassi* (Stanton) was found in the basal 1 foot of the formation at Cabin Creek at about the center of sec. 10, T. 52 N., R. 66 W. (loc. D1148, fossil identified by W. A. Cobban).

W. W. Rubey (1931, p. 5) reported marine fossils from the upper 20 feet of the Fall River formation. These fossils were *Halymenites* (now known as *Ophiomorpha*), found a few miles east of Aladdin, Crook County, Wyo., plesiosaurian teeth found 5½ miles northeast of Upton, Weston County, Wyo., and plesiosaurian bones found in sec. 36, T. 55 N., R. 66 W. (Rubey, written communication, 1957; identification of vertebrates by C. W. Gilmore). The writers found no positively identified marine fossils in the Fall River although at Government Canyon in sec. 20, T. 57 N., R. 64 W., beds of sandstone near the middle of the formation contain casts of organisms of the same general nature as *Ophiomorpha* (identified by J. B. Reeside, Jr.).

Fossil plants from the Fall River and Lakota formations in the vicinity of Aladdin and elsewhere in the Black Hills have been described by L. F. Ward and others (Ward, 1894, 1899). T. W. Stanton and W. W. Rubey in 1924 collected the following plant fossils from the Fall River formation, which were identified by F. H. Knowlton.

Loc. R. 50–24. About 8 miles northwest of Aladdin, Wyo., near south line of sec. 13, T. 55 N., R. 62 W. on north bank of Pine Creek in beds 2 to 20 ft above creek level

Zamites borealis Heer
Athrotaxopsis grandis Fontaine
Baieropsis pluripartita Fontaine
Sequoia reichenbachi (Gein) Heer
Matonidium althausii (Dunker) Ward
Pinus susquaensis (Dawson)
Glyptostrobus brookensis Fontaine
Feistmantelia oblonga Ward

Loc. R. 51–24. Same locality as R. 50–24 from bed 12 to 15 ft higher in section

Geinitzia Jenneyi Fontaine
Proteaephyllum or *Rogersia*
Onychiopsis göpperti (Schenk) Berry
Sassafras Cretaceum Lesquereux var.?
Sapindopsis variabilis Fontaine?
Ficophyllum serratum Fontaine?
Sassafras? n. sp.

Other plant fossils collected by C. R. Longwell and W. W. Rubey in 1922 and identified by F. H. Knowlton include *Weichselia reticulata* (Stokes and Webb) Ward and *Cephalotaxopsis magnifolia* Fontaine from sec. 32, T. 47 N., R. 62 W., on the west side of Oil Creek and *Weichselia reticulata* (Stokes and Webb) Ward from the east side of Skull Creek in sec. 7, T. 46 N., R. 62 W.

Fifteen measured sections that include parts of the Fall River, Lakota, and Morrison formations follow. Most of these sections, and some additional ones, are shown graphically on plate 3.

Parts of the Fall River and Lakota formations near Aladdin in the center of the north half of the SE¼ sec. 28, T. 54 N., R. 61 W., Crook County, Wyo. (section 34, pl. 3)

[Measured by K. M. Waagé and Copeland MacClintock, 1955]

Fall River formation (part):	Feet
21. Sandstone, weathers brown to orange brown, medium-grained, massive, cross-laminated; thickens laterally to coalesce with unit 19 below	4+
20. Mostly covered by slope wash; silty light-gray shale in lower part	10.6
19. Sandstone, weathers yellow gray to orange brown, fine- to medium-grained, massive, cross-laminated	11.5
18. Sandstone, weathers light gray, local yellow to orange-brown stain, fine- to medium-grained, thin-bedded, laminated; forms shelving ledge	13.6
17. Covered slope; platy laminated sandstone in float	30

Parts of the Fall River and Lakota formations near Aladdin in the center of the north half of the SE¼ sec. 28, T. 54 N., R. 61 W., Crook County, Wyo. (section 34, pl. 3)—Continued

	Feet
Fall River formation (part)—Continued	
16. Sandstone, weathers light yellow gray to brown, fine-grained, massive, laminated to cross-laminated	3.7
15. Covered slope	6.0
14. Sandstone, weathers buff to brown, fine- to medium-grained, cross-laminated; has "worm" borings and casts and ripple marks on bedding surfaces; some vertical borings	4.0
13. Shale, gray to dark-gray, silty, carbonaceous	4.6
Partial thickness (rounded) of Fall River formation	88
Lakota formation (part):	
12. Siltstone and silty claystone, light-gray to white	.5
11. Claystone, silty, and some clayey siltstone; white, mottled yellow and orange, massive	2.0
10. Covered; slump and slope wash	44
9. Sandstone, medium-grained; channel fills of brown-weathering massive cross-laminated sandstone irregularly interbedded with friable crossbedded sandstone like unit 8	21.5
8. Sandstone, weathers gray white with pink to red stain, medium-grained, thinly crossbedded locally friable, locally silty; contains iron-impregnated layers and local lenses of thick-bedded sandstone	20.4
7. Sandstone, weathers brown, medium-grained massive, cross-laminated; some scattered sandy claystone pellets in lower part	15
6. Sandstone, fine-grained; and shaly soft siltstone with some thin iron-impregnated layers; weathers white with pink stain	5.3
5. Sandstone, weathers buff to brown with pink cast, medium-grained, massive, cross-laminated, lenticular	5.0
4. Covered; gray-white shaly siltstone in float	2.5
3. Sandstone, weathers buff to brown, medium-grained, locally conglomeratic, massive, cross-laminated; thin layers and scattered granules and pebbles of chert and quartzite; a few lenses contain siltstone and sandstone fragments and pebbles; locally has iron-impregnated upper surface	13
2. Conglomerate; mixture of large blocks and poorly rounded pieces of sandstone, hard platy siltstone, pellets of claystone, and granules and scattered polished pebbles of chert and quartzite in matrix of fine- to coarse-grained sandstone; iron-stained molds of plant fragments	.5–2.5
1. Sandstone, weathers light gray to buff with pinkish cast, medium-grained, massive, cross-laminated; basal 6.0 ft. contains molds of plant stems and oval ferruginous concretions	33.5
Partial thickness (rounded) of Lakota formation	165

Caved mine entry.

Parts of the Fall River and Lakota formations north of Wyoming State Highway 111, about 4 miles southeast of Alva, SE¼ sec. 13 and the adjacent part of sec. 24, T. 54 N., R. 63 W., Crook County, Wyo. (section 31, pl. 3)

	Feet
Top of ridge.	
Fall River formation (part):	
15. Sandstone, yellowish-gray, weathers brown, fine-grained; locally impregnated with manganese and iron oxides; forms hard slabby ledges	39
14. Covered	20
13. Sandstone, yellowish-gray, very fine grained; in beds mostly less than 1 ft thick; top surface impregnated with iron oxide; forms ledge	5
12. Covered	39±
11. Poorly exposed; some light-gray carbonaceous siltstone; nonresistant	5
Partial thickness of Fall River formation	108±
Lakota formation (part):	
10. Partly covered; mostly gray silty claystone mottled red; contains small ferruginous pellets (spherulites)	16±
9. Sandstone, light-gray to light yellowish-gray, fine-grained, friable, lenticular; forms ledge	4
8. Mostly covered; some light-gray clayey siltstone stained pink and yellow; local very small ferruginous pellets	12
7. Sandstone, yellowish-gray, mostly fine- to medium-grained, grading to granule sandstone in bottom 2 ft, friable, crossbedded, lenticular; forms ledges	14
6. Claystone, medium-gray to olive-gray, silty	25
5. Siltstone, light-gray, mottled yellow, pink, and purple, hard; breaks with conchoidal fracture; grades into unit above	13
4. Claystone, very light gray, mottled yellow, pink, and purple, sandy to very sandy; a few lenticular beds of clayey poorly sorted sandstone that locally makes ledges; a few seams of gray chert; grades into unit below	39
3. Sandstone, light-gray to light yellowish-gray, very fine to medium-grained with scattered coarser grains; polished pebbles weathering out on slope; very soft and friable, nonresistant	34
2. Sandstone, yellowish-gray, mostly medium- to coarse-grained; local lenses of very coarse grained to granule sandstone; friable; conspicuously crossbedded; forms upper part of massive cliff	28
1. Sandstone, light-gray, stained and mottled pink, fine-grained; a few reworked fragments of white siltstone about 50 ft above base; friable; crossbedded; forms lower part of massive cliff	85
Partial thickness of Lakota formation	270±

Base of exposure.

Parts of the Fall River and Lakota formations at Mona Butte in SE¼ sec. 22, T. 56 N., R. 63 W., Crook County, Wyo. (section 28, pl. 3)

[Measured by K. M. Waagé and Copeland MacClintock, 1955]

Top of butte.

Fall River formation (part):	Feet
31. Sandstone, weathers brownish orange, medium-grained, crossbedded to crosslaminated, friable	5.3
30. Sandstone, weathers variably yellow gray or orange red, medium-grained, massive; contains seams and small hollow concretions cemented with iron oxide; basal 0.1 ft is ironstone; forms ledges and cliffs	51
Partial thickness (rounded) of Fall River formation	56

Lakota formation (part):	
29. Siltstone, gray, clayey; weathers to white clayey wash; abundant ferruginous specks; sandy at base	4.7
28. Sandstone, light-gray to yellowish-gray, fine-grained, massive; upper 0.5 to 1.0 ft locally quartzitic; locally has vertical tubular ferruginous concretions	2.7
27. Sandstone, fine-grained, friable, locally clayey, scattered yellow ferruginous specks	3.2
26. Sandstone, mostly medium-grained, massive, cross-laminated; some coarse-grained sandstone lenses in lower part; forms cliff	62
25. Sandstone, coarse-grained, locally conglomeratic, friable	18
24. Sandstone as in unit 26	3
23. Conglomerate; contains granules to small pebbles mostly of gray to black chert and quartzite; some claystone	13
22. Covered by slope wash, upper foot appears to be conglomerate like unit 23 with claystone matrix	5
21. Sandstone, fine-grained, clayey, friable; some interbedded gray sandy claystone	3.5
20. Claystone, dark-gray, sandy; irregular laminae and thin lenses of fine-grained sandstone	6.5
19. Sandstone, fine-grained; irregularly interbedded and laminated with dark-gray carbonaceous friable sandy shale and claystone	5.5
18. Sandstone, weathers white, medium-grained, friable; alternates with dark-gray to black shale; beds mostly 0.4 to 1.0 ft thick	22
17. Claystone, dark-gray to black, plastic, somewhat shaly; leaf fragments at top; sandy at base	7
16. Sandstone, mostly medium-grained, clayey, massive; lower foot contains scattered coarse grains of chert	6.4
15. Claystone, light-gray, sandy; grades to unit below	4.2
14. Sandstone, medium-grained, friable; more clayey in lower part	9.2
13. Claystone, light-gray, weathers yellowish gray, sandy; locally a clayey sandstone	6
12. Sandstone, gray, medium-grained, friable; partings of shaly coal in lower 2.0 ft	10.6

Parts of the Fall River and Lakota formations at Mona Butte in SE¼ sec. 22, T. 56 N., R. 63 W., Crook County, Wyo. (section 28, pl. 3)—Continued

Lakota formation (part)—Continued	Feet
11. Sandstone, gray, brown, and black, medium- to coarse-grained; thinly interbedded with hard conglomeratic coaly sandy shale; conglomerate contains granules and small pebbles of chert, claystone, and carbonized wood	2.6
10. Sandstone, light-gray, medium- to coarse-grained, massive, cross-laminated, friable; scattered chert granules locally in lower 2.0 ft	11.2
9. Claystone, black to brown, sandy and conglomeratic, coaly; granules and small pebbles of chert, sandstone, claystone, and carbonized wood	.7
8. Claystone, gray to brownish-gray, slightly sandy; carbonaceous specks	4.6
7. Sandstone, medium-grained, friable; some interbedded sandy claystone	4.9
6. Sandstone, light-gray, medium- to coarse-grained, conglomeratic; granules and small pebbles of chert scattered throughout upper 9.0 ft; lower 2.0 ft clayey; some yellow and red stain	11
5. Claystone, gray, sandy; locally a clayey sandstone	3.7
4. Sandstone, fine- to coarse-grained; conglomeratic in lower 6.0 ft; granules and small pebbles of chert and quartzite; mostly friable but lower 2 or 3 ft locally makes resistant ledge	8
3. Chert, gray-white to yellow-gray, irregularly bedded	2.2
2. Claystone; upper half is gray, weathers purplish, lower half greenish-gray; locally sandy; lenses of slabby fine-grained sandstone at top	6
1. Sandstone, fine-grained; veinlets of gray chert	2+
Partial thickness (rounded) of Lakota formation	249

Slope wash.

Parts of the Fall River and Lakota formations on the north side of Government Canyon in the SE¼ sec. 20 and NE¼ sec. 29, T. 57 N., R. 64 W., Crook County, Wyo. (section 1, pl. 3)

[Measured by K. M. Waagé and Copeland MacClintock, 1955]

Grass-covered flat.

Fall River formation (part):	Feet
63. Partly covered; appears to be mostly very fine grained thin-bedded sandstone with thin interbeds of gray shale. Top of unit is about the top of Fall River formation	3
62. Sandstone, very fine grained, thin-bedded; numerous red-brown iron-impregnated layers and vermicular concretionary iron masses	2
61. Sandstone, very fine grained, mostly massive, friable; some zones of platy or shaly sandstone and siltstone in lower part; scattered thin iron-impregnated layers	12
60. Shale, gray, weathers brownish gray; some thin beds of siltstone; upper 2.0 ft mostly siltstone with some interbedded silty shale and fine-grained sandstone	8

Parts of the Fall River and Lakota formations on the north side of Government Canyon in the SE¼ sec. 20 and NE¼ sec. 29, T. 57 N., R. 64 W., Crook County, Wyo. (section 1, pl. 3)—Continued

Fall River formation (part)—Continued	Feet
59. Sandstone, white, very fine grained, thin-bedded; a few thin beds of gray shale	0.7
58. Ironstone, weathers purplish brown; forms concretionary ledge	.6
57. Shale, gray; interbedded and interlaminated with siltstone	3.4
56. Shale, dark-gray to black at base; grades to gray at top; contains siltstone laminae which become more numerous upward	2.9
55. Shale, light-gray, silty; unit capped by thin layer of ferruginous fine-grained sandstone with "worm" borings and casts	.7
54. Shale, dark-gray; breaks into papery fragments in upper 1.0 ft; grades downward to slickensided black slightly silty clay shale	2.6
53. Shale, gray, stained red to pink, silty; contains carbonaceous fragments	.5
52. Sandstone, weathers buff with much local red to orange stain, fine- to medium-grained, cross-laminated; upper 7 to 10 ft massive; lower part in beds 0.5 to 2 ft thick with some shaly sandstone partings; forms prominent ledge that caps nearby ridges	15
51. Siltstone, gray with pink and lavender stain, clayey, laminated; interbedded with silty clay and thin lenses of cross-laminated sandstone; some iron-impregnated layers; many "worm" borings and casts	2.2
50. Siltstone, gray, clayey; contains carbonaceous flecks; locally a silty shale	1
49. Sandstone, upper 1.1 ft white with ferruginous, brown cap, remainder is buff and brown, fine to very fine grained, friable, ripple marked, in beds as much as 1.0 ft thick, laminated and cross-laminated; some silty layers; many "worm" borings and casts; basal 1.5 to 2.0 ft iron impregnated	10.6
48. Siltstone, grayish-white, shaly; interlaminated with silty shale; scattered layers of siltstone in upper 1.4 ft; forms crumbly ledges commonly with indistinct vertical columnar structure	5.7
47. Sandstone, very fine grained, irregularly thin-bedded to laminated; some interbedded shale mostly in lower part; "worm" casts and borings on bedding planes	2.1
46. Sandstone, weathers yellowish gray, very fine grained, massive to vaguely laminated, lenticular	1.3
45. Sandstone, very fine grained; locally interlaminated with dark-gray sandy shale; contains carbonaceous flecks	.9
44. Sandstone, fine- to very fine grained, laminated to thin-bedded, cross-laminated; local partings of sandy shale; bedding irregular with some ripple marks and "worm" casts and borings on surfaces	4.5

Parts of the Fall River and Lakota formations on the north side of Government Canyon in the SE¼ sec. 20 and NE¼ sec. 29, T. 57 N., R. 64 W., Crook County, Wyo. (section 1, pl. 3)—Continued

Fall River formation (part)—Continued	Feet
43. Sandstone; basal 0.9 ft is iron impregnated and brown; remainder weathers yellowish gray; fine to very fine grained, massive	2.5
42. Sandstone, weathers light buff, fine to very fine grained, silty, locally clayey, friable, irregularly bedded; many "worm" borings and casts in iron-impregnated layers which weather brown	2
41. Siltstone, gray, weathers gray white to light gray, sandy, massive to shaly; scattered carbonaceous fragments	.8
40. Shale; gray at top, reddish purple in lower 0.3 ft, sandy	.5
39. Sandstone, very fine grained, cross-laminated, hard	.5
38. Sandstone, weathers light buff to pinkish gray, fine- to very fine-grained; "worm" borings and casts throughout	1.1
37. Sandstone, weathers buff, fine-grained, mostly massive, cross-laminated; red, iron-impregnated crust on surface has "worm" borings and casts; many slender "worm" borings extend from top to base of bed	2.0
36. Sandstone, weathers shades of brown and reddish brown in alternating bands, fine-grained, even-bedded, iron-impregnated; "worm" borings and casts on bedding surfaces	1.5
35. Siltstone, gray, stained pink to yellowish brown; interbedded with silty gray claystone; claystone predominates in basal 0.5 ft; upper 1.0 ft contains some interbedded fine-grained sandstone	3.4
34. Shale, gray to dark-gray, silty	2.8
33. Siltstone, sandy; interbedded with shaly siltstone	1.8
32. Shale, gray, silty	1.0
31. Shale, pink to reddish-purple, sandy	.5
30. Sandstone, weathers buff, fine to very fine grained, thin-bedded, laminated to cross-laminated; some interbedded sandy shale in upper 1.5 ft	7.0
29. Sandstone, weathers buff, fine to very fine grained, massive, ripple-marked, cross-laminated	1.1
28. Sandstone, fine to very fine grained; interlaminated with siltstone, scattered iron-impregnated ledges 0.1 to 0.3 ft thick	1.6
27. Siltstone, shaly, laminated to thin-bedded, locally clayey; scattered thin iron-impregnated beds with "worm" borings and casts	4.6
26. Ironstone, reddish-brown, concretionary	.3
25. Shale, gray, silty to sandy, hard	1.4
24. Sandstone, weathers light yellowish gray, fine to very fine grained; carbonaceous fragments throughout; interbedded gray clayey siltstone in lower 1.5 ft	3.2
23. Shale, dark-brown to black, coaly; locally shaly coal	.5

Parts of the Fall River and Lakota formations on the north side of Government Canyon in the SE¼ sec. 20 and NE¼ sec. 29, T. 57 N., R. 64 W., Crook County, Wyo. (section 1, pl. 3)—Continued

Fall River formation (part)—Continued	Feet
22. Siltstone, dark-gray; grades upward to dark-gray silty claystone; carbonaceous fragments throughout	0–1.3
Partial thickness (rounded) of Fall River formation	120

Lakota formation (part):

21. Siltstone, light-gray, weathers yellowish white, clayey; and hard silty claystone; contains carbonized rootlets and irregular branching ferruginous concretions	4.4
20. Sandstone, gray-white with local purplish streaks, fine-grained, argillaceous; grades into unit below	1.0
19. Claystone, gray, silty, tough, locally flinty; contains orange to red concretionary masses made up of ferruginous ooliths	3.0
18. Claystone, purple in lower part grading upward to greenish-gray mottled purple, soft, plastic	2.4
17. Claystone, light greenish-gray, locally stained orange brown and red in lower part, mottled purple in upper part, tough	3.0
16. Claystone, red to orange-red, locally mottled green and purple, tough	6.6
15. Claystone, gray mottled green, grades to brick red in upper foot, tough, silty; lower foot is clayey siltstone	3.6
14. Claystone, light-purple mottled green, tough	1.4
13. Claystone; lower 1.0 ft dark gray to gray, soft, shaly; grades upward to tough silty light greenish-gray claystone with yellow and red stain on fractures; local silty zone 2.0 to 2.5 ft above base	5.5
12. Shale, dark-gray to black, locally carbonaceous	3.5
11. Claystone, light-gray with greenish cast, tough	2.4
10. Siltstone, greenish-gray with some brown iron-impregnated masses; locally forms ledge	.5
9. Claystone; dark gray in lower 3.0 ft; grades upward to light gray; tough	5.0
8. Claystone, gray and dark-gray, soft; shaly in upper part with scattered carbonaceous fragments; weathers to tough, lumpy crust; probably bentonitic	10.6
7. Claystone, gray, soft, locally silty; lower 2.0 ft has scattered spots of red iron stain; yellowish-gray gypsum concretions weather out locally; weathers to lumpy crust; probably bentonitic	6.0
6. Claystone, weathers gray white with some streaks stained yellow, sandy; some clayey sandstone; a few scattered polished chert pebbles in float	2.2
5. Sandstone, light-gray, mostly fine- to coarse-grained, locally conglomeratic, clayey, friable, mostly massive; some yellow-weathering hard layers 1.0 to 4.0 ft below top which locally contain thin irregular layers of gray chert; rounded polished fragments from granule size to 0.7 ft in diameter of red quartzite and varicolored chert scattered sparsely throughout; thickens locally to 20 ft to the southwest	3.4

Parts of the Fall River and Lakota formations on the north side of Government Canyon in the SE¼ sec. 20 and NE¼ sec. 29, T. 57 N., R. 64 W., Crook County, Wyo. (section 1, pl. 3)—Continued

Lakota formation (part)—Continued	Feet
4. Claystone, upper part light greenish gray, lower part yellowish tan to light greenish-gray mottled red; bentonitic in upper foot	3.4
3. Claystone, red, tough; becomes purplish red and silty at base	9.0
2. Claystone, red to brownish-red, silty; grades locally to clayey siltstone; lenticular masses of white porcellanite as much as 1.0 ft long and 0.4 ft thick locally at top of unit; basal 4 ft hard clayey siltstone with scattered ferruginous (?) nodules	20
1. Claystone, silty, green	1
Partial thickness (rounded) of Lakota formation	98

Base of exposures in gully bottom.

Lakota and parts of the Fall River and Morrison formations in AEC drill hole HC-202 near the mouth of Hulett Creek in the NE¼ sec. 9, T. 55 N., R. 67 W., Crook County, Wyo. (section 25, pl. 3)

Ground surface.

Fall River formation (part):	Feet
32. No core; probably sandstone as in unit 31, below	4
31. Sandstone, light-gray to light yellowish-gray, fine-grained; a few dark-gray shale laminae	1½
30. Sandstone, light-gray, some yellowish-gray stain, fine-grained, becoming very fine grained at top; some thin layers impregnated with iron oxides. (1-ft core loss in top 2 ft)	14½
29. Sandstone, siltstone, and shale, interlaminated; sandstone is light gray, very fine grained; siltstone and shale is dark gray; very shaly in bottom 3 ft	9½
28. Siltstone, laminated light-and dark-gray; many irregular partings of dark-gray silty shale; micaceous	14
27. Sandstone, light yellowish-gray, very fine grained; a few dark-gray shale laminae in zone about ½-ft thick about ½-ft below the top	21
26. Siltstone, laminated light- and dark-gray; irregular partings of dark-gray silty shale; carbonaceous, micaceous; a few thin stringers of light-gray very fine grained sandstone in bottom 3 ft	12
25. Shale, dark-gray, very silty, micaceous, a few siltstone laminae	8½
24. Siltstone and sandstone, interlaminated; siltstone is dark gray, micaceous; sandstone is light gray, very fine grained; unit more sandy in bottom half	6
23. Sandstone, light-gray, fine grained becoming very fine grained at bottom; some contorted dark-gray shale laminae in top 2 ft	34
22. Sandstone, light-gray to brownish-gray, very fine grained to silty; some contorted dark-gray shale laminae; locally carbonaceous, micaceous; grades to sandy siltstone in basal 5 ft	11

Lakota and parts of the Fall River and Morrison formations in AEC drill hole HC-202 near the mouth of Hulett Creek in the NE¼ sec. 9, T. 55 N., R. 67 W., Crook County, Wyo. (section 25, pl. 3)—Continued

	Feet
Fall River formation (part)—Continued	
21. Siltstone, dark-gray, carbonaceous	1
Partial thickness of Fall River formation	137
Lakota formation:	
20. Claystone, light-gray, mottled red and purplish red in middle part; scattered ferruginous specks about 1/16 in. in diameter about ½ ft below top	4
19. Claystone, olive-gray, sandy	5
18. Sandstone, grayish-white, fine to very fine grained, clayey	9
17. Claystone, grayish-white to olive-gray, silty and sandy; some pyrite	6
16. Sandstone, grayish-white, mottled pink and pale green locally, very fine grained, clayey	5
15. Claystone, olive-gray (about ½ ft lost in coring)	2
14. Sandstone, light-gray, locally stained pink, fine to very fine grained; some olive-gray and green silty claystone partings	10
13. Sandstone, light-gray, fine-grained with scattered coarse to very coarse grains in bottom 4 ft, olive-gray claystone partings about 1 in. thick a foot from top and 5 ft above base	17½
12. Claystone, dark olive-gray, very sandy; grades into underlying unit	2
11. Sandstone, light to very light gray, mottled pink locally, fine- to medium-grained with a few scattered coarse grains; very clayey at top and in basal ½ ft; a few irregular blebs of pyrite	21½
10. Sandstone, olive-gray in top 5 ft grading downward to light gray, fine to very fine grained, a few olive-gray clay pellets in top 5 ft	57
9. Sandstone, light-gray to light greenish-gray, fine- to medium-grained with stringers of coarse to very coarse grained sandstone	9½
8. Sandstone, light-gray, fine to very fine grained with a few scattered medium to coarse grains; some pellets of green claystone	2½
7. Claystone, greenish-gray and grayish-red; sandy in top 1–2 ft; noncalcareous	14
6. Sandstone, light-gray, fine-grained; clay pellets in basal 2–3 in	2
5. Claystone, greenish-gray and grayish-red, slightly sandy	7
4. Sandstone, light-gray, mostly fine to very fine grained with a bed of coarse-grained sandstone about 5 ft above base; slightly carbonaceous	15
3. Claystone, dark-gray, sandy	10
2. Siltstone, gray, very clayey	10
Thickness of Lakota formation	209
Morrison formation (part):	
1. Claystone, green, noncalcareous; contains pyrite	9
End of core; total depth	355

Parts of the Fall River and Lakota formations on the north side of Sourdough Creek in sec. 12, T. 55 N., R. 65 W., Crook County, Wyo. (section 3, pl. 3)

	Feet
Top of ridge.	
Fall River formation (part):	
36. Sandstone, very light gray, fine-grained; many laminae of dark-gray shale; unit capped by slabby bed 1 ft thick of yellowish-gray sandstone	4
35. Sandstone, light yellowish-gray, fine-grained; in beds mostly ½ to 1 ft thick; cross-laminated; forms blocky ledges	12
34. Sandstone and siltstone, interbedded, light-, medium-, and dark-gray, thin-bedded, slabby; a few thin seams cemented with dark-brown iron oxides; micaceous; mostly nonresistant	12
33. Shale, dark-gray; some interlaminated siltstone; makes a gray band on cliff	1
32. Sandstone and siltstone, interbedded; sandstone is light yellowish gray, very fine grained, locally cross laminated; siltstone is light to medium gray, micaceous, laminated to cross laminated; several thin seams and nodules cemented with dark-brown iron oxides; mostly nonresistant	38
31. Mostly covered; some interbedded siltstone and shale	12
30. Sandstone, light yellowish-gray, fine to very fine grained, micaceous, cross-laminated; firmly cemented with dark-brown iron oxides at top and base; forms ledge locally	4
29. Sandstone, light yellowish-gray mottled grayish red, fine to very fine grained, friable, nonresistant	2½
28. Siltstone, dark-gray with a slight purplish tint, micaceous, shaly	3
27. Sandstone, light yellowish-gray, fine to very fine grained; in beds as much as 2 ft thick; thin seams and scattered concretions cemented with dark-brown iron oxides; forms prominent blocky ledge	12½
26. Siltstone, dark-gray, very shaly	2
25. Sandstone, light yellowish-gray, fine to very fine grained; in blocky beds as much as 2 ft thick; a few scattered concretions cemented with dark-brown iron oxides; forms prominent ledge	8
24. Sandstone, light-gray, very fine grained, micaceous, slightly carbonaceous, ripple-marked; cemented with dark-brown iron oxides at top and base; thin bedded, slabby	4
23. Siltstone, laminated light- and dark-gray, shaly, nonresistant	8
22. Sandstone, light-gray, very fine grained to silty, massive; top ½ ft cemented with dark-brown iron oxides	4
21. Siltstone, light- to dark-gray; interlaminated dark-gray silty shale; carbonaceous	3½
20. Sandstone, very light gray, very fine grained to silty, massive, carbonaceous; locally forms blocky ledge	1
19. Shale, dark-gray, silty, very carbonaceous	½
Partial thickness of Fall River formation	132

Parts of the Fall River and Lakota formations on the north side of Sourdough Creek in sec. 12, T. 55 N., R. 65 W., Crook County, Wyo. (section 3, pl. 3)—Continued

Lakota formation (part):	Feet
18. Siltstone, light- to medium-gray, weathers yellowish gray, clayey; yellow and brown ferruginous specks in middle and upper parts; a lens of light-gray very fine grained sandstone as much as 8 ft thick crops out 2 ft below top of unit locally	10
17. Sandstone, light-gray, very fine grained; a few seams cemented with dark-brown iron oxides	2
16. Sandstone, light-gray, very fine grained, slightly carbonaceous	2
15. Claystone, medium- to oliver-gray, silty; grades upward in top 4 ft to clayey siltstone	21
14. Claystone, medium-gray mottled green, red, and yellow, weathers to tough red lumpy crust	5
13. Sandstone, light-gray, very fine grained to silty, friable	1½
12. Claystone, medium-gray, slightly silty	7½
11. Claystone, black	3½
10. Claystone, medium-gray; a few thin stringers of light-gray very fine grained sandstone in upper part	12
9. Claystone; dark gray in lower part becoming grayish black in top 5 to 6 ft; weathers to tough lumpy crust	30
8. Claystone, silty, and clayey siltstone, light-gray, olive-gray, and greenish-gray; weathers to hard brittle chips; forms slope	62
7. Poorly exposed; appears to be mostly medium-gray slightly silty soft claystone mottled purplish gray and red	9
6. Siltstone, light-gray, fissile, soft	2
5. Sandstone, light-gray to grayish-yellow, fine to very fine grained, friable; some clayey seams in middle part	2½
4. Claystone; olive gray at base becoming medium gray at top; silty to slightly sandy	5½
3. Claystone, grayish-red and yellow, silty	1
2. Covered	25±
1. Sandstone, very light gray, fine to very fine grained, friable; in beds 2 to 3 ft thick; crops out in streambank	10
Partial thickness of Lakota formation	212±

Lakota formation and parts of the Fall River and Sundance formations at Sawmill Gulch in the N½ sec. 13, T. 54 N., R. 66 W., Crook County, Wyo. (section 6, pl. 3)

Fall River formation (part):	Feet
16. Sandstone, light grayish-yellow, weathers light brown, fine to very fine grained; in beds 1 to 6 in. thick; a few partings of gray siltstone in basal 1 ft; forms slabby ledges at crest of ridge	8
15. Covered; base of Fall River formation in this interval	8
Partial thickness (approximate) of Fall River formation	16

Lakota formation and parts of the Fall River and Sundance formations at Sawmill Gulch in the N½ sec. 13, T. 54 N., R. 66 W., Crook County, Wyo. (section 6, pl. 3)—Continued

Lakota formation:	Feet
14. Claystone, medium-gray mottled grayish red and purplish gray in upper part becoming grayish yellow in basal 3 ft	17
13. Sandstone, light-gray locally mottled purplish gray, fine-grained, fairly well sorted; a lenticular bed as much as 1 ft thick cemented with dark-red iron oxides at top of unit; forms ledges	12
Section following is offset about 100 yards east	
12. Covered	20
11. Claystone, medium-gray, noncalcareous, locally sandy	20
10. Covered	6
9. Sandstone, grayish-yellow, fine-grained, friable, lenticular	1–2
8. Claystone; lower part light gray mottled purplish gray and yellow, upper part moderate red; scattered fine to coarse sand grains and a few seams of poorly sorted clayey sandstone; a lens 1 ft thick consisting mostly of clay pellets and woody fragments 6 ft above base of unit nearby to east	24
Section following is offset about 150 yards southeast	
7. Sandstone, grayish-white, mottled pink, yellow, and grayish purple, mostly fine-grained to clayey; a few lenses of coarse-grained to granule sandstone in basal 6 ft, hard and blocky in basal part becoming slabby at top; forms ledges at about crest of ridge	15
6. Claystone, light- to medium-gray mottled pink and red, sandy; a few thin lenses of clayey sandstone in upper half	14
5. Sandstone, light-gray, mottled pink and orange, fine-grained, with scattered coarse grains and granules, mostly friable; grades into unit below	15
4. Sandstone, orange-brown, mottled and streaked pink and yellow, mostly fine- to medium-grained; lenticular beds as much as 4 ft thick of coarse-grained sandstone and granulite, coarser fragments mostly subrounded chert grains, but include clay pellets and sandstone fragments; conspicuously crossbedded; forms cliff	65
Thickness (approximate) of Lakota formation	210

Unconformity.

Sundance formation (part):

Redwater shale member:

3. Grass-covered slope; probably mostly shale as in unit below	15

Lakota formation and parts of the Fall River and Sundance formations at Sawmill Gulch in the N½ sec. 13, T. 54 N., R. 66 W., Crook County, Wyo. (section 6, pl. 3)—Continued

Sundance formation (part)—Continued

Redwater shale member—Continued

	Feet
2. Shale, greenish-gray with a few pale-red bands, noncalcareous, soft; abundant belemnites	15
Thickness (approximate) of Redwater shale member	30

Lak member:

1. Sandstone, light yellowish-gray to light-gray, very fine grained, calcareous, thin-bedded; forms slabby ledge	3
Partial thickness (approximate) of Sundance formation	33

Lakota, Morrison, and part of the Fall River formations at Cabin Creek in the E½ sec. 10, T. 52 N., R. 66 W., Crook County, Wyo. (section 10, pl. 3)

[Measured in part by K. M. Waagé and Copeland MacClintock, 1955]

Top of small pinnacle.

Fall River formation (part):

	Feet
43. Sandstone, yellowish-gray, very fine grained, cross-laminated, ripple-marked; in slabby beds 2 to 4 in. thick; some thin layers cemented with iron oxides	2
42. Not described in detail; mostly dark-gray silty shale in upper part; interbedded light-gray very fine grained sandstone and medium-gray siltstone in lower part	24
41. Sandstone, light-gray to light yellowish-gray, very fine grained, massive, indistinctly crossbedded; forms ledge	2
40. Sandstone, light-gray, very fine grained; in beds mostly about 1 in. thick	5
39. Poorly exposed; appears to be mostly interbedded light-gray sandstone, gray siltstone, and silty shale; thin-bedded	30
38. Sandstone, light-gray, weathers buff with orange-brown stain, fine-grained, somewhat micaceous; a single massive bed; locally has narrow vertical "worm" tubes	2
37. Sandstone and sandy siltstone, light-gray, weathers light purplish gray with yellow stain; sandstone is very fine grained, clayey, carbonaceous, nonresistant	3½
36. Siltstone and silty shale, gray, weathers rusty to yellowish gray, carbonaceous	1
35. Sandstone, light-gray, very fine grained, laminated, ferruginous	½
34. Shale, gray in upper part; grades downward to black; silty, fissile	1
33. Sandstone, light-gray, weathers grayish white with yellow stain, fine to very fine grained, locally silty, massive	3½

Lakota, Morrison, and part of the Fall River formations at Cabin Creek in the E½ sec. 10, T. 52 N., R. 66 W., Crook County, Wyo. (section 10, pl. 3)—Continued

Fall River formation (part)—Continued

	Feet
32. Sandstone, light-gray, fine to very fine grained, thin-bedded, cross-laminated; upper half contains shaly partings, seams cemented with iron oxides, and ripple marks; lower part is silty; "worm" borings and casts on bedding surfaces	7½
31. Siltstone and very fine grained sandstone interlaminated with black shale; laminae locally disrupted; "worm" borings and casts	2
30. Shale, dark-gray, silty; abundant carbonized plant fragments and local ferruginous stain; contains nonmarine pelycepod *Protelliptio douglassi* (Stanton) (loc. D1148, identified by W. A. Cobban)	2
Partial thickness of Fall River formation	86

Lakota formation:

29. Claystone, light-gray, silty, massive; a few layers of clayey siltstone; less silty in lower part; scattered ferruginous specks that weather bright orange	4½
28. Claystone, gray mottled red and yellow; scattered ferruginous specks; silty at base	2½
27. Siltstone, light-gray to white, massive; clayey at top, ferruginous specks throughout	6
26. Siltstone, gray-white, friable; local clayey lenses and scattered thin hard beds	3
25. Siltstone with interbedded fine-grained sandstone abundant in lower part; lower 1.0 ft mostly sandstone	2
24. Sandstone, weathers gray-white with yellow stain to red-brown, massive to thinly crossbedded, mostly fine- to medium-grained with local thin layers of chert- and quartz-pebble conglomerate in lower 5 to 10 ft	34
23. Covered	3
22. Partly covered; upper 5.0 ft soft gray claystone weathering to lumpy crust	10½
21. Claystone, gray, weathers light gray, slightly sandy; some scattered coarse grains of chert and quartz	4½
20. Sandstone, clayey, and sandy claystone, congolomeratic; contains coarse grains and granules of chert and quartz; some white claystone fragments in upper 0.3 ft that may be porcellanite; polished chert and quartztite pebbles in float	1
19. Claystone, light- to dark-gray, sandy; scattered chert granules; polished chert and quartz pebbles in float	2½
18. Sandstone, gray-white, medium- to coarse-grained; interstitial gray claystone and local zones of sandy conglomeratic claystone that contain chert and quartz granules and scattered polished pebbles of chert, quartz, and quartzite	12

Lakota, Morrison, and part of the Fall River formations at Cabin Creek in the E½ sec. 10, T. 52 N., R. 66 W., Crook County, Wyo. (section 10, pl. 3)—Continued

Lakota formation—Continued	Feet
17. Claystone, light-gray with greenish cast, slightly sandy; scattered sand grains and granules of chert and quartz; crystals of selenite	2½
16. Claystone, mottled red, reddish-gray, gray, and purple, sandy; scattered medium to coarse chert and quartz grains	8
15. Sandstone, gray, weathers white, fine- to medium-grained with scattered granules of chert and quartz, clayey, friable	8
14. Claystone, gray-green, sandy; scattered chert and quartz grains chiefly in upper part	4
13. Claystone, upper 3.0 ft red and green; lower 5.0 ft chiefly red; locally mottled bright green and yellow; scattered chert and quartz grains	10½
12. Claystone, red with minor green mottling, sandy; scattered chert and quartz grains	13
11. Sandstone and sandy claystone, locally conglomeratic; upper 2.0 ft chiefly sandy greenish-gray claystone, remainder mostly gray to yellowish-gray unconsolidated fine- to medium-grained sandstone with scattered granules and small pebbles of chert and quartz; basal 0.3 ft is a hard gray limy conglomeratic bed which crops out locally as ledge	15½
10. Sandstone, light-gray, fine-grained to conglomeratic; some sandy claystone in upper 2.0 ft; unit becomes coarser in lower part with scattered chert and quartz granules; basal 0.4 to 0.8 ft is hard limy coarsely conglomeratic sandstone	6½
9. Sandstone, light-gray to white, fine-grained to conglomeratic, locally calcareous; a zone of sandy to conglomeratic limestone concretions 1.0 ft from top and ledge of sandy conglomeratic limestone 0.8 to 1.0 ft thick at base; coarser fragments in conglomerate composed of granules to small pebbles of chert and quartz	3½
8. Sandstone, grayish-white with some brown stain, limy throughout with 2 or 3 zones of small hard sandy to conglomeratic limestone concretions and several conglomeratic zones including one at base as much as 3.5 ft thick which contains carbonized plant fragments	20
7. Marl, sandy, and calcareous clayey sandstone; gray and dark gray in upper part; light gray near base; a few scattered chert and quartz granules; thin bed of marl at base thickens laterally and includes lenses as much as 2 ft thick of light-gray limestone that weathers orange brown	6½
6. Sandstone, gray, weathers yellowish gray, fine-grained to clayey, calcareous; grades downward to sandy marl; at base of unit is a lenticular bed 2 ft thick of very calcareous sandstone containing scattered granules of chert and some reworked sandstone fragments	14½

Lakota, Morrison, and part of the Fall River formations at Cabin Creek in the E½ sec. 10, T. 52 N., R. 66 W., Crook County, Wyo. (section 10, pl. 3)—Continued

Lakota formation—Continued	Feet
5. Claystone, red, very sandy; a bed of light-gray sandy limestone concretions about 3 ft below top, and lenses of light-gray granule sandstone in basal part	12
Thickness of Lakota formation	210
Morrison formation:	
4. Marl; upper 40 ft chiefly red with a few green bands; lower part mostly greenish gray with some red bands, several lenses and thin beds of gray limestone, and some zones of scattered limestone nodules; ostracodes (unidentified) in limestone beds in lower part (loc. 26914)	54
3. Sandstone, light-gray, fine to very fine grained; weathers to a platy brown ledge	2½
2. Mostly covered, appears to be mostly greenish-gray and grayish-red marl	24½
Thickness of Morrison formation	81
Sundance formation (part):	
Redwater shale member (part):	
1. Sandstone yellow, very fine grained, calcareous	4
Slope wash.	

Lakota, Morrison, and part of the Fall River formations near Corral Creek in the NE¼ sec. 20 and NW¼ sec. 21, T. 51 N., R. 65 W., Crook County, Wyo. (section 13, pl. 3)

Top of hill.

Fall River formation (part):	Feet
26. Sandstone, light-gray, fine to very fine grained, friable; a few seams cemented with dark-brown iron oxides; locally ripple marked; forms rounded ledges	12
25. Sandstone, light-gray to light yellowish-gray, very fine grained, cross-laminated; in beds less than 2 in. thick; a few seams cemented with dark-brown iron oxides; forms a few slabby ledges	9
24. Siltstone, light-gray, very thin bedded; a few seams cemented with dark-brown iron oxides; grades into units above and below	24
23. Shale, dark-gray; a few laminae of dark- to medium-gray siltstone	18
Section following is offset about ¼ mile west	
22. Sandstone, light-gray to light yellowish-gray, very fine grained; ripple marked at top; slightly carbonaceous; a bed about 1 ft thick about middle of unit divides it into two prominent ledges	18
21. Sandstone, light-gray to light yellowish-gray, very fine grained to silty, thin-bedded; interlaminated dark-gray silty shale in lower part; nonresistant	7
20. Sandstone, light-gray, very fine grained, thin-bedded; a few seams cemented with dark-brown iron oxides; forms blocky ledges	3½

Lakota, Morrison, and part of the Fall River formations near Corral Creek in the NE¼ sec. 20 and NW¼ sec. 21, T. 51 N., R. 65 W., Crook County, Wyo. (section 13, pl. 3)—Con.

Fall River formation (part)—Continued	Feet
19. Shale, dark-gray, silty, carbonaceous	3½
Partial thickness of Fall River formation	95

Lakota formation:	
18. Sandstone, very light gray faintly mottled yellow and pink; basal 5 to 10 ft mostly medium to coarse grained with scattered granules and small pebbles of chert and quartzite; fine grained in upper part; friable, crossbedded, nonresistant	31
17. Claystone, greenish-gray and red; sandy in lower half	40
16. Sandstone, grayish-white, very fine grained, calcareous, friable; forms ledges locally	7
15. Claystone; dark gray in lower part grading upward to greenish-gray and red; noncalcareous in lower part becoming calcareous at top; very sandy at top	19
14. Shale, brown to olive-gray; abundant ostracodes	1
13. Limestone, light-gray to grayish-white, silty; in beds ½ to 2 ft thick alternating with beds 1 to 2½ ft thick of greenish-gray claystone; contains unidentified gastropods and charophytes and the following ostracodes (identified by I. G. Sohn, USGS locs. 24644 and 24645): *Cypridea longispina*? Peck, *C.* spp., *Darwinula* sp., "*Metacypris*" spp.; gen. undet., large smooth; and gen. undet., small, smooth	7
12. Claystone, greenish-gray with bright-green, yellowish-gray, and reddish-purple bands in lower part; sandy; locally calcareous in upper part	40
Thickness of Lakota formation	145

Morrison formation:	
11. Claystone, greenish-gray, locally silty, calcareous; a few lenses of grayish-white marl; scattered spherical to tabular limestone concretions with fibrous crystals radiating from the centers	13
10. Sandstone, light-gray, very fine grained to silty, calcareous; upper part makes few slabby ledges	6
9. Claystone, greenish-gray, calcareous, silty	2
8. Sandstone, light-gray, very fine grained to silty, friable, calcareous; a few clay pellets in bottom 2 ft	8
7. Claystone, greenish-gray, calcareous, locally silty and sandy; lens 1 ft thick of light-gray very fine grained sandstone about 18 ft above base; a few thin lenticular beds of light-gray marl; unidentified ostracodes (loc. 26912) in upper 2 ft	38

Lakota, Morrison, and part of the Fall River formations near Corral Creek in the NE¼ sec. 20 and NW¼ sec. 21, T. 51 N., R. 65 W., Crook County, Wyo. (section 13, pl. 3)—Con.

Morrison formation—Continued	Feet
6. Limestone, light-gray, clayey; forms a ledge	2
5. Claystone, greenish-gray, calcareous	3
4. Limestone, very light-gray, with contorted gray laminae, sandy; a few vugs filled with coarsely crystalline calcite; forms ledge	2
3. Claystone, greenish-gray, calcareous	1
Thickness of Morrison formation	75

Sundance formation (part):	
Redwater shale member (part):	
2. Sandstone, grayish-yellow, very fine grained, very calcareous, shaly at base; forms minor ledge	3
1. Poorly exposed; scattered outcrops of greenish-gray sandy shale	5
Partial thickness of Sundance formation	8

Lakota and Morrison formations in roadcuts and on a nearby hillside along a tributary to Little Houston Creek, sec. 9, T. 50 N., R. 64 W., Crook County, Wyo. (section 14, pl. 3)

Top of hill.

Fall River formation (part):	Feet
22. Slumped slabs of light-brown fine-grained thin-bedded sandstone	4

Lakota formation:	
21. Poorly exposed; appears to be mostly gray to olive-gray silty claystone locally mottled red; upper part contains a few limonite pellets mostly less than 1 mm in diameter	19
20. Sandstone, light-gray mottled yellow and red, fine-grained with scattered medium to very coarse grains, massive; forms slope	5
19. Sandstone, light-gray to grayish-orange with some local pink stain; mostly fine grained with pebbles, granules, and some coarse-grained sandstone in basal 6 to 8 ft; crossbedded, friable; forms rounded ledges	35±
18. Sandstone, light-gray mottled red and purple in basal 1 ft and locally stained pink in middle and upper parts, fine-grained, friable; parting ½ ft thick of gray to purplish-gray claystone about 5 ft below top	25
17. Claystone, medium-gray mottled red and yellow in top 2 to 3 ft, noncalcareous; grades into unit below	8
16. Shale, brownish-black to very dark gray, noncalcareous, locally carbonaceous	9
15. Shale, light-gray to light brownish-gray, calcareous; weathers to platy fragments; contains abundant remains of the conchostracan *Cyzicus* and the following ostracodes (identified by I. G. Sohn, loc. 25643): *Cypridea* sp., *Illiocypris*? sp., "*Bairdiocypris*" *trapezoidalis* Roth, large smooth-shelled gen. undet., and small smooth-shelled gen. undet.	4.5

Lakota and Morrison formations in roadcuts and on a nearby hillside along a tributary to Little Houston Creek, sec. 9, T. 50 N., R. 64 W., Crook County, Wyo. (section 14, pl. 3)—Con.

Lakota formation—Continued	Feet
14. Sandstone, light-gray, fine to very fine grained, calcareous; in upper part some dark-gray shale partings; forms ledges	10
Thickness of Lakota formation	115±

Section following is offset about 200 yards east

Morrison formation:	
13. Claystone, grayish-green, noncalcareous	6
12. Claystone, medium-gray to olive-gray, calcareous, silty; a layer of limonite-stained selenite 0.2 ft thick at top of unit	3.5
11. Siltstone, olive-brown, clayey, calcareous	2.5
10. Claystone, greenish-gray with some grayish-red bands, calcareous; contains some scattered light-gray limestone nodules; unidentified ostracodes (loc. 26911) 15 ft above base	28
9. Sandstone, very light gray, very fine grained, calcareous, thin-bedded, lenticular; forms slabby ledge	1
8. Claystone, greenish-gray, calcareous; unidentified ostracodes (loc. 26910) at top	8
7. Sandstone as in unit 9, above	.5
6. Claystone, greenish-gray, calcareous	9
5. Sandstone as in unit 9, above; unidentified ostracodes (loc. 26909) at top	.5
4. Claystone, greenish-gray, calcareous; contains a few nodules of light-gray limestone; unidentified ostracodes (loc. 26945) in middle of unit	3
3. Covered	2
2. Sandstone as in unit 9, above	1
Thickness of Morrison formation	65

Sundance formation (part):

Redwater shale member (part):

1. Sandstone, moderate-yellow, fine to very fine grained, very calcareous, grading locally into sandy limestone — 2

Lakota and parts of the Fall River and Morrison formations near Mason Creek in the SW¼ sec. 32, T. 49 N., R. 63 W., and NW¼ sec. 5, T. 48 N., R. 63 W., Crook and Weston Counties, Wyo. (section 16, pl. 3)

Top of hill.

Fall River formation (part):	Feet
15. Mostly covered; a few thin ledges of brown-weathering siltstone and sandstone weathering out on the slope; dark-gray carbonaceous shale in this interval nearby	7

Lakota formation:	
14. Partly covered; upper half mostly light-gray silty claystone mottled yellow and red; contains numerous ferruginous specks	14

Lakota and parts of the Fall River and Morrison formations near Mason County in the SW¼ sec. 32, T. 49 N., R. 63 W., and NW¼ sec. 5, T. 48 N., R. 63 W., Crook and Weston Counties, Wyo. (section 16, pl. 3)—Continued

Lakota formation—Continued	Feet
13. Sandstone, yellowish-gray to orange-brown, mostly fine-grained becoming medium grained in basal part, friable, crossbedded; scattered nodules cemented with dark-brown iron oxides; forms prominent rounded ledge	33
12. Claystone, grayish-white mottled yellow and grayish-purple, sandy	7
11. Mostly covered; some grayish-white siltstone and very fine grained sandstone in lower part of unit	35±

Section following is offset about 200 yards north

10. Sandstone, very light gray, fine to very fine grained, friable, inconspicuously crossbedded; forms rounded ledges and local cliffs	37
9. Covered	7
8. Sandstone, light-gray, very fine grained, friable, nonresistant	4
7. Claystone, greenish-gray and brown; some interbedded friable light-gray sandstone and a few seams of brown carbonaceous shale	7
6. Claystone, olive-gray, slightly silty	6
5. Sandstone, light-gray, very fine grained, friable, nonresistant	2
4. Covered	5±

Section following is offset about 200 yards east along graded road

3. Claystone, olive-gray to brownish-gray, slightly carbonaceous; thin beds of very light gray fine-grained carbonaceous sandstone in upper part	10
Thickness of Lakota formation	167±

Morrison formation:	
2. Claystone, greenish-gray, noncalcareous	8
1. Claystone, greenish-gray, calcareous; lenticular beds of light-gray marl that contain unidentified ostracodes and charophytes (locs. 26904 at top, 26905 at base)	12
Partial thickness of Morrison formation	20

Parts of the Fall River and Lakota formations near the mouth of Oil Creek in the SE¼ sec. 33, T. 46 N., R. 62 W., Weston County, Wyo. (section 20, pl. 3)

Top of ridge.

Fall River formation (part):	Feet
18. Sandstone, grayish-orange to grayish-yellow, fine-grained; bottom half essentially a single bed, becomes medium- to thin-bedded in upper part; crossbedded; scattered nodules cemented by iron oxide; forms cliff	50
17. Sandstone and siltstone, interbedded; sandstone is light gray, very fine grained; siltstone is medium gray	3.5
16. Siltstone; dark gray at base becoming medium gray at top; contains contorted light and dark gray laminae; a few seams cemented with iron oxide; very thin bedded, nonresistant	5.2

Parts of the Fall River and Lakota formations near the mouth of Oil Creek in the SE¼ sec. 33, T. 46 N., R. 52 W., Weston County, Wyo. (section 20, pl. 3)—Continued

Fall River formation (part)—Continued	Feet
15. Sandstone, light-gray to grayish-yellow, very fine grained; in beds mostly less than ½ ft thick becoming somewhat thicker bedded at top; cross laminated; many thin seams cemented with iron oxide; worm trails locally on bedding surfaces; forms slabby ledges	29
14. Siltstone, light- and dark-gray, laminated, thin-bedded	2.0
13. Siltstone, dark-gray, carbonaceous, massive	3.0
12. Siltstone and sandstone, interlaminated; siltstone is dark gray; sandstone is light gray, very fine grained; some thin layers cemented with iron oxide, thin bedded at base becoming massive at top, worn trails on some bedding surfaces; nonresistant	5.5
11. Shale, dark-gray, silty	.3
10. Siltstone, light- to medium-gray, carbonaceous, shaly; top 2 ft forms blocky ledge	3.8
9. Shale, dark-gray, silty, slightly carbonaceous	2.5
Partial thickness (rounded) of Fall River formation	105

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

Base of exposure.

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

Top of hill.

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

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

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

Morrison formation:	Feet
11. Claystone, dark-brown, noncalcareous, silty	8
10. Claystone, dark greenish-gray, noncalcareous	29
9. Claystone, dark greenish-gray, calcareous	17
8. Claystone, banded greenish-gray and grayish-red, calcareous; a few thin beds of light-gray marl; a zone of limonite-cemented clay nodules mostly less than ½ in. in diameter in a zone about 6 in. thick about 5 ft above base	34
7. Sandstone, light-gray, very fine grained, calcareous, thin-bedded; a few partings of greenish-gray sandy claystone in middle part; forms slabby ledges	11
6. Sandstone, light-gray, very fine grained, calcareous; many partings of greenish-gray sandy claystone and siltstone; nonresistant	9
5. Sandstone, light-gray, very fine grained, calcareous; a few partings of grayish-green sandy claystone; forms ledge	7½
4. Covered	3½
3. Sandstone, light-gray, very fine grained, calcareous, friable, irregularly thin-bedded; forms slabby ledges	12½
Thickness (rounded) of Morrison formation	131

Sundance formation (part):	
Redwater shale member (part):	
2. Sandstone, grayish-yellow and light-gray; a few pink streaks; very fine grained, calcareous, friable	4
1. Mostly covered; some greenish-gray shale interbedded with very fine grained sandstone and siltstone in scattered outcrops; fragments of light-gray sandy fossiliferous limestone weathering out on slope near base	30
Partial thickness of Sundance formation	34

Parts of the Fall River and Lakota formations along West Plum Creek in the NW¼ sec. 13, T. 46 N., R. 62 W., Weston County, Wyo.

Top of ridge.

Fall River formation (part):	Feet
17. Sandstone, light-gray, weathers brown; medium grained at base; fine grained in upper part; friable; locally faintly crossbedded; a few seams cemented with dark-brown iron oxides; forms cliff	37
16. Siltstone, very light gray with dark-gray laminae, locally cross-laminated, nonresistant	7

Parts of the Fall River and Lakota formations along West Plum Creek in the NW¼ sec. 13, T. 46 N., R. 62 W., Weston County, Wyo.—Continued

Fall River formation (part)—Continued	Feet
15. Sandstone, very light gray, weathers tan, very fine grained, with a few seams of coarse-grained sandstone at top, cross laminated; forms slabby ledges	15
14. Sandstone, light-gray, mostly fine-grained, with scattered coarse grains and a few granules, nonresistant	1
13. Sandstone, light-gray, weathers reddish brown, mostly very fine grained; seams of coarse-grained to granule sandstone at top and base, in beds mostly less than 1 in. thick; many thin seams cemented with dark-brown iron oxides; raised markings that resemble worm trails on bedding surfaces; forms slabby ledges	5½
12. Sandstone, very light gray, mostly very fine grained; a few scattered coarse grains, massive	2½
11. Mostly covered; some dark-gray shaly siltstone in middle part	11½
10. Siltstone, light yellowish-gray, a few nodules cemented with dark-brown iron oxides, forms a blocky ledge	2
9. Covered	6
8. Siltstone, dark-gray and olive gray, shaly	3
Partial thickness (rounded) of Fall River formation	90

Lakota formation (part):	
7. Sandstone, grayish-white, very fine grained, massive; forms ledge	7
6. Poorly exposed; scattered outcrops of gray and purple claystone	38
5. Sandstone, light-gray to light yellowish-gray, mostly fine- to medium-grained, with seams and lenses of coarse-grained to pebbly sandstone; clayey in upper part; crossbedded, friable; forms rounded ledges locally	85
4. Sandstone, very light gray, fine- to medium-grained, locally crossbedded, friable; forms rounded ledges	21
3. Sandstone, light-gray to brown, fine to very fine grained; bed about 1 ft thick of shaly carbonaceous sandstone about 12 ft above base; forms blocky ledges	18
2. Sandstone, light-gray to brown, very fine grained, shaly, carbonaceous	2
1. Sandstone, very light gray, locally stained yellow-brown, fine to very fine grained; mostly in thick tabular beds; locally inconspicuously crossbedded; friable; forms ledges and cliffs	40
Partial thickness of Lakota formation	211

Base of exposure.

Fall River and part of the Lakota formations at Newcastle in the SE¼ sec. 20, T. 45 N., R. 61 W., Weston County, Wyo. (section 22, pl. 3)

Section begins in railroad cut near mouth of Cambria Creek.

	Feet
Skull Creek shale (part):	
25. Shale, black, very fissile, soft, noncalcareous	15
Fall River formation:	
24. Sandstone, yellowish-gray, fine to very fine grained, thin-bedded; cemented in top 6 in. by dark reddish-brown iron oxides; cross-laminated; some interlaminated grayish-black shale; forms ledge	9
23. Shale, grayish-black, soft; interlaminated ferruginous yellowish-gray very fine grained sandstone; becomes sandier at base	6
22. Sandstone, interlaminated with siltstone and shale; sandstone is light gray, very fine grained, cross laminated, in irregular beds mostly about 2 in. thick but including beds 2 ft thick 2 ft below top and about 6 ft above the base; several thin seams cemented with iron oxides; worm trails on some of 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 with siltstone and shale as in unit 22; becomes more shaly at base	6½
19. Coal, shaly	½
Section following is offset about 100 yards northwest to top of ridge on west side of Cambria Creek	
18. Sandstone, light-gray, some red stain, fine to very 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 ½ in. 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
15. Sandstone, light-gray, very fine grained; wavy dark-gray micaceous siltstone partings; cross laminated; a few thin concretionary seams cemented with iron oxides; in beds mostly 1 to 2 in. thick; gradational with underlying unit	16
14. Siltstone, laminated dark- and light-gray, shaly; in paper-thin beds with a few thin lenses and partings as much as 4 in. thick of light-gray very fine grained cross-laminated sandstone	11
Section following is offset about 200 feet northward along ridge	
13. Sandstone, light-gray, weathers light yellowish-brown, very fine grained; in beds mostly less than 1 in. thick; dark-gray siltstone and silty shale partings and laminae; cross laminated; some layers and seams cemented by iron oxides; ripple marked; forms thin slabby ledges	16

Fall River and part of the Lakota formations at Newcastle in the SE¼ sec. 20, T. 45 N., R. 61 W., Weston County, Wyo. (section 22, pl. 3)—Continued

	Feet
Fall River formation—Continued	
12. Sandstone, light grayish-yellow, fine-grained; in beds about 1 ft thick; forms 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 bottom 6 in. and top 18 in.; lenticular	3
9. Sandstone, light-gray with medium- to dark-gray laminae, fine to very fine grained, very carbonaceous, friable; in irregular thin beds	5
8. Sandstone, light-gray to light grayish-yellow; mostly medium grained at base becoming fine to very fine grained in upper part; some scattered coarse grains in basal 5 ft; friable; in tabular beds mostly 2 to 6 ft thick; locally cross laminated with cross laminae inclined mostly to the north; forms cliff in stream bank on west side of canyon	65
Thickness of Fall River formation	200
Section following is offset to east side of canyon	
Lakota formation (part):	
7. Covered	20±
6. Sandstone, light-gray to light greenish-gray, very fine grained to clayey, friable, nonresistant	5
5. Claystone; gray at base; mottled red and green in upper part, sandy	7
4. Sandstone, light-gray, very fine grained, thin-bedded; grades upward to gray siltstone in top 2 ft; upper part nonresistant; 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 locally; grades into unit below	14
1. Sandstone, light-gray to light yellowish-gray, fine grained; beds mostly 2 to 4 ft thick; cross laminated, friable; a few thin partings of gray sandy shale; forms cliff in stream bank	30
Partial thickness of Lakota formation	87±

Base of exposure.

SKULL CREEK SHALE

The Skull Creek shale was named by Collier (1922, p. 79) for exposures along Skull Creek southeast of Osage, Weston County, Wyo. The formation, in general, is exposed in scattered outcrops on low rolling hills, which are mostly covered by dark-gray to black gumbo soil, and sparse grass and sage brush. Locally, however, as in the vicinity of New Haven (T. 55 N., R. 67 W.), the Skull Creek shale forms badlands on the sides of step hills capped by resistant beds of the overlying Newcastle sandstone.

The formation is about 200 feet thick in the vicinity of Osage and Newcastle, as shown by the logs of numerous oil wells. It thickens to about 260 feet at the Oil Butte-Pine Ridge anticline a few miles north of Moorcroft, and it is between 240 and 270 feet thick at the northern end of the Black Hills. Local variations in thickness may be due to the interfingering of beds at the top of the Skull Creek shale with the over-overlying Newcastle sandstone.

The Skull Creek shale consists of dark-gray to black soft flaky noncalcareous shale, a few interbeds of sandstone or siltstone, mostly near the top and base, and numerous siderite and limestone concretions. The sandstone is fine grained, silty and clayey, and occurs in beds that in general range from less than 1 inch to 1 foot thick, although locally some lenses of sandstone are as much as 4 feet thick. Most commonly, the sandstone occurs as thin seams and partings in the shale. One or more beds of bentonite, 1 inch to 2 feet thick, are usually present 5 to 15 feet above the base of the formation.

Ferruginous siltstone and siderite concretions that weather red to purplish black are abundant in the lower third of the formation and are present, but are less numerous, in the middle and upper parts. They are tabular to spheroidal and range from less than 1 inch to 4 feet in maximum dimension. Many of the siltstone and sandstone beds contain numerous ferruginous concretions particularly at the base of the formation, and these beds on weathering locally give a reddish color to the soil.

Dark-gray limestone concretions that weather light gray or yellowish brown, and yellow-weathering limestone cone-in-cone concretions are locally abundant in the upper part of the formation. Many of the limestone concretions are septarian with veins of light-yellow to yellowish-brown calcite, and, rarely, gray barite.

Sandstone dikes occur near the top of the Skull Creek shale at several places in the mapped area but most notably north of Upton in the southeast part of T. 49 N., R. 65 W. Here, the formation is nearly flat lying, and the upper part is exposed over a wide area. The dikes strike in various directions and dip steeply. Some may be followed for several hundred yards. The dikes appear to pinch out with depth, usually within 30 to 50 feet of the top of the formation; some extend upward a few feet into the overlying Newcastle sandstone. The dikes consist of fine-grained light-gray silicified sandstone, and most of them are a foot or less thick.

The contact of the Skull Creek shale with the underlying Fall River formation is gradational. It is arbitrarily placed at the base of beds that are predominantly dark-gray to black shale. Beds in the Fall River formation below this horizon may be shaly, but the shale is mostly medium gray or brownish gray and sandy and contains numerous interbeds of brownish-gray micaceous fine-grained standstone. The upper inch or so of the Fall River formation is commonly sandstone cemented by iron oxides.

Specimens of *Inoceramus bellvuensis* Reeside were collected by W. W. Rubey and C. R. Longwell from near the middle of the Skull Creek shale at about the center of sec. 33, T. 50 N., R. 65 W. (loc. 11335), and from the upper part of the formation in the north half of sec. 15, T. 47 N., R. 64 W. (loc. 11229). Rubey and Longwell also found *Lingula* n. sp., *Modiolus* n. sp., and undetermined fish teeth and bones in thin sandy beds 75 and about 150 feet above the base of the formation in sec. 28, T. 50 N., R. 65 W. (locs. 12051 and 12061). These fossils were identified by J. B. Reeside, Jr. Crowley (1951, p. 83–85) reported abundant Foraminifera in the Skull Creek shale from the vicinity of the Black Hills including the genera: *Verneuilina*, *Ammobaculites*, *Ammobaculoides*, *Haplophragmoides*, *Ammomarginulina?*, *Haplositche*, *Spiroplectammina*, *Texturlaria*, *Quinqueloculina*, *Robulus*, *Rzebakina*, and *Cornuspira*. Skolnick (1958a, p. 275–285; 1958b, p. 787–815) and Eicher (1958) also reported Foraminifera from the Skull Creek in the northern Black Hills. Vertebrae and phalanges of an undetermined plesiosaur were found within a few feet of the base of the formation near Government Canyon in the SW¼ sec. 6, T. 56 N., R. 64 W. and near the Keyhole Reservoir in the NE¼ sec. 35, T. 51 N., R. 66 W., Crook County, Wyo.

The following sections illustrate the lithology and thickness of the Skull Creek shale on the northern flank of the Black Hills uplift.

Skull Creek shale along the Belle Fourche River in the southern part of sec. 36, T. 57 N., R. 63 W., Crook County, Wyo.

[After Knechtel and Patterson, 1962, p. 909]

Newcastle sandstone.

Skull Creek shale:	*Feet*
1. Poorly exposed; mostly shale, dark-gray, soft, fissile; contains a few dark-colored clayey ironstone concretions and some calcareous cone-in-cone concretions as much as 1½ ft in maximum dimension	70
2. Shale, dark-gray, soft, fissile; a zone of clayey ironstone concretions at top; concretions weather dark-brown, are veined with white calcite, and are as much as 1½ ft in maximum dimension	70
3. Shale, dark-gray, soft, fissile; a zone of clayey ironstone concretions at top; concretions are gray, weather very dark brown, and are as much as 2 ft in maximum dimension	88

Skull Creek along the Belle Fourche River in the southern part of sec. 36, T. 57 N., R. 63 W., Crook County, Wyo.—Con.

Skull Creek shale—Continued	Feet
4. Poorly exposed; mostly shale, dark-gray, soft; contains dark-brown concretions and some sandy zones	28
Thickness of Skull Creek shale	256

Fall River sandstone.

Skull Creek shale and part of the Newcastle sandstone east of Hulett Creek in the SW¼ sec. 7 and the SE¼ sec. 3, T. 55 N., R. 67 W., Crook County, Wyo.

Top of hill.

Newcastle sandstone (part):	Feet
27. Sandstone, light brownish-gray, weathers light brown, fine to very fine grained, micaceous, calcareous; in beds less than 1 in. thick; gradational with underlying unit	0.5
26. Sandstone, light yellowish-brown, very fine grained, micaceous; lower part contains some carbonaceous material; streaked with yellow iron stain; massive; parallel laminated with laminae about 0.1 in. thick; vertical joints strike N. 60° E. and N. 25° W.; gradational with underlying unit; forms cliff	12.3
25. Sandstone, light-gray, silty, sparsely carbonaceous, parallel- and cross-laminated, ripple-marked; gradational with underlying unit	1.9
24. Siltstone, medium-gray, weathers light gray; locally shaly and sandy; gradational with underlying unit; nonresistant	8.4
23. Sandstone and shale; sandstone comprises about 60 percent of unit and is yellowish brown, very fine grained to silty, micaceous, in beds as much as 2 in. thick; shale is dark brownish gray to black, silty; about 1 ft above base is a bed as much as 3 in. thick of calcareous sandstone which is mostly fine to medium grained with black phosphatic grains and pebbles as much as 2 in. diameter; gradational with underlying unit; nonresistant	9.6
Partial thickness (rounded) of Newcastle sandstone	33

Skull Creek shale:	
22. Shale, dark-gray to black and dark brownish-gray, weathers medium gray, silty; iron stained on bedding surfaces; contains elliptical dark-gray siderite-cemented siltstone concretions as much as 3 in. in maximum dimension that weather rusty brown, and yellow aragonite cone-in-cone concretions surrounded by layers of siderite-cemented siltstone as much as 5 in. thick; concretions are in beds less than 1 to 5 ft apart stratigraphically; shale adjacent to concretions is silty; gradational with underlying unit; nonresistant	26.2
21. Shale, dark brownish-gray to black, weathers medium gray; some iron-stained silty laminae; gradational with underlying unit; nonresistant	16.6

Skull Creek shale and part of the Newcastle sandstone east of Hulett Creek in the SW¼ sec. 2 and the SE¼ sec. 3, T. 55 N., R. 67 W., Crook County, Wyo.—Continued

Skull Creek shale—Continued	Feet
20. Siltstone, grayish-brown and brownish-gray, weathers light-brown; interbedded dark-gray shale at base; sandy in upper half; contains siderite-cemented siltstone and cone-in-cone concretions similar to those in unit 22 above; gradational with underlying unit; nonresistant	3.4
19. Shale, dark-gray to black, weathers medium gray; bed 1 to 2 ft thick of laminated silty shale and gray siltstone near middle; gradational with underlying unit; nonresistant	16.7
18. Shale, similar to unit 22	37.7
17. Partly covered; appears to be mostly dark-gray to black shale with siderite-cemented siltstone and cone-in-cone concretions	25.0
Section following is offset about 1,000 feet northwest	
16. Shale, similar to unit 22	14.8
15. Shale, black to very dark gray, weathers dark gray, mostly nonsilty; rare siderite-cemented siltstone concretions; bed 1 to 3 in. thick of light-gray siltstone about 33 ft above base; gradational with underlying unit; nonresistant	48.9
14. Shale, dark-gray to black and dark brownish-gray, weathers medium gray; a few siderite-cemented concretions; at top of unit a bed 1 to 4 in. thick of light-gray siltstone; sharp contact with underlying unit; nonresistant	7.1
Section following is offset about 1,500 feet southwest to SE¼ sec. 3	
13. Shale and siltstone, gray and brownish-gray, weathers light brownish-gray; siltstone in beds less than ¼ in. thick and comprises about 40 percent of unit; gradational with underlying unit; nonresistant	2.5
12. Shale, dark brownish-gray to black, weathers dark gray, slightly silty; gradational with underlying unit; nonresistant	4.9
11. Shale and siltstone, dark-gray and dark brownish-gray; siltstone comprises about 40 percent of unit and is in beds ¼ to 1 in. thick; gradational with underlying unit; nonresistant	1.9
10. Shale, black and dark brownish-gray; moderately silty in lower part becoming less silty at top; gradational with underlying unit; nonresistant	9.5
9. Shale, dark-brown, weathers light brown, silty; some ferruginous siltstone seams less than ¼ in. thick, abundant siltstone concretions 1 to 2 ft long and 4 to 8 in. thick; gradational with underlying unit; nonresistant	2.6
8. Shale, dark-brown and black, weathers brownish gray; slightly silty in the lower part; gradational with underlying unit; nonresistant	7.1
7. Shale, dark-brown, silty; interbedded siltstone in beds as much as ½ in. thick comprises at least 30 percent of unit; gradational with underlying unit; nonresistant	1.1

Skull Creek shale and part of the Newcastle sandstone east of Hulett Creek in the SW¼ sec. 2 and the SE¼ sec. 3, T. 55 N., R. 67 W., Crook County, Wyo.—Continued

	Feet
Skull Creek shale—Continued	
6. Shale, dark-gray to black, moderately silty; gradational with underlying unit; nonresistant	2.2
5. Shale, brownish-gray and dark-gray; contains siderite-cemented siltstone concretions 1 to 2 ft in diameter and 4 to 8 in. thick; gradational with underlying unit; nonresistant	1.8
4. Shale, dark-gray to black, weathers medium gray, slightly silty; gradational with underlying unit, nonresistant	2.6
3. Shale, dark-gray and dark brownish-gray, weathers brownish gray, silty; lenses ¼ to 1 in. thick of ferruginous siltstone; gradational with underlying unit; nonresistant	2.1
2. Shale, black to dark-gray, weathers dark gray, slightly silty; swells on weathering (bentonitic?); gradational with underlying unit; nonresistant	5.9
Thickness (rounded) of Skull Creek shale	241
Fall River formation (part):	
1. Sandstone, siltstone, and shale, interbedded, light- and dark-gray, in beds mostly less than ½ in. thick	2

Skull Creek shale and parts of the Newcastle sandstone and Fall River formation of Oil Butte in the NW¼ sec. 35, T. 52 N., R. 67 W., Crook County, Wyo.

	Feet
Top of hill.	
Newcastle sandstone (part):	
16. Sandstone, very light gray, fine to very fine grained, well-sorted, calcareous, thin-bedded; lower part friable and nonresistant; upper part forms hard slabby ledges	6
15. Covered	13
14. Sandstone, very light gray, fine to very fine grained, shaly, very thin bedded	2
13. Shale, dark-gray, slightly carbonaceous; a bed 3 in. thick of yellowish-gray bentonite near base	4
12. Shale, medium-gray, very soft and plastic	1½
11. Bentonite, yellowish-gray to light-gray	2
10. Shale, dark-brown to black, carbonaceous	3½
9. Sandstone, very light gray, fine to very fine grained, calcareous, medium-bedded, carbonaceous; forms slabby ledges locally	9
Partial thickness of Newcastle sandstone	41
Skull Creek shale:	
8. Covered	9
7. Partly covered; grayish-black shale in scattered exposures; a few yellow-weathering cone-in-cone limestone concretions in upper part	147
6. Shale, grayish-black; scattered grayish-black siderite concretions that weather dark red; concretions locally contain veinlets of light-gray barite	38

Skull Creek shale and parts of the Newcastle sandstone and Fall River formation of Oil Butte in the NW¼ sec. 35, T. 52 N., R. 67 W., Crook County, Wyo.—Continued

	Feet
Skull Creek shale—Continued	
5. Partly covered; grayish-black shale in scattered exposures	45
4. Shale, grayish-black; thin irregular laminae of light olive-gray siltstone in upper part and silty grayish-red limestone concretions near top; yellowish-gray bentonite 1 in. thick 7 ft above base	14
3. Shale; grayish black in lower part, dark purplish red in upper part; a bed about 6 in. thick of grayish-red calcareous siltstone near top	6
Thickness of Skull Creek shale	259
Fall River formation (part):	
2. Sandstone, very light gray, fine to very fine grained; many partings of dark-gray siltstone; thin bedded	1½
1. Sandstone, very light gray, weathers light yellowish gray, fine-grained, well-sorted, ripple-marked; forms dip slope	5
Partial thickness (rounded) of Fall River formation	6

NEWCASTLE SANDSTONE

The Newcastle sandstone, named by Hancock (1920b, p. 40) for exposures near Newcastle, Weston County, Wyo., is a varied unit consisting for the most part of lenticular beds of sandstone and shale, with lesser amounts of siltstone, carbonaceous shale, coal, and bentonite. The formation crops out in a prominent hogback from Newcastle northward to Hulett Creek in T. 55 N., R. 67 W. North of Hulett Creek, it forms gentle dip slopes or caps nearly level divides and isolated buttes. Most of the formation is fairly well exposed except for the topmost few feet, which commonly weathers back on dip slopes.

The Newcastle sandstone because of its importance as a source of oil has received more study than most other formations in the mapped area. Among the more comprehensive published reports are those of Summerford, Schieck, and Hiestand (1950) on the sedimentary facies of the Newcastle sandstone, Crowley (1951) on the possible origin of the Newcastle sandstone, Grace (1952) on the correlation of units and environment of deposition of the Newcastle sandstone in the Black Hills, Skolnick (1958a, 1958b) on the Foraminifera and stratigraphy of the Newcastle sandstone and Skull Creek shale, and Baker (1962) on the stratigraphy of the formation near Newcastle in Weston County.

The Newcastle sandstone at most places is between 20 and 60 feet thick. It is nearly 100 feet thick near Newcastle in NW¼ sec. 28, T. 45 N., R. 61 W. (Dobbin and

Horn, 1949), and it is apparently absent on the flanks of the Colony anticline in T. 57 N., R. 61 W. Variations in the thickness and lithology of the Newcastle sandstone are shown on plate 4.

The formation is characterized by light-gray to yellowish-gray fine- to medium-grained massive to thin-bedded locally crossbedded sandstone that usually forms slabby ledges. Some beds are micaceous, arkosic, or carbonaceous. Much of the sandstone is calcareous, and locally some is silicified. Most of the sandstone beds range from about 1 inch to about 15 feet thick, although a bed 28 feet thick has been reported in the subsurface (Summerford and others, 1950, p. 1862).

Siltstone occurs as thin-bedded, shaly, usually carbonaceous beds, which range in thickness from a few inches to as much as 5 feet.

Shale in the Newcastle sandstone is light to dark gray, brown, or black. The beds are usually 2 to 3 feet thick, although locally they may be as much as 10 feet thick. Much of the shale is bentonitic and some is sandy and silty. Beds of brown and black carbonaceous shale that locally contain thin stringers and lenticular beds of coal are fairly common.

The formation contains several beds of bentonite. Knechtel and Patterson (1955; 1962, p. 965) reported that in the upper part of the formation a bed of bentonite, at most places 3 to 5 feet thick, crops out intermittently for about 30 miles in northern Crook County, Wyo. This bed is 30 feet thick in an auger hole in sec 6, T. 56 N., R. 62 W. (Knechtel and Patterson, 1962, p. 966). A bed of bentonite near the top of the formation is 1 to 7 feet thick in an area of several square miles in the Upton-Newcastle region, and another bentonite bed near the middle of the formation is nearly 4 feet thick on the west side of the Oil Butte-Pine Ridge anticline in sec. 2, T. 51 N., R. 67 W., Crook County, Wyo.

The contact of the Newcastle sandstone with the underlying Skull Creek shale is gradational through an interval of a few inches to about 25 feet in which fine-grained sandstone, siltstone, and sandy and silty shale are interbedded. At the base of the Newcastle sandstone along the Little Missouri River in Tps. 55, 56, and 57 N. are phosphatic nodules that range from very fine grains to pebbles an inch or two in diameter. An analysis of nodules from NW¼ sec. 26, T. 56 N., R. 67 W., shows 30.2 percent P_2O_5 (D. L. Ferguson, analyst). Similar nodules, which occur at the contact of the Mowry and Skull Creek shales on the flanks of the Colony anticline, where the Newcastle is absent, contain 28.5 percent P_2O_5 (W. W. Rubey, collector; J. G. Fairchild, anayst).

Where the Newcastle sandstone is absent, the Mowry shale rests directly on the Skull Creek shale, and the interval normally occupied by the Newcastle sandstone is represented by thin beds of sandy or silty shale or by silty or sandy siderite concretions and phosphatic nodules.

Fossils are relatively scarce in the Newcastle sandstone. Collier (1922, p. 82) reported finding a fragment of the femur of a dinosaur in the formation near Osage. Most of the other fossils reported suggest a marine or brackish-water environment. Mollusks collected by W. W. Rubey from the top of the formation in the SE¼ sec. 22, T. 52 N., R. 67 W. (loc. 12072) were identified by J. B. Reeside as a pelecypod fragment resembling *Corbula subtrigonalis* Meek and Hayden, and a gastropod fragment resembling *Viviparus* sp. Rubey also found numerous poorly preserved marine pelecypods in the lower 15 feet of the formation in the SE¼ sec. 34, T. 55 N., R. 67 W. (loc. 12728) which Reeside referred doubtfully to the genera *Protocardia*, *Thracia*, *Tellina*, and *Mactra*. The fossils at this locality are accompanied by *Halymenites major* Lesquereux and the remains of a conifer. Crowley (1951, p. 85) noted that some of the shale beds contain an abundant microfauna similar to that which occurs in the Skull Creek shale and Skolnick (1958a, p. 275–285) identified several genera of Foraminifera from the Newcastle sandstone. Plant fossils obtained by W. W. Rubey and H. W. Hoots were identified by E. W. Berry and included fragments of dicotyledons, twigs of *Geinitzia* (probably *Geinitzia formosa* Heer), a cyclic conifer *Thuja cretacea* (Heer) Newberry, and Atane, Raritan, and Magothy species from 2½ miles east of Newcastle, Wyoming (loc. 7907); and *Sequoia* twigs, *Cycadolepis* n. sp., *Alismacites* n. sp., and *Salix flexuosa* Newberry from near the junction of Hulett Creek and the Little Missouri River (loc. 7908).

Many geologists (Collier, 1922; Summerford, Schieck, and Hiestand, 1950; Grace, 1952, Skolnick, 1958b) who have studied the Newcastle sandstone concluded that it was deposited in a shallow marine or marginal marine environment. Baker (1962), on the other hand, viewed the Newcastle as a nonmarine deposit. Opinions also differ about the source of the sediment. Summerford, Schieck, and Hiestand (1950, p. 1864) stated that the Newcastle was derived from some remote source; Crowley (1951, p. 83–90) concluded, on the basis of spectrographic analysis of gold for minor elements, that the sediments were derived from the nearby Black Hills; and Grace (1952, p. 22) and Skolnick (1958b, p. 799) concluded that the carbonaceous material was probably derived from a low island in the area of the present Black Hills, but that there was no definite evidence favoring a nearby source for the other sediments. Heavy-mineral studies by W. A. Chisholm

(oral communication, 1957; Mapel, Chisholm, and Bergenback, 1964) indicated that the nonopaque heavy-mineral assemblage of the Newcastle sandstone is similar to that of the Fall River and typical of sediments that have gone through several cycles of erosion. The assemblage does not resemble that found along present-day streams draining the central core of the Black Hills in the Custer-Hill City area or that of Oligocene rocks clearly derived from the Black Hills.

Graphic sections given on plate 4 and the descriptions that follow show variations in thickness and lithology of the Newcastle at 11 places in the northern part of the Black Hills uplift. Partial sections of the Newcastle sandstone are given, also on pages 43–44, and some additional sections are given by Grace (1952, p. 25–44) and Baker (1962).

Newcastle sandstone in sec. 2, T. 54 N., R. 61 W., Crook County, Wyo. (section 1, pl. 4)

	Feet
Mowry shale (part):	
4. Shale, dark-gray to black, weathers light gray, brittle, siliceous	4
Newcastle sandstone:	
3. Sandstone, light-gray very fine grained; irregular lenses of gray claystone	1
2. Shale, dark-gray to black, silty; phosphatic nodules in middle and at base	8
Thickness of Newcastle sandstone	9
Skull Creek shale (part):	
1. Shale, dark-gray to black	12

Newcastle sandstone in the NE¼ sec. 25, T. 57 N., R. 83 W., Crook County, Wyo. (section 2, pl. 4)

[After Knechtel and Patterson, 1962, p. 10–11]

	Feet
Mowry shale (part):	
1. Shale, brownish-gray siliceous; lower 3 ft contains thin beds of dark-gray shale; gradational with unit below	3
2. Shale, dark-gray, fissile	12
Partial thickness of Mowry shale	15
Newcastle sandstone:	
3. Siltstone, light-gray, platy, friable; contains many "worm" borings	4
4. Siltstone, light-gray; contains many plant remains	1
5. Coal, silty, poorly consolidated	.5
6. Sandstone, light-gray, iron-stained, friable; contains "worm" borings or root tubes in upper part	6
7. Shale, gray, weathers light-gray, silty, soft	8
8. Bentonite, greenish-gray, waxy; swells on weathering	5
9. Coal and carbonaceous shale, fissile; contains much sand and silt	1

Newcastle sandstone in the NE¼ sec. 25, T. 57 N., R. 83 W., Crook County, Wyo. (section 2, pl. 4)—Continued

	Feet
Newcastle sandstone—Continued	
10. Sandstone, light-gray, medium-grained, friable	1
11. Sandstone, light-gray, medium-grained, cross-bedded, poorly consolidated	6
12. Sandstone, light-gray, medium-grained, massive, resistant	3
13. Sandstone, light-brown, medium-grained, friable	3
14. Sandstone and siltstone interlaminated with dark-gray shale	1
15. Siltstone, light yellowish-gray, soft	2
16. Shale, light brownish-gray, weathers very light gray, silty	12
17. Sandstone, brownish-gray, medium-grained, soft, friable	3
18. Sandstone, light-gray, fine-grained, friable; wedges out 200 yd from measured section	5
19. Sandstone, dark brownish-gray, friable; contains many fragmental plant remains	5
Thickness (rounded) of Newcastle sandstone	66
Skull Creek shale (part):	
20. Shale, dark-gray, fissile.	

Newcastle sandstone in SE¼ sec. 30, T. 58 N., R. 83 W., Crook County, Wyo. (section 3, pl. 4)

	Feet
Mowry shale (part):	
13. Shale, dark-gray to black	5
Newcastle sandstone:	
12. Claystone, medium- to dark-gray, carbonaceous, silty	1½
11. Siltstone, medium- to dark-gray, carbonaceous, a bed 2 in. thick of grayish-white bentonite at top	1½
10. Sandstone, grayish-yellow, fine-grained to silty, in beds 2 in. to 1 ft thick, friable at top, well cemented in middle and lower parts	6
9. Siltstone, medium- to light-gray, very bentonitic	5
8. Claystone, medium-gray, kaolinitic	2½
7. Bentonite, light yellowish-gray	1
6. Claystone, black, very carbonaceous	1
5. Siltstone, medium to very dark gray, carbonaceous, thin seam of bentonite near base; sandy in upper 1 ft	3½
4. Claystone, medium-gray, bentonitic	1½
3. Shale, medium- to dark-gray	2½
2. Sandstone, grayish-white, fine-grained, micaceous; a few partings of dark-gray claystone near middle	5
Thickness of Newcastle sandstone	31
Skull Creek shale (part):	
1. Shale, black, 10 ft below top a bed of dark-gray siderite concretions that weather dark red	15

Part of the Newcastle sandstone in the E½ sec. 11, T. 57 N., R. 65 W., Crook County, Wyo. (section 4, pl. 4)

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

	Feet
Newcastle sandstone (part):	
18. Siltstone, light-gray, laminated; local very fine grained sandstone; seams impregnated with iron oxides 1 and 5 ft below top; bottom 1 ft massive and clayey; grades to silty claystone at base	7.7
17. Shale, black, silty, tough; weathers fissile	.3
16. Bentonite	3.3
15. Coal and coaly shale; contains pyrite and scattered fragments of carbonized wood	.8
14. Claystone, gray, silty; vertical markings that suggest plant roots	1.0
13. Shale, silty, carbonaceous; local seams of coal and shaly coaly siltstone	1.3
12. Claystone, gray to dark-gray, carbonaceous; scattered selenite	.8
11. Claystone, light-gray, weathers white, silty, massive; grades downward to siltstone; vertical markings that suggest plant roots	2.8
10. Sandstone, brown-weathering, fine-grained to silty, calcareous; scattered nodules of sandstone cemented by barite; grades into units above and below; forms crumbly lenticular ledges	.7
9. Siltstone, clayey, and silty claystone, light-gray, massive; scattered ferruginous specks that weather orange and yellow and give outcrops splotchy stains	3.2
8. Siltstone, gray to light-gray, thin-bedded; grades downward to silty shale in bottom ½ ft; forms minor ledge	2.2
7. Bentonite	1.3
6. Claystone, coaly, silty, contains thin lenses of coal	1.3
5. Claystone, gray to dark-gray and brownish-gray, tough, silty, plant fragments in top 3 ft; grades in bottom 2½ ft to light gray silty claystone with ferruginous specks concentrated locally in orange-brown clusters	5.5
4. Claystone, clayey siltstone, and siltstone, interbedded, dark-gray to brown; bottom 1 ft mostly brown siltstone with thin sandy lenses	3.0
3. Sandstone and siltstone, interbedded; brownish-gray, weathers white to yellowish gray, carbonaceous; bottom 1 ft clayey and coaly	2.0
2. Shale, greenish-gray, bentonitic	.8
Partial thickness of Newcastle sandstone	38
Skull Creek shale (part):	
1. Shale, dark-gray to black; a bed ½ ft thick of glauconitic shale 1½ ft below top	4

Part of the Newcastle sandstone in the SE¼ sec. 13 and the NE¼ sec. 24, T. 56 N., R. 67 W.; Crook County, Wyo. (section 5, pl. 4)

	Feet
Mowry shale (part):	
11. Shale, dark brownish-gray, weathers gray; siliceous in upper 2 ft	6
Mowry (?) shale:	
10. Covered	10
Newcastle sandstone (part):	
9. Claystone and shale, medium- to dark-gray	2
8. Shale, black, carbonaceous; a few partings of brown carbonaceous siltstone and fine-grained sandstone	4½
7. Claystone, medium- to dark-gray; very sandy in upper part	1
6. Partly covered; mostly light-gray fine-grained sandstone and siltstone, friable	1½
5. Sandstone, gray, weathers brown, fine-grained, micaceous; calcareous in upper part; in beds about 2 in. thick; forms ledge	3
4. Siltstone, dark-gray	2
3. Shale, dark brownish-gray; silty near top	8
2. Sandstone, grayish-white and yellowish-gray, fine to very fine grained, micaceous; wavy carbonaceous laminae; in beds as much as 8 in. thick; forms local ledges	10
1. Shale, dark-gray to brownish-gray, carbonaceous; many laminae of fine-grained sandstone and siltstone	5
Partial thickness of Newcastle sandstone	37

Base of exposure.

Newcastle sandstone in the SE¼ sec. 22, T. 52 N., R. 67 W., Crook County, Wyo. (section 6, pl. 4)

[After V. H. Barnett, 1915, p. 101]

	Feet
Mowry shale (part):	
18. Shale, grayish-black	2+
Newcastle sandstone:	
17. Sandstone, reddish-brown, fine-grained, concretionary; contains a pelecypod fragment, *Corbula* cf. *C. subtrigonalis* Meek and Hayden, and a gastropod fragment, *Viviparus* cf. *V.* sp. (collected by W. W. Rubey, identified by J. B. Reeside, Jr., loc. 12072)	½
16. Shale, dark-gray, soft, sandy	2
15. Shale, brown, carbonaceous, sandy	4
14. Shale, black, very carbonaceous	½
13. Shale, light-gray, bentonitic	3
12. Shale, black, carbonaceous	½
11. Shale, gray, sandy	1
10. Sandstone, brownish-gray, fine-grained, hard, carbonaceous	1½

Newcastle sandstone in the SE¼ sec. 22, T. 52 N., R. 67 W., Crook Couty, Wyo. (section 6, pl. 4)—Continued

	Feet
Newcastle sandstone—Continued	
9. Shale, dark-brown, carbonaceous, sandy	6
8. Sandstone, brown, weathers gray; fine-grained, hard	5
7. Shale, gray, soft, sandy	4½
6. Shale, black, very carbonaceous	2
5. Claystone, brownish-gray, bentonitic	1½
4. Shale, brownish-gray	7
3. Shale, dark-brown to black, carbonaceous, sandy	2
2. Sandstone, brown, weathers light-gray, fine-grained, friable, carbonaceous, strong odor of oil	3
Thickness of Newcastle sandstone	44
Skull Creek shale (part):	
1. Shale, grayish-black	4+

Newcastle sandstone on the northeast side of Thornton dome in about the center of sec. 8, T. 48 N., R. 65 W., Weston County, Wyo. (section 7, pl. 4)

	Feet
Mowry shale (part):	
10. Bentonite, light-gray; some dark-gray shale in upper part	2.0
Newcastle sandstone:	
9. Siltstone and shale, interlaminated; siltstone is light gray; shale is medium gray and silicified; lenticular; forms minor ledge	0.4
8. Shale, dark-brown to black, carbonaceous, silty; a few stringers of light yellowish-gray bentonite	1.2
7. Bentonite, mostly light-gray, brownish-gray in top ½ ft; forms tough popcornlike crust where weathered	3.5
6. Shale, dark-brown to grayish-black, coaly	1.5
5. Poorly exposed, mostly medium-gray bentonitic shale	4.0
4. Sandstone, very light gray, very fine grained, slightly carbonaceous, thin-bedded, lenticular; forms hard blocky ledge	1–4
3. Sandstone and sandy claystone, light- to dark-gray, bentonitic, top ½ ft grayish black and very carbonaceous	2.0
2. Bentonite, olive-gray mottled red locally, silty	2.0
Thickness of Newcastle sandstone	18±
Skull Creek shale (part):	
1. Shale, grayish-black; black siderite concretions that weather dark red about 12 ft below top	15

Newcastle sandstone and part of the Mowry shale on the east side of the Pump Creek anticline in the SE¼ sec. 11, T. 47 N., R. 64 W., Weston County, Wyo. (section 8, pl. 4)

	Feet
Mowry shale (part):	
18. Shale, dark-gray, soft	5+
17. Sandstone, light-gray, weathers brown, very fine grained, calcareous, thin-bedded, interbedded and interlaminated gray shale in lower 4 ft, upper 1 ft forms slabby ledge	5

Newcastle sandstone and part of the Mowry shale on the east side of the Pump Creek anticline in the SE¼ sec. 11, T. 47 N., R. 64 W., Weston County, Wyo. (section 8, pl. 4)—Continued

	Feet
Mowry shale (part)—Continued	
16. Shale, very dark gray; contains beds of gray bentonite 4 in. thick near top and base	18
Partial thickness of Mowry shale	28
Newcastle sandstone:	
15. Siltstone, light yellowish-gray; many partings of dark-gray shale	2
14. Shale, dark-brown, very carbonaceous, silty	1½
13. Claystone, gray, bentonitic	2
12. Bentonite, light gray; grades into overlying unit	3
11. Claystone, greenish-gray, bentonitic, silty, slightly carbonaceous	4
10. Shale, grayish-black; scattered dark purplish-red siderite concretions in middle part	6
9. Sandstone, very light gray, very fine grained, thin-bedded; discontinuous hard calcareous layers	1
8. Claystone, like unit 11	3
7. Claystone, greenish-gray, bentonitic, locally silty	4
6. Claystone, medium-gray; silty layers	6
5. Shale, dark-brown to black, very carbonaceous	1
4. Claystone, medium-gray	2
3. Covered	8
2. Sandstone, very light gray, very fine grained; lower part friable and slightly carbonaceous, upper 1 to 3 ft hard and slabby, upper part forms ledge	10
Thickness (rounded) of Newcastle sandstone	54
Skull Creek shale (part):	
1. Shale, black; fragments of dark-red siderite concretions in the soil; upper 2 to 3 ft poorly exposed	15

Newcastle sandstone and part of the Mowry shale southeast of Osage in the SE¼ sec. 25, T. 46 N., R. 63 W., Weston County, Wyo. (section 9, pl. 4)

	Feet
Mowry shale (part):	
7. Shale, dark-gray; weathers dark gray in lower part, light gray in upper part; upper part siliceous; forms tree-covered slopes bare of grass	20
6. Poorly exposed; appears to be mostly dark-gray shale	10
Partial thickness of Mowry shale	30
Newcastle sandstone:	
5. Sandstone, light-gray, very fine grained, calcareous, thin-bedded, slightly carbonaceous; forms 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 of Newcastle sandstone	14

Newcastle sandstone and part of the Mowry shale southeast of Osage in the SE¼ sec. 25, T. 46 N., R. 63 W., Weston County, Wyo. (section 9, pl. 4)—Continued

Skull Creek shale (part):	Feet
1. Shale, black; a bed of dark-red-weathering siderite concretions about 15 ft below top	20+

Parts of the Newcastle sandstone and Mowry shale in the SE¼ sec. 24, T. 45 N., R. 62 W., Weston County, Wyo. (section 10, pl. 4)

Mowry shale (part):	Feet
11. Shale, dark-gray, weathers light gray; siliceous, contains fish scales	10
10. Sandstone, light-yellowish-gray, very fine grained	1
9. Poorly exposed; mostly dark-gray shale with a few laminae of very fine grained sandstone in upper part	17
Partial thickness of Mowry shale	28

Newcastle sandstone (part):	
8. Sandstone, light-gray to light yellowish-gray, fine to very fine grained, calcareous, thin- to medium-bedded, cross-laminated; forms ledges	10
7. Shale, medium-gray; grades in lower half to bentonitic shale and bentonite	2
6. Shale, black, carbonaceous	3½
5. Sandstone, light-gray, fine to very fine grained, carbonaceous, calcareous; a parting ½ ft thick of gray siltstone near top	4
4. Shale, dark-brown, carbonaceous	12
3. Sandstone, light-gray, fine to very fine grained, calcareous, alternating thin and medium beds; forms ledges	15
2. Shale, black, carbonaceous	1½
1. Covered by talus; probably sandstone	5+
Partial thickness of Newcastle sandstone	53

Part of the Newcastle sandstone in roadcut along U.S. Highway 85 east of Newcastle in sec. 28, T. 45 N., R. 61 W., Weston County, Wyo. (section 11, pl. 4)

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

Newcastle sandstone (part):	Feet
19. Sandstone, weathers yellow gray to brown, fine to very fine grained, hard; in thick massive beds	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 with ferruginous stain on bedding surfaces; irregularly bedded; scattered carbonaceous fragments	1.0

Part of the Newcastle sandstone in roadcut along U.S. Highway 85 east of Newcastle in sec. 28, T. 45 N., R. 61 W., Weston County, Wyo. (section 11, pl. 4)—Continued

Newcastle sandstone (part)—Continued	Feet
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, fine to very 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 base a bed of white porcellanite 0.1 to 0.2 ft thick	.6
9. Shale, black, carbonaceous; silty at base; thickens to northeast at expense of unit 8, and a thin bed of porcellanite appears 1.7 ft from base; gray siltstone beneath porcellanite	1.7–3.5
8. Sandstone, light-gray, fine-grained, hard, tabular to massive, cross-laminated	3.0–5.5
7. Claystone, light-gray, silty; blocky to splintery fracture	2.8
6. Sandstone, gray, fine-grained; some interbedded siltstone; laminated to thin-bedded with a few cross-laminated layers; forms shelving ledge	15.5
5. Sandstone, fine-grained, soft, thin-bedded; contains laminae of black carbonaceous shale	1.7
4. Claystone, grading downward to siltstone, dark-gray; sandy at base	8.0
3. Sandstone, fine-grained, carbonaceous; forms single massive ledge	2.6
2. Siltstone interlaminated and thinly interbedded with dark-gray silty shale; some bedding 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) of Newcastle sandstone	77

Fault (Skull Creek shale probably no more than 10 ft stratigraphically below unit 1).

MOWRY SHALE

The Mowry shale crops out in a low ridge or hogback that commonly is bare of grass but which supports a generous growth of pines and junipers. The formation is about 180 feet thick near Newcastle and thickens gradually northward to about 230 feet near the corner common to Wyoming, Montana, and South Dakota. The Mowry consists chiefly of dark-gray siliceous shale that weathers to hard, brittle, light silvery gray chips. A few beds are silty or sandy. Beds of bentonite, mostly less than 6 inches thick, are common throughout the formation. At the top is the commercially important Clay Spur bentonite bed, which is as much as 7 feet thick, and which has been mined extensively along the northern and western sides of the Black Hills. The

formation is less siliceous near its base, and the basal 10 to 20 feet at many places is a soft dark-gray shale and sandstone that was called the Nefsy shale by Collier (1922, p. 82). A bed of very fine grained sandstone and siltstone as much as 5 feet thick occurs about 18 feet above the base of the formation east of the Pump Creek anticline near Osage, but sandy beds in the lower part of the Mowry where observed elsewhere are less than 1 foot thick.

Rubey (1929) has discussed in detail the composition and origin of the Mowry shale. He reported (p. 157, 169) that the shale is exceptionally high in silica and low in ferrous iron and carbonates as compared to the average composition of other shales. He concluded that at least 70 percent of the rock is uncombined silica, and that the high silica content is due to a high percentage of altered volcanic ash in the shale.

Fossils reported from the Mowry shale in the northern and western Black Hills include abundant fish scales, a few impressions of the ammonites *Metengonoceras* and *Neogastroplites*, Radiolaria of the suborder Nasselaria (and Spumellaria?) (Rubey, 1929, p. 154), and the Foraminifera *Trochammina deprassa* Lozo (Skolnick, 1958a, p. 284). W. W. Rubey collected *Inoceramas labiatus* Schlotheim and scales of *Leuchichthyops vagans* Cockerell from the Mowry shale northeast of of Poison Creek in the northwest part of T. 54 N., R. 66 W. (loc. 12739), and *Leuchichthyops vagans* Cockerell, *Holcolepis transversus* Cockerell, *Eythrinolepis mowriensis* Cockerell, and *Ichthyodectus?* sp. from an outcrop 2 miles west of Newcastle on the slope north of the railroad (loc. 11187). The stratigraphy of the Mowry and the distribution of the amonite *Neogastroplites* in the Western Interior Regions of the United States and Canada, including the Black Hills, are discussed by Reeside and Cobban (1960).

Four stratigraphic sections of the Mowry shale follow. The first and last sections illustrate in detail the number and thickness of bentonite beds in the Mowry.

Mowry shale on cut bank of Belle Fourche River near the center of sec. 20, T. 57 N., R. 62 W., Crook County, Wyo.

[After Knechtel and Patterson, 1962, p. 912–913]

Mowry shale:	Feet
1. Shale, gray, weathers light gray, siliceous, interlaminated with gray bentonitic shale	0.9
2. Bentonite, light yellowish-green, waxy (Clay Spur bed)	2
3. Shale, dark brownish-gray, weathers light silvery gray, siliceous; limonitic stain along joints; contains fish remains in lower part; somewhat less resistant than underlying siliceous strata	31
4. Bentonite, light-gray, waxy, limonite-stained	.9
5. Shale, gray to brownish-gray, siliceous; limonitic stain along joints, upper 2 in. very hard	13

Mowry shale on cut bank of Belle Fourche River near the center of sec. 20, T. 57 N., R. 62 W., Crook County, Wyo.—Con.

Mowry shale—Continued	Feet
6. Bentonite, light-gray, waxy	0.9
7. Shale, brownish-gray, siliceous; limonitic stain along joints, abundant fish remains	11
8. Bentonite, light-gray, waxy	.9
9. Shale, brownish-gray, siliceous, hard; contains calcareous lenses as much as 4 in. thick and 3½ ft long with poorly developed cone-in-cone structure; some lenses overlain by thin seams of fibrous gypsum	3.1
10. Bentonite, light-gray, waxy	.3
11. Shale, dark brownish-gray, siliceous, hard; abundant fish remains	3.2
12. Bentonite, mostly light brownish-gray; dark-gray laminae in upper part; waxy	.1
13. Shale, dark brownish-gray, siliceous, hard; limonitic stains along joints	.4
14. Bentonite, light yellowish-gray, waxy	.1
15. Shale, dark brownish-gray, siliceous, hard	.7
16. Bentonite, light yellowish-gray, waxy	.6
17. Shale, brownish-gray, siliceous, hard; yellow stains along joints	9
18. Shale, dark-gray, somewhat siliceous; much softer than adjacent strata	1.2
19. Shale, brownish-gray, siliceous, hard; yellow stains and tiny gypsum crystals along joints; abundant fish remains	25
20. Shale, dark-gray, siliceous; several laminae of bentonite	.9
21. Shale, dark brownish-gray, siliceous; limonitic stain along joints; fish remains	2.2
22. Shale, dark-gray, siliceous; many thin laminae of bentonite	4.5
23. Shale, dark brownish-gray, siliceous, hard; many vertical joints most of which are coated by yellow powdery residue and stain	10
24. Shale, dark-gray, somewhat siliceous; much softer than adjacent beds; bentonitic near base	1.1
25. Bentonite, brownish-gray, waxy, limonite-stained	.2
26. Shale, dark brownish-gray, siliceous, hard; yellow powdery residue along joints; contains abundant fish remains	2.5
27. Shale, dark-gray, soft; bentonitic in lower part	.4
28. Bentonite, brownish-gray, waxy	.1
29. Shale, dark brownish-gray, siliceous, hard	1.7
30. Bentonite, light-gray, waxy	.1
31. Shale, dark-gray, siliceous, platy	2.7
32. Bentonite, laminated dark- and light-gray, waxy	.1
33. Shale, dark-gray, siliceous, silty	2.7
34. Bentonite, laminated light- and dark-gray, waxy	.2
35. Shale, dark-gray, siliceous	.1
36. Bentonite, gray, waxy; a few light-gray laminae	.5
37. Bentonite, light-gray, waxy, iron-stained	.9
38. Shale, dark brownish-gray, siliceous, hard, upper 1 in. exceptionally hard	2.2
39. Bentonite, light-gray, waxy	1.0

Mowry shale on cut bank of Belle Fourche River near the center of sec. 20, T. 57 N., R. 62 W., Crook County, Wyo.—Con.

Mowry shale—Continued	Feet
40. Shale, dark brownish-gray, siliceous, hard; limonitic stain along joints; abundant fish remains	4.9
41. Shale, dark-gray, soft, bentonitic	.1
42. Bentonite, light-gray, waxy; dark-gray laminae in upper part	.3
43. Shale, dark brownish-gray, siliceous, hard; yellow powdery mineral on weathered surfaces	6.1
44. Bentonite, yellowish-gray, waxy	.3
45. Gypsum, gray, fibrous, shaly	.1
46. Shale, dark-gray, soft, fissile	.1
47. Siltstone, brownish-gray, weathers reddish brown, soft; a lens	2.1
48. Shale, dark brownish-gray, siliceous, hard	1.3
49. Shale, dark-gray, bentonitic, soft	.7
50. Bentonite; lower half is brownish gray; upper half is light gray; limonite-stained, waxy	.5
51. Shale, dark brownish-gray, siliceous, hard; limonitic stain along joints; abundant fish remains	3.3
52. Shale, dark-gray, soft, platy	.1
53. Shale, dark brownish-gray, siliceous, hard; abundant fish remains	3.5
54. Shale, dark-gray, soft; bentonitic in lower part	.7
55. Shale, gray, siliceous, hard; limonitic stain along joints; abundant fish remains	3.2
56. Bentonite, light-gray, iron-stained, waxy; upper 3 in. contains dark-gray laminae	1.9
57. Shale, gray, siliceous, cherty, very hard	.1
58. Shale, dark brownish-gray, siliceous; many vertical joints; abundant fish remains	3.1
59. Bentonite, light-gray, waxy; dark-gray laminae in upper part; a lens	.2
60. Shale, dark brownish-gray, siliceous, hard; some fish remains	.9
61. Covered; approximate interval to top of Newcastle sandstone	50±
Thickness (rounded) of Mowry shale	225±

Mowry shale in the NE¼ sec. 10 and SW¼ sec. 11, T. 57 N., R. 65 W., Crook County, Wyo.

Belle Fourche shale (part):	Feet
23. Shale, very dark gray, soft; a few thin seams of gray bentonite less than ½ ft thick; numerous dark gray siderite concretions that weather dark-red; a few yellow cone-in-cone concretions	20
22. Bentonite, light yellowish-gray	.5
21. Shale, very dark gray to dark brownish-gray; slightly brittle in lower part	5
Partial thickness (rounded) of Belle Fourche shale	25
Mowry shale:	
20. Bentonite, light yellowish-gray to light-gray (Clay Spur bed)	1.0
19. Partly covered; mostly dark-gray shale that weathers light gray and is platy, brittle, and siliceous; a few seams of bentonite about 1 in. thick	16.5

Mowry shale in the NE¼ sec. 10 and SW¼ sec. 11, T. 57 N., R. 65 W., Crook County, Wyo.—Continued

Mowry shale—Continued	Feet
18. Shale, dark-gray, weathers light gray, platy, brittle, siliceous; numerous fish scales; four beds of bentonite ranging from 1 to 6 in. thick spaced about evenly	52
17. Covered in upper 4 ft; lower 2 ft is dark-gray brittle siliceous shale that weathers light gray	6
16. Shale, light pinkish-gray, brittle; breaks into papery fragments	1
15. Shale, dark-gray, weathers light gray, brittle, siliceous	16.5
14. Partly covered; mostly dark-gray siliceous shale that weathers light gray	23
13. Covered	17.5
12. Shale, dark-gray, weathers light gray, brittle, siliceous; two seams 1 in. thick of bentonite in lower half	29
11. Partly covered; mostly dark-gray siliceous shale that weathers light gray	14
10. Bentonite, light yellowish-gray	.2
9. Shale, dark-gray, weathers light gray, brittle, siliceous	4.5
8. Partly covered; mostly dark-gray siliceous shale that weathers light gray	9
7. Bentonite	.5
6. Shale, dark-gray, weathers light gray, brittle, siliceous; a seam of bentonite 1 in. thick	3
5. Bentonite, yellowish-gray, slightly shaly	1.2
4. Shale, dark-gray, weathers light gray, brittle, siliceous, silty in lower part; abundant fish scales	5
3. Covered to estimated base of Mowry shale	10
Thickness (rounded) of Mowry shale	210
Newcastle sandstone (part):	
2. Covered	5
1. Sandstone, grayish-white and yellowish-gray, fine-grained, silty and clayey, friable	1
Partial thickness of Newcastle sandstone	6

Mowry shale on the northeast side of Thornton dome about the center of sec. 8, T. 48 N., R. 65 W., Weston County, Wyo.

Belle Fourche shale (part):	Feet
18. Shale grayish-black; a bed 1 ft thick of light-gray bentonite 5 ft above the base; several beds of purplish-black siderite concretions that weather dark red	25
Mowry shale:	
17. Bentonite (Clay Spur bed), very light gray, swelling	2.5
16. Partly covered; mostly dark-gray siliceous shale that weathers light gray; abundant fish scales; a dark-gray limestone concretion 20 ft long and 1½ ft thick about 6 ft above base of unit	44
15. Bentonite, light-gray	1.7
14. Shale as in unit 15	7
13. Bentonite, light-gray; shale parting 0.6 ft thick	1.7
12. Shale as in unit 15	17

Mowry shale on the northeast side of Thornton dome about the center of sec. 8, T. 48 N., R. 65 W., Weston County, Wyo.—Con.

	Feet
Mowry shale—Continued	
11. Bentonite, light-gray; some interbedded black shale	0.8
10. Shale as in unit 15; three beds 0.1 to 0.4 ft thick of light-gray bentonite in lower half	80
9. Bentonite, pale yellowish-gray	.5
8. Shale as in unit 15	5
7. Bentonite, very light gray	1.5
6. Shale as in unit 15; 2 beds 1 in. thick of light-gray bentonite in upper part	31
5. Bentonite, very light gray	.8
4. Shale as in unit 15	3
3. Bentonite, pale yellowish-gray	.4
2. Poorly exposed; some dark gray shale and bentonite; brown-weathering calcareous cone-in-cone siltstone concretions about 5 ft below top	18
Thickness (rounded) of Mowry shale	215
Newcastle sandstone (part):	
1. Sandstone and shale, interlaminated; sandstone is light gray and very fine grained; shale is medium gray and silicified; forms minor ledge	.5

Mowry shale and parts of adjacent formations southwest of Salt Creek, SW¼ 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 bottom part, grayish-tan in the upper part, slightly swelling	3
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 of 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, weathers medium to dark gray, 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

Mowry shale and parts of adjacent formations southwest of Salt Creek. SW¼ sec. 35, T. 45 N., R. 61 W., Weston County, Wyo.—Continued

	Feet
Mowry shale—Continued	
25. Shale, dark-gray, weathers medium gray, hard; contains fish scales	23
24. Bentonite, light-gray, nonswelling	.1
23. Shale, dark-gray, weathers medium gray, hard; contains fish scales	32
22. Sandstone, very light gray, very fine grained to silty, hard; forms ledges	.5
21. Shale, dark-gray, weathers medium gray, 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 minor ledge	.5
17. Shale, dark-gray, weathers medium gray, hard	5
16. Sandstone, as in unit 18 above	1.4
15. Shale, dark-gray, weathers medium gray, hard	4.7
14. Bentonite, light-gray, nonswelling	.3
13. Shale, dark-gray, weathers medium gray, hard	12
12. Bentonite, light-gray, nonswelling	.2
11. Shale, dark-gray, weathers medium gray, hard	9
10. Bentonite, light-gray, nonswelling	.4
9. Shale, dark-gray, weathers medium gray, hard, silty	3
8. Siltstone, light-gray with dark-gray laminae, sandy; upper part forms minor ledge	3.5
7. Bentonite, light olive-gray, nonswelling	.2
6. Shale, grayish-black, silty, soft; contains 2 thin streaks of bentonite	8.5
5. Bentonite, olive-gray, nonswelling	.6
4. Shale, grayish-black, soft	14
Thickness (rounded) of Mowry shale	195
Newcastle sandstone (part):	
3. Sandstone, brown, weathers, light gray, 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 of Newcastle sandstone	18

UPPER CRETACEOUS SERIES

Upper Cretaceous rocks on the northern and western flanks of the Black Hills include the Belle Fourche shale, Greenhorn formation, Carlile shale, Niobrara formation, Pierre shale, Fox Hills sandstone, and Lance formation. All but the Lance formation are marine deposits, chiefly shale and some sandstone, and they have an aggregate thickness of as much as 4,150 feet. The Lance formation consists of continental deposits of sandstone and shale and is as much as 1,600 feet thick. Maps showing the variations in thickness of Upper Cretaceous marine rocks (and the Lower Cretaceous Mowry shale) are given on figure 5.

The outcrop pattern of these formations in general outlines the Black Hills uplift. Formations from the Belle Fourche to the Niobrara, inclusive, crop out in a band that extends from the vicinity of Newcastle in Weston County, Wyo., northward or northwestward into Carter County, Mont., and from there eastward or southeastward across Carter County to Butte County, S. Dak., a distance of about 140 miles. In Weston and Crook Counties, Wyo., the outcrop width of these formations is about ½ to 4 miles, but it widens to nearly 20 miles in south-central Carter County, Mont. The Pierre shale and Fox Hills sandstone crop out west of the Niobrara formation in a band ranging from about 20 miles wide south of Newcastle in Weston County to about half a mile wide near Oshoto in central Crook County. The Lance formation crops out west of the Fox Hills sandstone in a band 3 to 6 miles wide in much of Crook County. The outcrop thins to about half a mile in T. 56 N., R. 69 W., Campbell County, Wyo., a few miles north of Stroner, and widens to nearly 20 miles in Powder River and Carter Counties, Mont.

BELLE FOURCHE SHALE

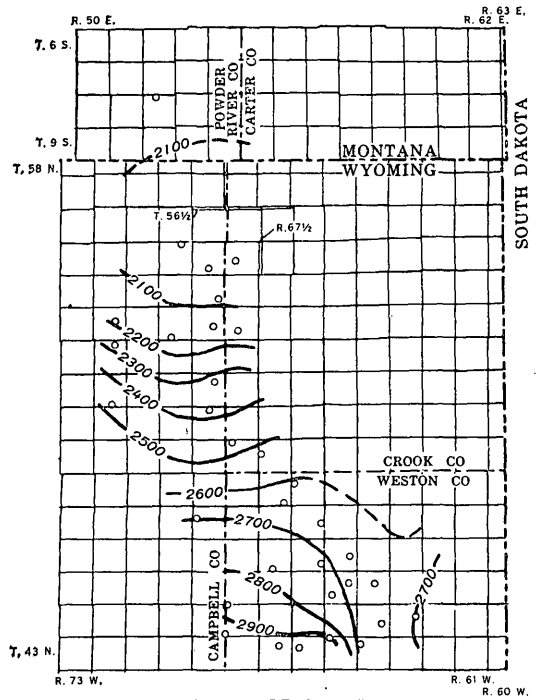
The Belle Fourche shale was named by Collier (1922, p. 83) for exposures along the Belle Fourche River in the vicinity of Wind Creek, Crook County, Wyo. The formation is a dark marine shale that commonly forms a broad valley or low rolling sage- and grass-covered hills between ridges formed by the more resistant underlying Mowry shale and overlying Greenhorn formation. The Belle Fourche shale is about 370 feet thick along its outcrop between Newcastle and Osage in Weston County, Wyo. It thickens to about 750 feet at Thornton a few miles to the northwest, and is 750 to about 850 feet thick from Thornton northward to the vicinity of Cedar Ridge (T. 56 N., R. 67 W.) in northwestern Crook County, Wyo. The formation thins eastward from Cedar Ridge to about 450 feet near the Wyoming-South Dakota boundary. Changes in thickness in the Osage-Thornton area, and farther north in northern Crook County, Wyo., and southern Carter County, Mont., are due mostly to interfingering and lateral gradation of noncalcareous shale in the upper part of the Belle Fourche into calcareous shale, marl, and thin limestone beds assigned to the overlying Greenhorn formation. The stratigraphic relations at the Belle Fourche-Greenhorn contact are shown by the diagram, figure 6, and the columnar sections, figure 7.

The basal 40 to 50 feet of the Belle Fourche is mostly a soft grayish-black shale characterized by numerous flattened ovoid concretions—generally about a foot long—consisting of dark-gray siderite that weathers dark purplish red. The shale weathers almost black in striking contrast to the underlying Mowry shale, which weathers light gray. The base of the Belle Fourche is at the top of the Clay Spur bentonite bed of the Mowry shale; this contact approximately marks the change downward from black- to light-gray weathering shale. Two persistent beds of bentonite have been noted by Knechtel and Patterson (1955; 1962, p. 979–982) in the basal part of the Belle Fourche shale in northern Crook County, Wyo., and the same two beds are fairly prominent near Upton in Weston County, Wyo. These beds lie from 1 to 4 feet and from about 20 to 30 feet above the base of the formation, respectively. The stratigraphically higher bed, known as bed E, locally attains a thickness of 5 feet in sec. 18, T. 47 N., R. 64 W., Weston County, Wyo.

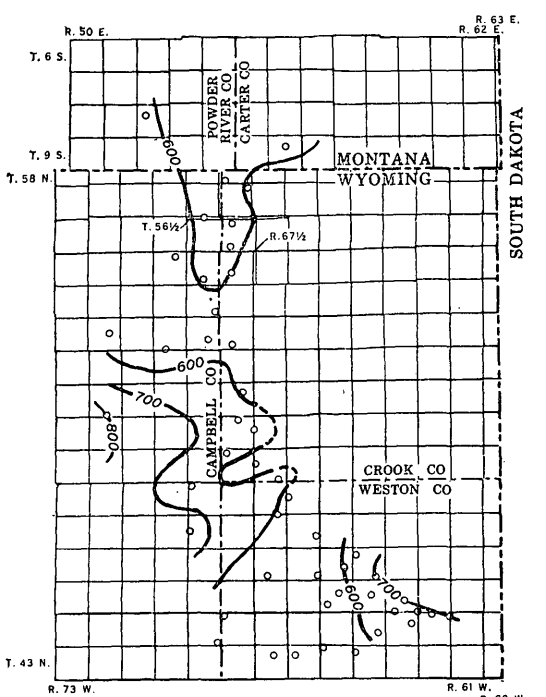
Overlying the basal part of the Belle Fourche shale just described, and making up most of the rest of the formation in the Newcastle-Osage area, and farther north in northeastern Crook County, Wyo. and the adjacent parts of South Dakota, are about 300 to 450 feet of grayish-black shale containing a few laminae of friable light-gray very fine grained sandstone or siltstone, scattered red-weathering ironstone concretions, and several beds of bentonite. Most of the bentonite beds are less than half a foot thick; however, one persistent bed referred to as the "Gray-red" bentonite by Bramlette and Rubey (in Moore, 1949, fig. 18) and as bed F by Knechtel and Patterson (1955; 1962, p. 982) averages about 4½ feet thick (Knechtel and Patterson, 1955; 1962, p. 983) in northern Crook County, and is about 3 feet thick where examined at several places south of the Belle Fourche River in southern Crook County and northern Weston County, Wyo. The Gray-red bentonite bed is about 350 feet above the base of the formation in the Newcastle-Osage area, about 475 feet above the base of the formation at Cabin Creek (T. 52 N., R. 67 W.), and about 500 feet above the base of the formation in northeastern Crook County (T. 57 N., R. 62 W.) (Knechtel and Patterson, 1962, p. 917).

The part of the Belle Fourche shale that lies above the Gray-red bentonite bed ranges in thickness from about 20 to 350 feet and consists of grayish-black noncalcareous shale; a few bentonite beds, including a locally prominent bentonite referred to as bed G by Knechtel and Patterson (1962, p. 986–989); and fairly numerous gray limestone concretions that weather light gray, grayish yellow, and grayish red. Many of the concretions are septarian with veins of pale-yellow or light-gray calcite, and some have cone-in-cone structure.

The following analysis was made of an ironstone, or siderite, concretion from the base of the Belle Fourche shale, collected by W. W. Rubey in 1923 from alongside



A. PIERRE SHALE



B. NIOBRARA FORMATION AND CARLILE SHALE

EXPLANATION

○ Well from which thickness was taken

——— Isopach lines dashed where inferred

0 10 20 30 40 MILES

the road from Thornton to Upton, Wyo., about 1½ miles from Upton. The analysis was made of the interior of the concretion after the oxidized surface was removed.

Analysis of ironstone concretion from base of Belle Fourche shale, sec. 28, T. 48 N., R. 65 W., Weston County, Wyo.

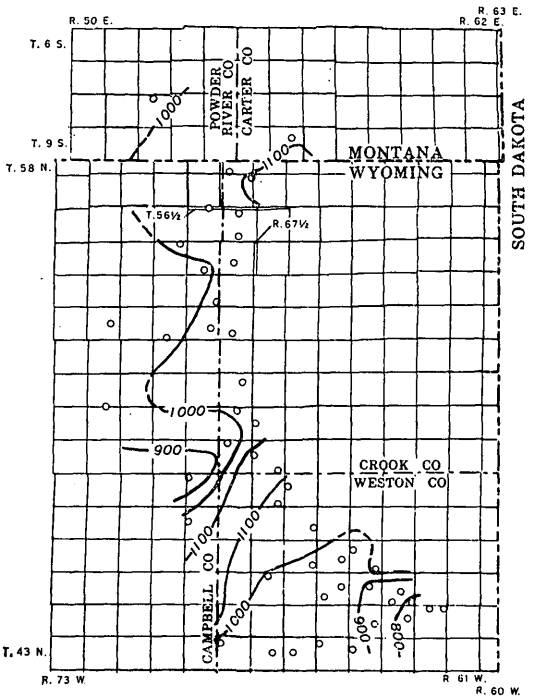
[Analyst, J. G. Fairchild]

Insoluble in HCl (largely SiO_2?)	5.30
Fe_2O_3	1.85
FeO	46.46
MgO	.31
CaO	1.21
MnO	6.67
P_2O_5	.64
S (soluble)	None
Co_2	33.96
Sp gr 3.70	96.40

Rubey concluded from this analysis and the examination of a thin section that the composition was approximately:

Manganiferous siderite	88.6
Quartz, feldspar, and clay	5.3
Water, interstitial	3.1
Phosphosiderite (?)	1.7
Limonite	1.3
	100.0

Fossils collected by Rubey and others from 1922 to 1924 from the Belle Fourche shale are tabulated below. In addition, fossils collected by W. W. Rubey near



C. GREENHORN FORMATION AND BELLE FOURCHE AND MOWRY SHALES

FIGURE 5.—Maps showing thicknesses of some Upper Cretaceous marine rocks on the west side of the Black Hills.

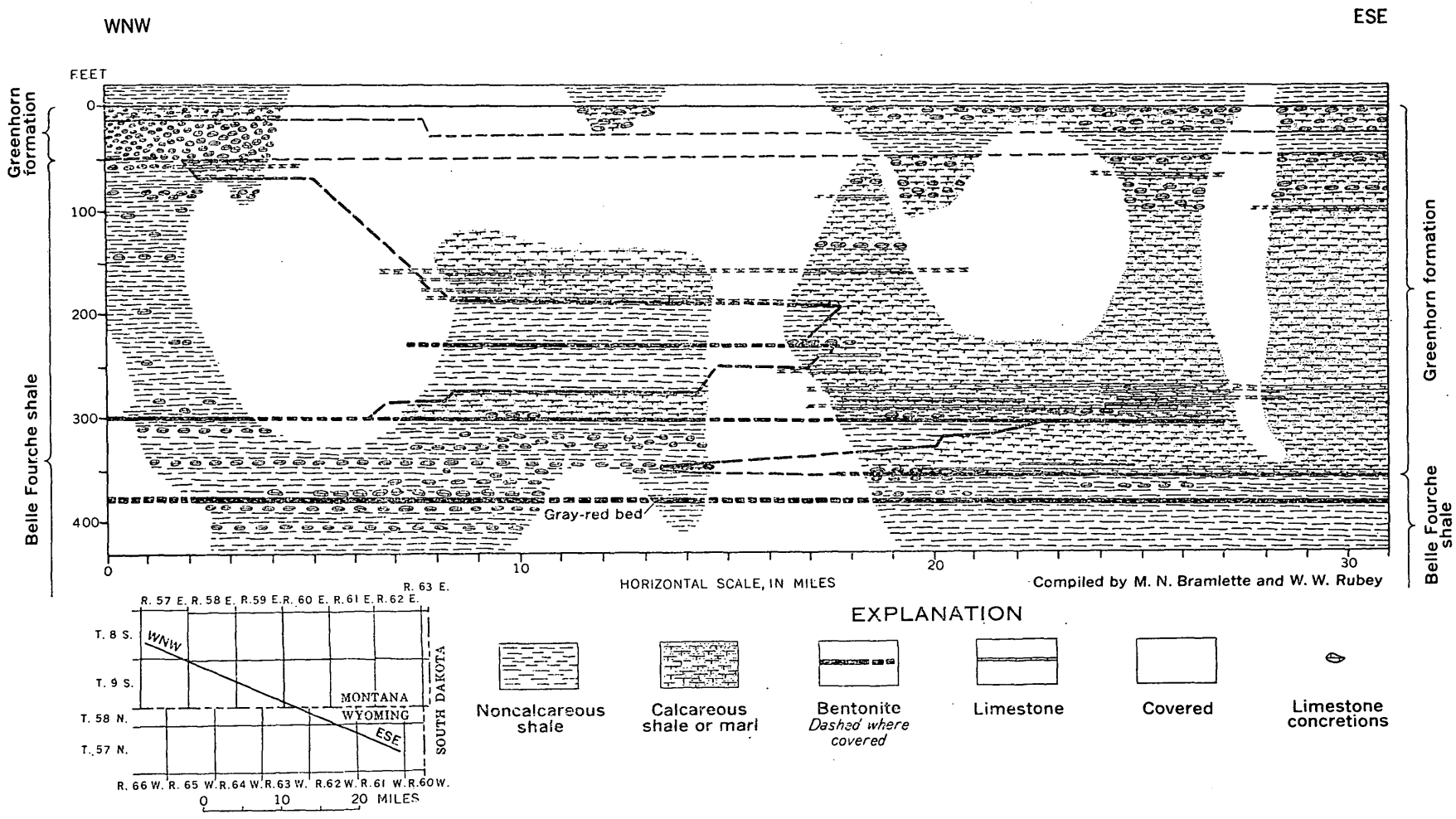


FIGURE 6.—Restored section showing interfingering of the Belle Fourche shale and Greenhorn formation, northern Black Hills.

Thornton dome (T. 48 N., R. 65 W., Weston County, Wyo.) are listed on page 59 in a stratigraphic section measured across the upper part of the Belle Fourche shale and the overlying Greenhorn formation. Cobban (1951, p. 2182) listed several collections from the Belle Fourche at the northern end of the Black Hills. Almost all the fossils so far reported from the formation are from the upper part, mostly above the Gray-red bentonite bed. The Belle Fourche shale, on the basis of its fossil content, is considered to be of Late Cretaceous age.

Fossils collected from the Belle Fourche shale

[Identified by J. B. Reeside, Jr.]

1. Sec. 23 or 24, T. 45 N., R. 62 W., 2.5 miles west of Newcastle, Wyo.
   Loc. 111862, 100 ft below base of Greenhorn formation.
   Inoceramus aff. *I. fragilis* Hall and Meek, but distinct from it.
   Fish tooth, probably *Galeucordo* sp.
2. SE¼ sec. 7, T. 46 N., R. 63 W., 2 miles west-southwest of Osage, Weston County, Wyo.
   Loc. 12674, 10 ft above highest yellow concretions.
   Globigerina bulloides d'Orbigny
   Inoceramus sp. fragments
   Metoicoceras whitei Hyatt
   Loc. 12648, highest yellow concretions.
   Globigerina bulloides d'Orbigny
   Inoceramus fragilis Hall and Meek
   Loc. 12698, 5 ft below highest yellow concretions.
   Globigerina bulloides d'Orbigny
   Inoceramus sp. broken fragments probably *I.* cf. *fragilis* Hall and Meek
   Ostrea sp. undet.
   Loc. 12705, 20 ft below highest yellow concretions.
   Inoceramus cf. *fragilis* Hall and Meek
3. W½ sec. 17, T. 46 N., R. 63 W., Weston County, Wyo.
   Loc. 11929, thin sandstone in middle of Belle Fourche shale.
   Inoceramus sp.
   Fish teeth and bones, undet.
4. Sec. 3(?), T. 47 N., R. 65 W., southwest of Upton, Weston County, Wyo.
   Loc. 11228, 10 ft below Greenhorn-Belle Fourche contact.
   Plicatula aff. *P. hydrotheca* White
   Astarte? n. sp.
   Callista orbiculata (Hall and Meek)
5. Sec. 19, T. 47 N., R. 64 W., 4.5 miles south-southeast of Upton, Weston County, Wyo.
   Loc. 12690, 30 ft above highest yellow concretions.
   Inoceramus fragilis Hall and Meek
   Astarte n. sp.
   Metoicoceras whitei Hyatt
   Fish remains, undet.
   Loc. 12711 and 12697, 5 ft below highest yellow concretions.
   Pteria aff. *P. nebrascana* (Evans and Shumard)?
   Inoceramus fragilis Hall and Meek
   Astarte n. sp.
   Callista orbiculata (Hall and Meek)
   Ammonite fragments, undet.
6. Sec. 18, T. 48 N., R. 65 W., 2 miles southeast of Thornton, Weston County, Wyo. (See also section p. 59)
   Loc. 12675, 80 ft above lowest yellow concretions.
   Acanthoceras? sp., fragments
   Loc. 12743, 20 ft below lowest yellow concretions.
   Helicoceras? sp. fragments
   Acanthoceras? n. sp.
7. Sec. 18, T. 48 N., R. 65 W., Weston County, Wyo.
   Loc. 11927, fossil tree trunk in upper part of Belle Fourche shale containing fossils.
   Ostrea sp., small simple species
   Callista obiculata (Hall and Meek)
   Turnus n. sp.
   Polinices cf *P. concinna* (Hall and Meek)
   Metoicoceras whitei Hyatt
8. Sec. 33, T. 48 N., R. 65 W., Weston, Crook County, Wyo.
   Loc. 11218, within 20 ft of base of Greenhorn formation.
   Inoceramus fragilis Hall and Meek
   Callista orbiculata (Hall and Meek)
9. Sec. 15, T. 51 N., R. 67 W., Crook County, Wyo.
   Loc. 12672A, 10 miles northeast of Moorcroft, Wyo.
   Acanthoceras? n. sp.
10. East of ¼ cor. sec. 21, T. 52 N., R. 67 W., Crook County, Wyo.
    Loc. 12658, just below Greenhorn-Belle Fourche contact.
    Inoceramus fragilis Hall and Meek
    Callista sp.
    Gyrodes n. sp. aff. *G. conradi* Meek
    Anchura? sp.
    Mammites? n. sp.
    Metoicoceras whitei Hyatt
    Loc. 12733, middle of yellow concretion zone.
    Ostrea sp., simple type
11. East-center, sec. 21, T. 52 N., R. 67 W., Crook County, Wyo.
    Locs. 12042 and 12712, uppermost part of Belle Fourche shale.
    Acanthoceras? n. sp.
    Ostrea sp. undet.
    Pinna? sp.
12. Sec. 22, T. 52 N., R. 67 W., Crook County, Wyo.
    Locs. 12067 and 12720, 15 miles north of Moorcroft, Wyo., a little above middle of Belle Fourche shale.
    Acanthoceras? n. sp.
13. SE¼ sec. 4, T. 57 N., R. 66 W., Crook County, Wyo.
    Loc. 12649, from concretions about 35 ft above the Gray-red bentonite bed.
    Glycimeris n. sp.
    Callistra obiculata (Hall and Meek)
    Turbonilla n. sp.
    Anchura n. sp.
    Helicoceras? n. sp.
    Baculites? n. sp.
    Hemitissotia n. sp.
    Puzosia (*Latidorsella*) n. sp.
    Mammites? n. sp.
14. W½ sec. 19, T. 57 N., R. 66 W., Crook County, Wyo.
    Loc. 12729, from calcite veins in top of Gray-red bentonite bed.
    Ostrea sp.
    Crustacean fragments
    Loc. 12062, gray calcareous concretions just below Gray-red bentonite bed.
    Acanthoceras? n. sp.

15. Sec. 22, T. 9 S., R. 57 E., Carter County, Mont.
    Locs. 12622 and 12713.
    Astarte n. sp.
    Callista orbiculata (Hall and Meek)
    Globirgerina bulloides d'Orbigny
    Leda? sp.
    Inoceramus fragilis Hall and Meek
    Pteria aff. *P. nebrascana* (Evans and Shumard)?
    Cuspidaria sp. (n. sp.?)
    Lucina aff. *L. subondata* Hall and Mark
    Dentalium n. sp.
    Polinices n. sp. aff. *P. concinna* (Hall and Meek)
    Anchura n. sp.
    Fasciolaria walcotti Stanton
    Puzosia (*Latidorsella*) n. sp.
    Metoicoceras whitei Hyatt
16. Sec. 23, T. 9 S., R. 57 E., 1 mile north of Alzada-Ridge road, 15 miles east of Ridge, Mont.
    Loc. 12625, 70 ft above Gray-red bentonite bed.
    Inoceramus fragilis Hall and Meek
    Stomohamites? *corrugatus* (Stanton)
17. SE¼ sec. 8, T. 9 S., R. 58 E., Carter County, Mont.
    Loc. 12620, 30 ft above Gray-red bentonite bed.
    Serpula sp.
    Yoldia? sp.
    Inoceramus fragilis Hall and Meek
    Ostrea sp., small simple form
    Lucina aff. *L. subundata* Hall and Meek
    Corbula nematophora Meek
    Mammites? n. sp.
18. SW¼ sec. 6, T. 9 S., R. 59 E., Carter County, Mont.
    Loc. 12621, 67 ft above Gray-red bentonite and 117 ft below base of Greenhorn formation.
    Inoceramus fragilis Hall and Meek
    Glycerimeris n. sp.
    Dentalium n. sp.
    Turbonilla n. sp. aff. *T. coalwillensis* (Meek)
    Anchura n. sp.
    Oligoptycha n. sp. aff. *O. concinna* (Hall and Meek)
    Puzosia (*Latidorsella*) n. sp.
    Mammites? n. sp.
    Fish bones.
19. SE¼ sec. 11, T. 9 S., R. 59 E., Carter County, Mont.
    Loc. 12741, 45 ft above Gray-red bentonite bed.
    Anchura n. sp.
    Helicoceras? n. sp.
    Mammites? n. sp.
20. Sec. 5(?), T. 57 N., R. 61 W.
    Loc. 12683.
    Inoceramus fragilis Hall and Meek
    Anomia sp.
    Astarte n. sp.
    Sciponoceras gracile (Shumard)
    Puzosia (*Latidorsella*) n. sp.
    Metoicoceras whitei Hyatt

The following five stratigraphic sections describe the lithology of the Belle Fourche shale. The first section is described in greater detail than the others and shows the thickness and stratigraphic position of 27 thin bentonite beds in the formation. Two of the sections also describe the overlying Greenhorn formation.

Belle Fourche shale in sec. 22, T. 57 N., R. 62 W., Crook County, Wyo.

[After Knechtel and Patterson, 1962, p. 917–918]

Greenhorn formation.

Belle Fourche shale:	Feet
1. Shale, dark-gray, soft, fissile	25
2. Bentonite (Gray-red bed), waxy; upper half gray; lower half reddish brown	4.5
3. Shale, dark-gray, soft, fissile; a few thin bentonite beds	63
4. Bentonite, dark reddish-brown, granular; many dark mineral particles	1.1
5. Shale, dark-gray, soft	8
6. Bentonite, gray, limonite-stained, waxy	.9
7. Shale, dark-gray, soft	12.5
8. Shale, dark-gray, soft; zone of flat cone-in-cone limestone lenses at top	26
9. Shale, dark-gray, soft; zone of small brown siltstone concretions at top	21
10. Shale, gray, iron-stained, sandy	1.1
11. Shale, dark-gray, soft; a few limestone concretions which are veined with white calcite and average 2½ by 4 ft long	38
12. Bentonite, greenish-gray, waxy	.1
13. Shale, dark-gray, soft	1
14. Bentonite, gray, waxy	.6
15. Shale, dark-gray, soft, fissile	2
16. Bentonite, gray, waxy	.2
17. Shale, dark-gray, soft, fissile	19
18. Bentonite, light yellowish-gray, waxy	.5
19. Shale, dark-gray, soft, fissile	14
20. Bentonite, light-gray, waxy	.1
21. Shale, dark-gray, soft, fissile	21
22. Bentonite, yellowish-brown	.1
23. Shale, dark-gray, soft, fissile	1
24. Bentonite, yellow, waxy	.2
25. Shale, dark-gray, soft	1
26. Bentonite, yellow, limonite-stained	.2
27. Shale, dark-gray, soft	7.5
28. Bentonite, dark-gray, waxy	.1
29. Shale, dark-gray, soft	2.5
30. Bentonite, gray, iron-stained, waxy	.1
31. Shale, dark-gray, soft, fissile	5
32. Bentonite, light yellowish-gray, waxy	.3
33. Shale, dark-gray, soft, sandy	21
34. Bentonite, gray, waxy	.1
35. Shale, dark-gray, soft, sandy	5
36. Bentonite, grayish-yellow, waxy	.1
37. Shale, dark-gray, soft; contains many thin friable gray sandstone lenses	54
38. Bentonite, waxy; lower part brown; upper 5 in. gray	1
39. Shale, dark-gray, soft; 1-inch thick bed of bentonite in middle part	6
40. Bentonite, gray, waxy	.2
41. Shale, dark-gray, soft, sandy	20
42. Sandstone, gray, fine-grained, soft	.1
43. Shale, dark-gray, soft, sandy	1.5
44. Sandstone, gray, fine-grained; interbedded limestone concretions with cone-in-cone structure	.4
45. Shale, dark-gray, soft, sandy	13
46. Bentonite, gray, waxy	.1

Belle Fourche shale in sec. 22, T. 57 N., R. 62 W., Crook County, Wyo.—Continued

Belle Fourche shale—Continued	Feet
47. Shale, dark-gray, soft; contains a few laminae of bentonite; some thin sandstone lenses	22
48. Shale, dark-gray, sandy; zone of overlapping cone-in-cone lenses at top; lenses are 2 in. thick and 2 ft long	20
49. Bentonite, light-gray, waxy	.2
50. Shale, dark-gray, soft; contains a few clayey ironstone concretions which average 6 in. in diameter	18
51. Bentonite, yellow, waxy	.1
52. Shale, dark-gray, soft	2
53. Bentonite, yellow, waxy	.1
54. Shale, dark-gray, soft, fissile; contains bentonite laminae in lower part	11
55. Bentonite, gray, waxy; grades upward to sandy shale	.3
56. Shale, dark-gray, soft, fissile	1.1
57. Bentonite, light-gray, waxy	.1
58. Shale, dark-gray, soft, fissile	16
59. Bentonite, brownish-orange, waxy	1.5
60. Shale, dark-gray, soft; contains many manganiferous siderite concretions which average about 5 in. in thickness and 1 ft in length	14
61. Bentonite (bed E), light-gray in upper and lower parts, reddish-brown in middle 8 in	1.1
62. Shale, dark-gray, soft; contains many manganiferous siderite concretions which average about 4 in. in thickness and 1 ft in length	24
63. Bentonite (bed D), waxy, lower half yellowish, upper half gray	.9
64. Shale, dark-gray, soft	4.5
Thickness (rounded) of Belle Fourche shale	537

Mowry shale.

Belle Fourche shale in secs. 29 and 30, T. 56 N., R. 67 W., Crook County, Wyo.

Greenhorn formation.

Belle Fourche shale:	Feet
12. Shale, dark-gray to black, weathers dark gray; dark-gray septarian limestone concretions 11 ft below top; concretions ½ to 2 ft long, weather light gray, and are cut by veins ¼ to 1 in. wide of brownish-yellow coarsely crystalline calcite	33
11. Shale, dark-gray and dark brownish-gray, weathers brownish gray, bentonitic	4
10. Shale, dark-gray to black, weathers medium to dark gray; beds of tabular dark-gray septarian limestone concretions about 5, 20, and 60 ft below top; concretions are 1 to 8 ft long, weather light gray, yellowish gray, or reddish gray, and are cut by veins ¼ to 1½ in. wide of yellowish-gray calcite; concretions in lowest zone have cone-in-cone structure	76
9. Bentonite, gray to yellowish-gray, locally reddish-gray; shaly in upper part; a few aragonite concretions	5

Belle Fourche shale in secs. 29 and 30, T. 56 N., R. 67 W., Crook County, Wyo.—Continued

Belle Fourche shale—Continued	Feet
8. Shale, dark-gray to black, weathers medium to dark gray; iron stained along partings; beds of tabular dark-gray septarian limestone concretions about 40, 65, 85, 100, and 145 ft below top; concretions are 1 to 20 ft long, weather light gray, yellowish gray, or reddish gray, are cut by veins ¼ to 2 in. wide of yellowish-brown calcite; concretions form low ridges	138
7. Bentonite, grayish-white to yellowish-gray; contains aragonite concretions	2
6. Shale, dark-gray to black, weathers medium to dark gray; iron stained along partings; contains three beds of dark-gray limestone or siderite concretions that weather gray, reddish gray, or dark reddish black; concretions are 1 to 3 ft long	43
5. Bentonite (Gray-red bed), yellowish-gray to reddish-gray, shaly; contains stringers of aragonite and at the base a bed of cone-in-cone aragonite concretions	4
4. Shale, dark-gray to black, weathers medium gray; iron stained along partings, contains red-weathering concretions about 10, 15, and 70 ft below top	104
3. Shale, black, bentonitic; a few aragonite concretions 1 to 2 ft long	1
2. Partly covered; mostly dark-gray to black shale; a few red-weathering siderite concretions	60
1. Mostly covered; scattered exposures of dark-gray shale containing red-weathering siderite concretions; base of unit is prospect trench in Clay Spur bentonite bed	280
Thickness of Belle Fourche shale	750

Mowry shale.

Greenhorn formation and Belle Fourche shale on the north side of Cabin Creek; SW¼ sec. 3, and SE¼ sec. 4, T. 52 N., R. 67 W., Crook County, Wyo. (see fig. 7)

Greenhorn formation:	Feet
21. Shale, dark-gray, weathers grayish brown, noncalcareous; several beds of septarian limestone concretions that weather light gray and have veins of white and brown calcite; concretions as much as 6 ft in diameter; lenses 1 to 2 in. thick of light-brown very fine grained calcareous sandstone; forms hogback	75
Belle Fourche shale:	
20. Shale, grayish-black, fissile; scattered gray septarian limestone concretions mostly about ½ to 1 ft in diameter with veinlets of brown and grayish-white calcite	35
19. Shale, grayish-black, fissile; several beds of yellow-weathering limestone concretions, locally septarian with veins of brown to yellow calcite; some yellowish-gray cone-in-cone concretions	66

Greenhorn formation and Belle Fourche shale on the north side of Cabin Creek, SW¼ sec. 3, and SE¼ sec. 4, T. 52 N., R. 67 W., Crook County, Wyo. (see fig. 7)—Continued

Belle Fourche shale—Continued	Feet
18. Partly covered; appears to be mostly grayish-black shale; a few scattered yellow-weathering limestone concretions as in unit 19 above	165
17. Shale, grayish-black; numerous yellow-weathering limestone concretions as in unit 19 above	45
16. Partly covered; appears to be mostly grayish-black shale	40
15. Bentonite (Gray-red bed), yellowish-gray; beds of yellow-weathering cone-in-cone limestone concretions at top and base; forms low ridge	1–2
14. Shale, grayish-black, weathers dark gray; numerous yellow-weathering limestone concretions 1 to 3 ft in diameter	31
13. Shale, grayish-black, weathers dark gray; several seams 1 to 3 in. thick of yellowish-gray bentonite; at top of unit a bed of yellow-weathering septarian limestone concretions 3 to 6 ft in diameter containing veinlets of yellow calcite	32
12. Shale, grayish-black, locally silty; a few partings 1 to 3 in. thick of brown-weathering siltstone; at top of unit a bed of sandy gray septarian limestone concretions 2 to 4 ft in diameter cut by veinlets of yellow calcite	40
11. Mostly covered; a few scattered outcrops of grayish-black shale	280
10. Shale, dark-gray to grayish-black; in middle part of unit 2 beds of grayish-black siderite concretions that weather dark red; dike of light-gray fine-grained quartzitic sandstone about ½ ft wide and 10 ft long near middle of unit	25
9. Shale, grayish-black; many thin seams of red-weathering calcareous siltstone; at top of unit a bed of grayish-black siderite concretions about 2 ft in diameter that weather dark red	34
8. Bentonite, gray	1½
7. Shale, grayish-black; 2 beds of grayish-black siderite concretions that weather dark red	31
6. Shale, dark-gray; seams of bentonite 1 to 2 in. thick at top and base of unit	1
5. Shale, grayish-black; scattered grayish-black siderite concretions that weather dark red	5
4. Covered	3
Thickness (rounded) of Belle Fourche shale	835

Mowry shale (part):	
3. Shale, medium- to dark-gray, weathers light gray, hard, brittle; a few seams of yellowish-gray bentonite	31
2. Bentonite, yellowish-orange	1
1. Shale, as in unit 3 above	10
Partial thickness of Mowry shale	42

Greenhorn formation and upper part of Belle Fourche shale near Thornton dome in the SW¼ sec. 18, T. 48 N., R. 65 W., Weston County, Wyo. (see fig. 7)

Carlile shale (part):	Feet
Lower unnamed member (part):	
14. Shale, dark-gray; a few laminae of light-gray siltstone	10
Greenhorn formation:	
13. Shale, dark-gray, weathers medium gray and brownish gray, silty and sandy, more sandy in upper half; in lower part several beds of septarian limestone concretions as much as 6 ft in diameter that weather light gray and have orange and yellow calcite veins; in upper half at least 5 beds of tabular gray limestone concretions 1 to 3 ft thick and as much as 20 ft long; forms a hogback; unit contains following fossils: Sandy lenses about 10 ft below the top, loc. D414, fossils identified by W. A. Cobban: *Inoceramus fragilis* Hall and Meek, *Ptychodus whipplei* Marcou, and *Squalicorax falcatus* (Agassiz). Concretions in lower part of unit, loc. 12644, fossils collected by W. W. Rubey and identified by J. B. Reeside, Jr.: *Inoceramus fragilis* Hall and Meek, *Inoceramus* sp., *Astarte* n. sp., *Callista orbiculata* (Hall and Meek), *Lunatia* n. sp. aff. *L. concinna* Hall and Meek, and *Fasciolaria* sp.	75
Belle Fourche shale (part):	
12. Shale, light- and dark-gray in alternating bands, noncalcareous; scattered limestone concretions that weather light gray; bed of closely spaced limestone concretions at base; concretions in lower part of the unit contain the following fossils, loc. D873, identified by W. A. Cobban: *Inoceramus* sp., *Callista orbiculata* (Hall and Meek)	55
11. Shale, grayish-black, noncalcareous; scattered septarian limestone concretions that weather light gray, light yellowish- gray, and brownish red; concretions are mostly 1 to 2 ft in diameter; unit contains the following fossils collected by W. W. Rubey and identified by J. B. Reeside, Jr.: Concretions about 50 ft below top of unit, loc. 12651; *Anomis*? sp., *Callista orbiculata* (Hall and Meek), *Corbula nemstophora* Meek, *Turnus* n. sp., *Natica* (*Amauropsis*?) n. sp., "*Puzosia*" n. sp., *Acanthoceras* n. sp., *Metoicoceras whitei* Hyatt, Ammonite n. gen. sp. B. Concretions about 80 ft below top of unit, loc. 12650: *Arca*? sp., *Inoceramus fragilis* Hall and Meek, *Astarte* n. sp., *Callista orbiculata* (Hall and Meek), molluscan borings in wood, possibly *Turnus* sp., *Natica* (*Amauropsis*?) n. sp., *Helicoceras* n. sp., *Turrilites* n. sp., "*Puzosia*" n. sp., *Acanthoceras* n. sp., *Mannites* n. sp., *Metoicoceras whitei* Hyatt, Ammonite n. gen. sp. A	125

Greenhorn formation and upper part of Belle Fourche shale near Thornton dome in the SW¼ sec. 18, T. 48 N., R. 65 W., Weston County, Wyo. (see fig. 7)—Continued

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

Base of exposure.

Belle Fourche shale and parts of adjacent formations northwest of Newcastel in the NW¼ sec. 23, T. 45 N., R. 62 W., Weston County, Wyo.

Greenhorn formation (part):	Feet
24. Shale, dark-gray, weathers olive gray, calcareous	20
23. Limestone, light-gray, weathers tan, very fossiliferous, lenticular	.3
22. Bentonite, very light gray and light reddish-brown, nonswelling	2
21. Limestone, as in unit 23 above	.5
Partial thickness (rounded) of Greenhorn formation	23
Belle Fourche shale:	
20. Shale, grayish-black, soft	17
19. Bentonite (Gray-red bed), very light gray in lower part, tan in upper part, swelling	2
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

Belle Fourche shale and parts of adjacent formations northwest of Newcastle in the NW¼ sec. 23, T. 45 N., R. 62 W., Weston County, Wyo.—Continued

Belle Fourche shale—Continued	Feet
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 (bed E), 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 top of unit makes a hard floor for overlying bentonite bed	21
Thickness (rounded) of Belle Fourche shale	370
Mowry shale (part):	
2. Bentonite (Clay Spur bed), very light gray and light brownish-red, slightly swelling	1.1
1. Shale, dark-gray, weathers medium gray, hard	10
Partial thickness (rounded) of Mowry shale	11

GREENHORN FORMATION

The Greenhorn formation consists of shale, limestone, and marl that overlies the Belle Fourche shale and underlies the Carlile shale. Two lithologic facies may be recognized according to the predominant rock type represented: a relatively thick limestone-marl facies exposed at the northeastern and southeastern ends of the outcrop area (pl. 1), and a thinner concretionary facies exposed farther west in the intervening central part of the outcrop area. The Greenhorn formation is more resistant to weathering than adjacent rocks, and it forms a grass- and sage-covered hogback on which the formation commonly is fairly well exposed.

Stratigraphic relations of the Greenhorn and adjacent formations in the northern part of the Black Hills uplift are shown by figures 6 and 7.

Where the Greenhorn formation is represented by the limestone-marl facies, some writers including Darton (1909, p. 54–55), Collier (1922, p. 84), Wing (1940, p. 7), Stevenson (1952, p. 10–11), and Dobbin, Kramer, and Horn (1957) restrict the Greenhorn to slabby rim-forming limestone beds that constitute the uppermost 30 to 60 feet of the Belle Fourche–Greenhorn sequence. Any underlying limestone, marl, or calcareous shale is referred to the Belle Fourche shale. In the present report, and in the work of several other writers including Bramlette and Rubey (in Moore, 1949, fig. 18), Cobban (1951, p. 2183–2184), Knechtel and Patterson (1955, 1962), and Haun (1958, chart 5), the contact of the Greenhorn formation with the underlying Belle Fourche shale is drawn to include in the Greenhorn the

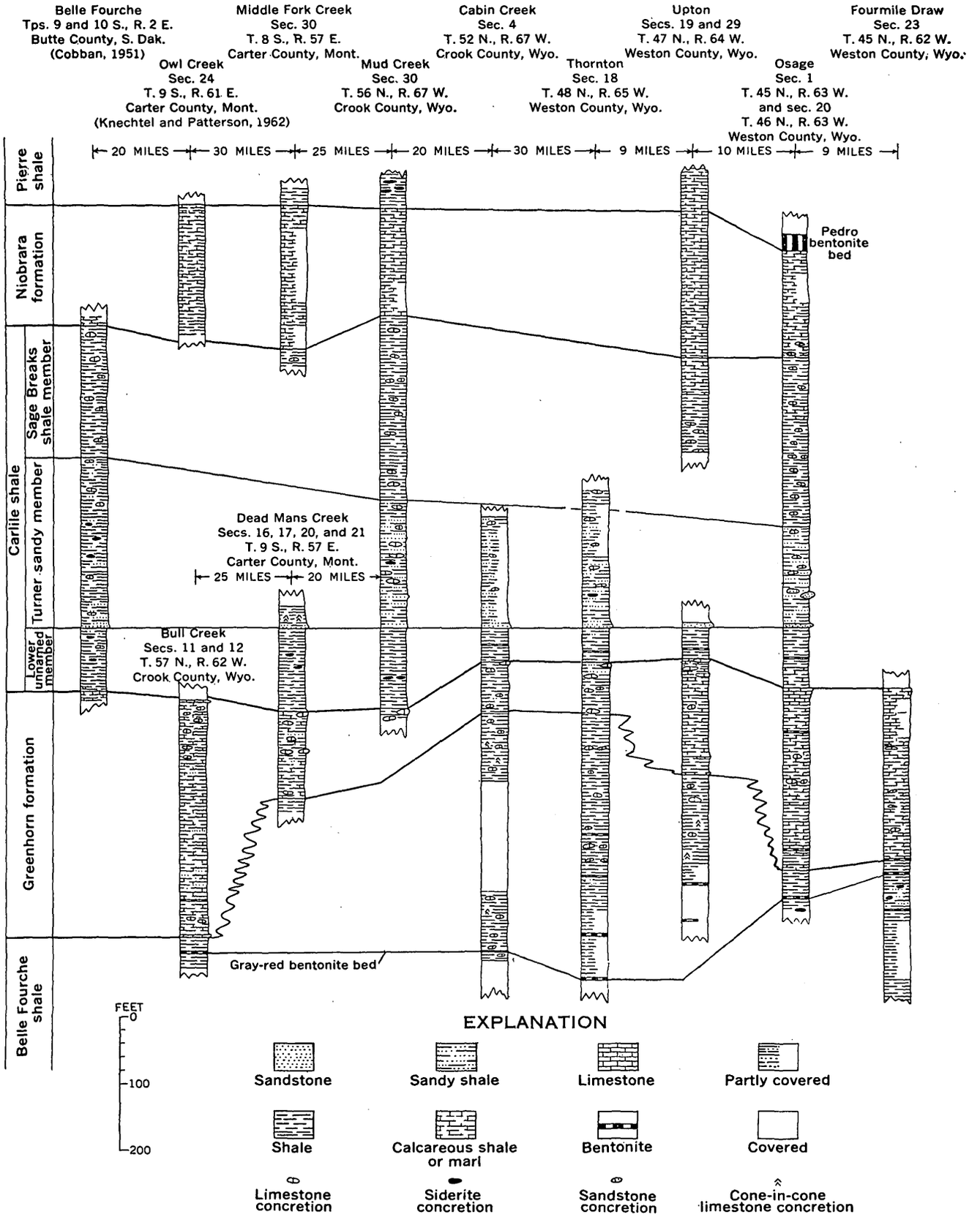


FIGURE 7.—Stratigraphic sections of the Greenhorn, Carlile, and Niobrara formations, northwestern flank of the Black Hills.

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stratigraphically lowest calcareous shale, marl, or persistent limestone beds. The contact accordingly cuts across planes of stratification in areas where calcareous shale and marl in the basal part of the Greenhorn grade into noncalcareous shale of the Belle Fourche (fig. 6).

LIMESTONE-MARL FACIES

The limestone-marl facies of the Greenhorn formation crops out east of a line that extends from a point near Osage, Weston County, Wyo., northward through the Willow Creek anticline in south-central Carter County, Mont. (pl. 1). Beds representing this facies have a maximum observed thickness of about 370 feet near the head of Ghost Creek in sec. 31, T. 57 N., R. 60 W., Crook County, Wyo. From Ghost Creek eastward, the basal bed of the limestone-marl facies is a brown-weathering sandy and shaly gypsiferous limestone averaging about 1 foot in thickness that has been called the Middle Creek limestone (Wing, 1940, p. 6), the Orman Lake limestone (Petsch, 1949, p. 9, 10), and the Bull Creek limestone (Bramlette and Rubey in Moore, 1949, p. 27, fig. 18). The beds lying above the basal limestone have been divided by Cobban (1951, p. 2183–2184) into four units. At the base is 125 to 250 feet of light-gray calcareous mudstone interbedded with marl, shaly limestone, and dark-gray noncalcareous shale. This unit is overlain, in turn, by as much as 80 feet of calcareous shale and marl containing calcareous ferruginous concretions and thin shaly limestone beds; 8 to 22 feet of dark bluish-gray noncalcareous shale; and, at the top of the formation, 8 to 60 feet of marl that weathers grayish-white and contains thin limestone concretions and thin lenses of limestone.

In the Osage-Newcastle area, the limestone-marl facies is 270 to 295 feet thick, thickening gradually southeastward. The lower 200 to 225 feet of the formation in this area consists of interbedded calcareous and noncalcareous shale that weathers to alternating brownish-gray and grayish-black bands and contains a few thin beds of light-gray to tan sandy limestone, light-gray and yellow limestone concretions, and a few thin bentonite beds. At the top of the formation is a ridge-forming unit 30 to 60 feet thick of very calcareous shale and marl with many thin lenticular beds of white-weathering limestone.

CONCRETIONARY FACIES

Within a short distance west of Ghost Creek at the northern end of the mapped area, and northwest of Osage at the southern end, limestone, marl, and calcareous shale, which make up the limestone-marl facies of the Greenhorn formation, interfinger with and pass laterally into slightly calcareous to noncalcareous shale containing fairly abundant limestone concretions. Shale in the lower part of this shale sequence weathers grayish-black and is assigned to the Belle Fourche shale; shale in the upper part weathers olive-gray to brownish-gray and comprises the concretionary facies of the Greenhorn.

The concretionary facies ranges in thickness from 70 to about 100 feet and averages about 90 feet. It crops out in a narrow band from a point about midway between Osage and Upton in Weston County, Wyo., northwestward and northward for about 70 miles to T. 8 S., R. 57 E., Carter County, Mont. Closely spaced septarian limestone concretions that weather light-gray and contain veins of coarsely crystalline white, pale-yellow, and brown calcite characterize the concretionary facies. The concretions commonly are 2 to 6 feet in diameter and form low ridges. Shale in the concretionary facies is less fissile than underlying shale of the Belle Fourche. At some places the shale is sandy, and locally the concretionary facies contains a few beds an inch or two thick of light-gray sandy limestone near the top.

The Greenhorn formation locally contains many fossil marine invertebrates, and fish bones and teeth. Cobban (1951, p. 2184, 2185) listed a large fauna from the limestone-marl facies at the northern end of the Black Hills. The pelecypod *Inoceramus labiatus* (Schlotheim), in particular, characterizes the upper part of the formation both at the northern end of the Black Hills and farther south in the Osage-Newcastle area. Invertebrate fossils collected by W. W. Rubey, and others in 1922–24 from the Greenhorn formation are given in the following tabulation:

Fossils collected from the Greenhorn formation

[Fossils identified by J. B. Reeside, Jr.]

1. Sec. 31, T. 45 N., R. 61 W., 1 mile south of Newcastle, Wyo.
   Loc. 12692, at base of Greenhorn formation.
   Globigerina bulloides d'Orbigny
   Inoceramus labiatus (Schlotheim)
   Ostrea sp., small simple species
   Metoicoceras whitei Hyatt
   Fish scales and bones, undet.
   Loc. 12706, 20 ft above base of Greenhorn formation
   Globigerina bulloides d'Orbigny
   Inoceramus cf. *I. fragilis* Hall and Meek
   Fish tooth
2. SE¼ sec. 5, T. 45 N., R. 62 W.
   Loc. 12038, base of Greenhorn formation.
   Inoceramus sp. fragments
   Metoicoceras whitei Hyatt

3. Sec. 19, T. 47 N., R. 64 W., 4½ miles southeast of Upton, Wyo.
   Loc. 12693, 6 ft below lowest yellow concretions in thin limestone bed, might be considered base of Greenhorn formation.
   Inoceramus cf. *I. fragilis* Hall and Meek
   Astarte n. sp., as in 12683, p. 57, No. 20
   Callista tenuis (Hall and Meek)
   Turnus n. sp., as in 11927, p. 56, No. 7
   Natica sp. fragments
   Sciponoceras sp., very young stages
   Stomohamites aff. *S. corrugatus* (Stanton)
   Puzosia (*Latidorsella*) n. sp.
   Ammonite, n. gen. sp. A
   Decaped crustacean fragments
   Lamna? sp., single tooth
   Loc. 12703, bluish-gray concretion 25 ft below top of Greenhorn formation.
   Astarte n. sp.
   Callista orbiculata (Hall and Meek)
   Loc. 12704, bluish-gray concretions 15 ft below top of Greenhorn formation.
   Inoceramus sp.
   Callista orbiculata (Hall and Meek)
4. Sec. 18(?), T. 48 N., R. 65 W., 2 miles southeast of Thornton, Wyo.
   Loc. 12644, middle zone of gray limestone concretions.
   Inoceramus fragilis Hall and Meek
   Inoceramus sp.
   Astarte n. sp.
   Callista orbiculata (Hall and Meek)
   Polinices n. sp. aff. *P. concinna* (Hall and Meek)
   Fasciolaria sp.
5. NE¼ sec. 15, T. 51 N., R. 67 W., 10 miles northeast of Moorcroft, Wyo.
   Loc. 12685, *Gryphaea* bed at base of Greenhorn formation.
   Gryphaea n. sp.
   Loc. 12672, from concretions forming ridge 35 to 40 ft above *Gryphaea* zone at base of Greenhorn formation.
   Astarte n. sp.
   Callista orbiculata (Hall and Meek)
6. Sec. 4, T. 52 N., R. 67 W., Crook County, Wyo., ¾ mile north of Cabin Creek.
   Loc. 12032, line of large gray limestone concretions 5 ft above base of Greenhorn formation.
   Inoceramus labiatus (Schlotheim)
   Loc. 12029, brown platy sandstone 10 ft above base of Greenhorn formation.
   Astarte n. sp.
   Callista orbiculata (Hall and Meek)
   Loc. 12659, base of Greenhorn formation.
   Gryphaea n. sp.
   Loc. 12645, 5 ft above *Gryphaea* zone.
   Astarte n. sp.
   Callista orbiculata (Hall and Meek)
7. Center sec. 16, T. 52 N., R. 67 W., 16 miles north of Moorcroft, Wyo.
   Loc. 12137, abundant at middle or base of Greenhorn formation.
   Gryphaea n. sp. related to *G. vesicularis* Lamarck
8. Sec. 21, T. 52 N., R. 67 W., 15 miles north of Moorcroft, Wyo.
   Loc. 12664, base of Greenhorn formation.
   Inoceramus sp. fragments
   Gryphaea n. sp.
   Gryphaea newberri Stanton
   Exogyra columbella Meek
   Pecten (*Camptonectes*?) sp.
   Anomia? sp.
   Gyrodes n. sp. aff. *G. conradi* Meek
   Gastropod, undet.
   Loc. 12672, 18 ft above base of light-gray sandy Greenhorn with small pebbles.
   Astarte n. sp.
   Callista orbiculata (Hall and Meek)
   Loc. 12732, upper part of red concretion zone in doubtful Greenhorn (Possibly lower part of Carlile shale).
   Inoceramus fragilis Hall and Meek
   Pteria n. sp. aff. *P. linguaeformis* (Evans and Shumard)
   Astarte n. sp.
   Lucina aff. *L. subundata* Hall and Meek
   Cardium sp.
   Polinices n. sp. aff. *P. concinna* (Hall and Meek)
   Selponoceras sp.
   Stomohamites? aff. *S. corrugatus* (Stanton)
   Metoicoceras whitei Hyatt
9. Sec. 5, T. 55 N., R. 67 W., Crook County, Wyo.
   Loc. 12068.
   Astarte n. sp.
10. N½ sec. 24, T. 57 N., R. 67 W., Crook County, Wyo.
   Locs. 12050 and 12060, slabby limestone at base of Greenhorn formation.
   Inoceramus fragilis Hall and Meek
   Callista orbiculata (Hall and Meek)
   Astarte n. sp.
   Metoicoceras sp., probably *M. whitei* Hyatt
   Fish vertebra and other bones
   Loc. 12046, gray concretions near base of Greenhorn formation.
   Phelopteria gastrodes (Meek)
   Inoceramus sp., fragments
   Boring in wood of *Martesia*?
   Astarte n. sp.
   Lunatia sp. (n. sp.?)
   Metoicoceras whitei Hyatt
   Loc. 12020, top bed of gray calcareous concretions at top (?) of Greenhorn formation.
   Inoceramus sp.
11. SE¼, sec. 4, T. 9 S., R. 59 E., Carter County, Mont.
   Loc. 12635, upper ledge of Greenhorn formation.
   Astarte n. sp.
   Callista orbiculata (Hall and Meek)
12. NE¼ sec. 6, T. 9 S., R. 59 E., Carter County, Mont.
   Loc. 12740, basal bed of Greenhorn formation.
   Puzosia (*Latidorsella*) n. sp.
   Mammites? n. sp.
   Metoicoceras whitei Hyatt
   Ammonite, n. gen., sp. B.
13. NW¼ sec. 30, T. 8 S., R. 59 E., Carter County, Mont.
   Loc. 12636, shale 30 ft above upper limestone ledge of Greenhorn formation.
   Globigerina sp. undet.
   Solemya n. sp.
   Nucula sp. undet.
   Inoceramus fragilis Hall and Meek
   Astarte n. sp.
   Callista orbiculata (Hall and Meek)
   Dentalium n. sp.

14. SW¼ sec. 34, T. 58 N., R. 62 W., Crook County, Wyo.
    Loc. 12640, basal sandy limestone ledge of Greenhorn formation.
    Camptonectes n. sp.
15. SE¼ sec. 11, T. 57 N., R. 62 W., Crook County, Wyo.
    Loc. 12735, basal bed of Greenhorn(?) 300 ft below top of Greenhorn formation.
    Inoceramus fragilis Hall and Meek
    Ammonite, undet.

The varied lithology of the Greenhorn formation is illustrated by the following five stratigraphic sections. Additional sections of the concretionary facies of the Greenhorn formation at Cabin Creek and near the Thornton dome are given on pages 58–59 with descriptions of the underlying Belle Fourche shale.

Parts of the Greenhorn formation (limestone-marl facies) and Belle Fourche shale southwest of Bull Creek in secs. 11 and 14, T. 57 N., R. 62 W., Crook County, Wyo. (See fig. 7.)

Top of hill.

Greenhorn formation (part):	Feet
10. Limestone, gray, sandy; contains poorly preserved oysters and fish bones	3
9. Shale, gray; in the upper half four beds of closely spaced light-gray-weathering septarian limestone concretions with veins of white calcite; basal 5 ft; contains scattered gypsiferous ferruginous nodules as much as 2 in. in diameter	45
8. Shale, gray, calcareous; weathers light gray to light grayish yellow	13
7. Shale, gray, calcareous; weathers light gray to light grayish yellow; contains several beds of closely spaced chalky limestone concretions	26
6. Shale, gray, calcareous; weathers light gray to light yellowish-gray; contains scattered beds ¼ to ½ in. thick of yellowish-gray calcareous sandstone; sandy beds more abundant towards base; weathers to subdued badlands	200
5. Shale, gray, calcareous; upper 3 ft weathers yellowish gray, remainder weathers medium- to light gray; capped by 1-in.-thick bed of yellowish-gray sandy bituminous limestone; a thin bed of bentonite about 10 ft below top; a few brown-weathering limestone concretions as much as 2 ft in diameter about 35 ft below top	65
4. Limestone, gray to brown; contains sandy bituminous layers as much as 1 in. thick; pyrite and phosphatic grains in lower part	3
Partial thickness of Greenhorn formation	355

Belle Fourche shale (part):	
3. Shale, grayish-black, noncalcareous	20±
2. Bentonite (Gray-red bed), pinkish gray at top, grades to grayish white at base; flakes of biotite in lower part	4
1. Shale, grayish-black, noncalcareous	20
Partial thickness of Belle Fourche shale	44±

Greenhorn formation (concretionary facies) in sec. 16, T. 9 S., R. 57 E., Carter County, Mont.

Carlile shale (part):	Feet
Lower unnamed member (part):	
7. Shale, dark-gray to black, weathers dark gray, noncalcareous	10
Greenhorn formation:	
6. Shale, dark brownish-gray, calcareous; contains scattered yellowish-brown-weathering septarian limestone concretions with veins of coarsely crystalline light-gray calcite; concretions as much as 4 ft long; a few thin beds of light brownish-gray sandy fossiliferous limestone	25
5. Shale, dark brownish-gray, very calcareous; contains several beds of closely spaced light-gray-weathering limestone concretions; concretions are 2 to 6 ft in diameter, locally slightly sandy	17
4. Shale, dark-gray to dark brownish-gray, calcareous; a bed of medium-gray septarian limestone concretions form prominent ridge about 25 ft below top; concretions contain veins of yellow-brown calcite and are 3 to 5 ft in diameter	70
3. Shale, medium- to dark-gray, very calcareous; some interbedded medium- to light-gray sandy limestone near top and base; limestone beds are ¼ to 1 in. thick and contain fish teeth	5
2. Shale, dark-gray, locally calcareous; beds of dark-gray limestone concretions at top and base; concretions are 2 to 3 ft in diameter, weather gray to light brown	9
Thickness of Greenhorn formation	126
Belle Fourche shale:	
1. Shale, medium-gray, noncalcareous	20

Greenhorn formation (concretionary facies) north of Mud Creek in the SE¼ sec. 30, T. 56 N., R. 67 W., Crook County, Wyo.

Carlile shale.

Greenhorn formation:	Feet
5. Shale, dark-gray to black, weathers light gray and brownish gray; calcareous along concretion zones; medium- to light-gray limestone concretions 1 to 6 ft long and ½ to 3 ft thick at top of unit and 25 and 41 ft above base; concretions cut by numerous light- to brownish-gray coarsely crystalline calcite veins 1/10 to ½ in. wide	45
4. Shale, dark-gray and brownish-gray; at the top a bed of closely spaced light-gray-weathering septarian limestone concretions with veins of light- to brownish-gray calcite; a bed of sandy limestone about 1 in. thick at base of concretion layer; scattered gray limestone concretions in upper half	22
3. Sandstone, medium-gray to brownish-gray, weathers tan, fine-grained, calcareous, platy	1

Greenhorn formation (concretionary facies) north of Mud Creek in the SE¼ sec. 30, T. 56 N., R. 67 W., Crook County, Wyo.—Continued

	Feet
Greenhorn formation—Continued	
2. Shale, dark grayish-brown; a few partings of light-gray calcareous sandstone	14
1. Shale, dark grayish-brown; a bed of yellowish-brown-weathering limestone concretions at top; concretions 2 to 4 ft long and 1 to 2 ft thick	5
Thickness of Greenhorn formation	87

Belle Fourche shale.

Greenhorn formation (limestone-marl facies) and parts of adjacent formations near Osage in the SW¼ sec. 17, T. 46 N., R. 63 W., Weston County, Wyo.

[Fossils identified by W. A. Cobban]

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

Greenhorn formation (limestone-marl facies) and parts of adjacent formations near Osage in the SW¼ sec. 17, T. 46 N., R. 63 W., Weston County, Wyo.—Continued

	Feet
Greenhorn formation—Continued	
8. Limestone, as in unit 12 above	0.3
7. Shale, grayish-black, noncalcareous, flaky	16
6. Shale, dark-gray to grayish-brown, calcareous	10
5. Limestone, dark-gray, silty, discontinuous	.5
Thickness (rounded) of Greenhorn formation	270
Belle Fourche shale (part):	
4. Shale, grayish-black, noncalcareous, flaky; scattered red-weathering silty siderite concretions	38
3. Bentonite (Gray-red bed), very light gray at top and base, light-brown to pinkish-brown in middle, swelling; chips of yellowish-gray aragonite weathering from upper part	2.3
2. Limestone, light-gray, very fossiliferous, discontinuous	.1
1. Shale, grayish-black, noncalcareous, flaky	10
Partial thickness (rounded) of Belle Fourche shale	50

Greenhorn formation (limestone-marl facies) and parts of adjacent formations near Newcastle in the NW¼ sec. 31, T. 45 N., R. 61 W., Weston County, Wyo.

[Measured by W. A. Cobban, written communication, 1959]

	Feet
Carlile shale (part):	
Lower unnamed member (part):	
19. Shale, dark bluish-gray, weathers gray brown, variably calcareous; contains a few thin limestone lenses and some soft yellowish-gray limestone concretions	55
Greenhorn formation:	
18. Shale, gray, calcareous; numerous thin lenticular beds of finely crystalline light-gray limestone that contain fragments of *Inoceramus labiatus;* forms prominent hogback	40
17. Shale, gray, calcareous; near the middle a bed of gray shaly limestone that contains *Inoceramus labiatus*	13
16. Bentonite, light yellowish-gray, stained rusty	.5
15. Shale, grayish-black, noncalcareous	15
14. Limestone, light-gray, weathers tan; partings of gray calcareous shale; forms ledge	1
13. Shale, gray, calcareous; several beds of light-gray septarian limestone concretions that weather tan and have veins of pale-yellow calcite	10
12. Shale, dark-gray and noncalcareous in lower part, light-gray and calcareous at top	16
11. Shale, dark-gray, noncalcareous; at least 8 thin beds of light-gray to tan limestone; limestone beds mostly less than 2 in. thick, have local ripple marks and worm trails	27
10. Shale, gray, calcareous; numerous very thin lenses of limestone	6

Greenhorn formation (limestone-marl facies) and parts of adjacent formations near Newcastle in the NW¼ sec. 31, T. 45 N., R. 61 W., Weston County, Wyo.—Continued

	Feet
Greenhorn formation—Continued	
9. Shale, dark-gray, mostly noncalcareous to slightly calcareous; a few thin limestone beds and some soft limestone concretions that weather yellow and red	132
8. Limestone, gray, weathers tan, shaly	.3
7. Shale, dark-gray, weathers light-gray, calcareous	12
6. Bentonite, light yellowish-gray, stained rusty	.4
5. Shale, gray, weathers light gray, calcareous; a few thin limestone seams that weather tan	20
4. Limestone, light-gray, weathers tan, very finely crystalline; abundant fragments of *Inoceramus;* a few shaly partings; forms a ledge	.9
Thickness (rounded) of Greenhorn formation	295
Belle Fourche shale (part):	
3. Shale, dark-gray, fissile	17
2. Bentonite (Gray-red bed), mostly light-gray, some parts pinkish lavender	3.0
1. Shale, dark-gray, fissile	25
Partial thickness of Belle Fourche shale	45

CARLILE SHALE

The Carlile shale is a dark marine shale—somewhat sandy in its middle part—that conformably overlies the Greenhorn formation, and is conformably overlain by the Niobrara formation. The Carlile ranges in thickness from about 450 feet near Newcastle, Wyo., to about 600 feet in southwestern Carter County, Mont. It is about 500 feet thick near Stroner in northwestern Crook County, and about 550 feet thick on the flanks of the Colony anticline in northeastern Crook County. At some places beds of sandstone or closely spaced concretions in the Carlile hold up one or more low ridges, but for the most part the formation is easily eroded, and it generally forms shallow valleys or low rolling hills.

The Carlile shale is divided into three members, which in ascending order are an unnamed lower member, the Turner sandy member, and the Sage Breaks member. The three members can be distinguished by their distinctive concretions, and in addition the Turner sandy member differs from the others by having appreciable amounts of sandstone.

Marine invertebrate fossils representing several faunal zones have been reported from the three members of the Carlile shale in the Black Hills region. Cobban (1951, p. 2187–2190) has described in some detail for the northern Black Hills the lithology of the formation, its fossil content, and its correlation with rocks in central Montana.

LOWER UNNAMED MEMBER

The lower unnamed member of the Carlile shale consists mostly of dark-gray shale containing a few calcareous or ferruginous concretions. The member is 100 feet thick at Newcastle and about 90 feet thick near Osage. It thins to about 40 feet at Thornton dome, a few miles northwest of Upton, Wyo., and is 40 to 80 feet thick from Thornton dome northward to Cabin Creek in T. 52 N., R. 67 W., Crook County, Wyo. The member thickens north of Cabin Creek and is 80 to about 130 feet thick in northern Crook County, Wyo., and southern Carter County, Mont.

Cobban (1951, p. 2187) recognized two lithologic units in the lower member in the northern Black Hills. He described these as (a) a lower unit, 13 feet thick near Belle Fourche, S. Dak., that consists of dark-gray papery shale containing some thin calcareous shale partings, a few seams as much as half an inch thick of buff-weathering limestone, and at the top, a bed of bluish-white or buff-weathering limestone concretions; and (b) an upper unit about 80 feet thick of dark-gray shale containing two thin bentonite beds in the lower part and numerous ironstone concretions in the top half. The ferruginous concretions characterize the upper part of the member in the northern Black Hills, but become less abundant southward and are absent in Weston County, Wyo. Near Osage (sec. 20, T. 46 N., R. 63 W.), the lower unnamed member consists of dark-gray slightly silty shale, which is locally calcareous in the basal part and which contains two thin bentonite beds and a few yellowish-gray limestone concretions in the middle part.

Regarding the fossils found in the lower unnamed member of the Carlile shale in the northern Black Hills, Cobban (1951, p. 2187–2188) stated:

> Fossils, which are abundant in the unnamed member of the Carlile shale, indicate two distinct faunas. The lower, characterized by *Inoceramus fragilis* Hall and Meek, *Scaphites larvaeformis* Meek and Hayden, and *Collignoniceras woollgari* (Mantell), is typical of the Fairport chalky shale member of the Carlile shale of Kansas. The upper fauna, characterized by *Scaphites carlilensis* Morrow, and *Collignoniceras hyatti* (Stanton) marks the Blue Hill shale member of the Carlile shale of Kansas.

In the southern part of the mapped area are fossils that correspond to the lower zone, as noted by Cobban at the northern end of the area, but none were found representing the upper zone. Fossils collected by W. W. Rubey and others from 1922 to 1924 are tabulated below. Additional fossils are listed with the stratigraphic sections on pages 73–74.

Fossils collected from the lower unnamed member of the Carlile formation

[Fossils identified by J. B. Reeside, Jr.]

1. Sec. 2, T. 44 N., R. 61 W., 2 miles west and north of LAK Ranch, Weston County, Wyo.
   Loc. 11192, 75 ft above base of Carlile shale.
   Inoceramus fragilis Hall and Meek
   Collignoniceras woollgari (Mantell)
   Tragodesmoceras n. sp.
2. Sec. 32, T. 45 N., R. 61 W., 1.5 miles south of Newcastle, Wyo.
   Loc. 11190, limy concretions in basal shale of Carlile.
   Inoceramus fragilis Hall and Meek
   Anisomyon n. sp.
   Scaphites larvaeformis Meek and Hayden
   Collignoniceras woollgari (Mantell)
   Hypsodon? sp.
   Loc. 12665, in concretions 60 ft above base of Carlile shale.
   Inoceramus fragilis Hall and Meek
   Ostrea sp., small simple form
   Anchura n. sp.
   Scaphites larvaeformis Meek and Hayden
   Tragodesmoceras sp.
   Collignoniceras woollgari
   Fish scale, undet.
3. Sec. 5, T. 45 N., R. 62 W.
   Loc. 11198, about 1½ miles east of Pedro Station.
   Inoceramus fragilis Hall and Meek
   Ostrea sp.
   Collignoniceras woollgari (Mantell)
4. Sec. 5, T. 45 N., R. 62 W.
   Loc. 11199, about 1¼ miles east of Pedro Station.
   Inoceramus fragilis Hall and Meek
   Collignoniceras woollgari (Mantell)
   Tragodesmoceras n. sp.
5. NE¼ sec. 8, T. 45 N., R. 62 W.
   Loc. 12059, upper bed of concretions from lower part of Carlile shale.
   Inoceramus fragilis Hall and Meek
   Collignoniceras sp.
   Fish bone.
6. Sec. 18, T. 48 N., R. 65 W., 2 miles southeast of Thornton, Wyo.
   Loc. 12628, 40 ft below base of Turner sandy member.
   Inoceramus sp. fragments
   Ostrea sp., small simple form
   Loc. 12708, 60 ft. below base of Turner sandy member.
   Inoceramus fragilis Hall and Meek
   Plicatula cf. *P. hydrotheca* (White)
   Astarte n. sp.
   Callistta orbiculata (Hall and Meek)
   Polinices n. sp. aff. *P. concinna* (Hall and Meek)
   Fasciolaria walcotti Stanton
   Baculites sp.
7. NE¼ sec. 13, T. 48 N., R. 66 W.
   Loc. 11928, 2 miles southeast of Thornton, Wyo.
   Callista orbiculata (Hall and Meek)
8. Center sec. 21, T. 52 N., R. 67 W., 15 miles north of Moorcroft, Wyo.
   Loc. 12725, 50 ft below base of Turner sandy member.
   Collignoniceras sp.
9. Sec. 21, T. 9 S., R. 57 E., Carter County, Wyo.
   Loc. 12681.
   Ostrea sp.
   Collignoniceras woollgari (Mantell)
   Fish scales and bones

TURNER SANDY MEMBER

Rubey (1931, p. 4) named the Turner sandy member of the Carlile shale for exposures of dark-gray sandy shale and sandstone along Turner Creek in Tps. 46 and 47 N., R. 64 W., Weston County, Wyo. The member is 150 feet thick in sec. 20, T. 46 N., R. 63 W. and in nearby areas to the south. It thickens northeastward to about 210 feet in secs. 3 and 4, T. 57 N., R. 61 W. (Knechtel and Patterson, 1962, p. 922), and 260 feet thick near Belle Fourche in sec. 11, T. 9 N., R. 2 E., S. Dak. (Cobban, 1951, p. 2188).

The base of the Turner sandy member is the base of a ledge-forming bed of light-gray fine- to coarse-grained calcareous sandstone as much as 5 feet thick. The sandstone is conglomeratic locally with granules and small pebbles of chert and phosphatic material. Abundant well-preserved fish teeth characterize the bed at many localities. The remainder of the member consists of dark-gray shale and sandy shale, a few thin beds and laminae of siltstone and sandstone, and many yellow-weathering silty limestone concretions, the largest of which are as much as 5 feet thick and 10 feet long. The concretions commonly are septarian with veins of yellow and brown calcite. In general, the member is somewhat more sandy in Weston County than it is farther to the north. Near Osage it contains several lenticular beds of sandstone and shaly sandstone 3 to 4 feet thick. In the Osage-Newcastle area, several beds of large conspicuous brown-weathering calcareous sandstone concretions crop out 20 to 40 feet above the base of the member and make a series of prominent ledges that may be traced for several miles.

A large and varied invertebrate marine fauna has been previously reported from the Turner sandy member in the northern Black Hills (Cobban, 1951, p. 2188, 2189). Fossils collected by W. W. Rubey and others from 1922 to 1924 are tabulated below, and the fossils collected by the authors are listed in the measured sections pages 72–73.

Fossils collected from the Turner sandy member of the Carlile shale

[Fossils identified by J. B. Reeside, Jr.]

1. Sec. 2, T. 44 N., R. 61 W.
   Loc. 11185, 3 miles southeast of Newcastle, Wyo., and half a mile east of highway.
   Inoceramus fragilis Hall and Meek
   Scaphites warreni Meek and Hayden
   Vertebral centrum of fish

Loc. 12691, 20 ft. above base of Turner sandy member of the Carlile shale.
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
Prionocylus wyomingensis Meek

2. Sec. 3 or 4, T. 44 N., R. 61 W., 2.5 miles south of Newcastle, Wyo.
Loc. 11189, in sandstone 350 ft. above top of Greenhorn formation.
Prionocyclus wyomingensis Meek
Scaphites warreni Meek and Hayden

3. Sec. 5, T. 45 N., R. 62 W., about 1.5 miles southeast of Pedro siding, Wyo.
Loc. 11200.
Scaphites corvensis Cobban
Fish scales, probably *Hypsodon lowoii* (Stewart) Cockerell
Loc. 11201
Inoceramus fragilis Hall and Meek
Loc. 11202
Inoceramus cf. *I. dimidius* White
Baculites cf. *B. besairiei* Collignon
Loc. 11203
Ostrea sp.

4. Sec. 6, T. 45 N., R. 62 W., along road near Pedro, Wyo., from base of Turner sandy member of the Carlile shale
Isurus cf. *I. hastalis* Agassiz

5. Sec. 25, T. 45 N., R. 62 W., on highway 2 miles west of Newcastle, Wyo.
Loc. 11184, 350 ft. above Greenhorn formation.
Inoceramus fragilis Hall and Meek
Lunatia sp.
Aporrhais prolabiata (White)
Prionocyclus wyomingensis Meek
Prionocyclus n. sp., possibly the adult of the little form described as *Mortonicoras vermilionense* Meek
Helicoceras? n. sp.

6. Sec. 35, T. 46 N., R. 63 W., 2.5 miles northwest of Pedro siding, Wyoming.
Loc. 11206.
Nucula coloradoensis Stanton
Inoceramus fragilis Hall and Meek
Ostrea sp., small simple species
Lucina aff. *L. juvensis* Stanton
Corbula nematophora Meek
Anchura sp.
Vanikuro? sp.
Scaphites warreni Meek and Hayden
Loc. 11207.
Inoceramus aff. *I. labiatus* (Schlotheim)
Loc. 12702, base of Turner sandy member of the Carlile shale.
Ptychodus sp.
Isurus sp.
Lamna sp.
Corax sp.
Myliobatis? sp.
Fuchodus sp.

7. Sec. 20, T. 46 N., R. 63 W., about 1.5 miles southwest of Osage, Wyo.
Loc. 11214, from base of Turner sandy member of Carlile shale.
Prionocyclus wyomingensis Meek
Ptychodus sp.
Isurus sp.
Lamna sp.
Corax sp.

8. Sec. 4, T. 52 N., R. 67 W.
Loc. 12647, 5 miles south of Oshoto, Wyo.
Phelopteria gastrodes (Meek)
Inoceramus fragilis Hall and Meek
Ostrea sp.
Polinices cf. *P. concinna* (Hall and Meek)
Fasciolaria? sp.
Baculites sp.
Scaphites warreni Meek and Hayden
Prionocyclus wyomingensis Meek

9. Sec. 21, T. 52 N., R. 67 W., 15 miles north of Moorcroft, Wyo.
Loc. 12188, pebbles from base of Turner sandy member of Carlile shale.
Inoceramus sp.
Scaphites warreni Meek and Hayden
Baculites sp.
Prionocyclus sp., ends of spines
Fish teeth, probably *Lamna cuspidata* Agassiz
Bone fragments
Loc. 12668, 10 ft above base of Turner sandy member of Carlile shale.
Inoceramus fragilis Hall and Meek
Scaphites warreni Meek and Hayden
Prionocyclus wyomingensis Meek
Loc. 12655, 20 ft above base of Turner sandy member of Carlile shale.
Inoceramus fragilis Hall and Meek
Anchura n. sp.
Scaphites warreni Meek and Hayden
Prionocyclus wyomingensis Meek

10. Sec. 33, T. 54 N., R. 67 W., 3 miles north of Oshoto, Wyo.
Loc. 12630, middle of Turner sandy member of Carlile shale.
Inoceramus fragilis Hall and Meek
Scaphites warreni Meek and Hayden

11. Sec. 5, T. 55 N., R. 67 W., Crook County, Wyo.
Loc. 12048.
Inoceramus fragilis Hall and Meek
Prionocyclus sp.

12. Sec. 31, T. 56½ N., R. 67 W., Crook County, Wyo.
Loc. 12022, near middle of series of yellow sandy concretions near top of Turner sandy member of Carlile shale.
Inoceramus fragilis Hall and Meek

13. NE¼ sec. 31, T. 58 N., R. 66 W., Crook County, Wyo.
Loc. 12669, near base of bright-yellow concretions in upper part of Turner sandy member of Carlile shale.
Inoceramus fragilis Hall and Meek
Prionocyclus wyomingensis Meek

14. Sec. 17, T. 9 S., R. 57 E., 12 miles east of Ridge, Mont.
    Loc. 12737, near top of Turner sandy member of Carlile shale.
    Nucula sp.
    Inoceramus fragilis Hall and Meek
    Anchura sp.
    Scaphites sp.
    Prionocylus wyomingensis Meek
15. NE¼ sec. 35, T. 9 S., R. 61 E., Carter County, Mont.
    Loc. 12638, top of yellow concretion zone at top of Turner sandy member of Carlile shale.
    Proplacenticeras pseudoplacenta (Hyatt)
16. SE¼ sec. 9, T. 8 S., R. 58 E., Carter County, Mont.
    Loc. 12634, 13 ft above base of Turner sandy member of Carlile shale.
    Yoldia n. sp.
    Inoceramus fragilis Hall and Meek
    Cardium pauperculum Meek
    Polinices n. sp. aff. *P. concinna* (Hall and Meek)
    Fusus sp.
    Scaphites warreni Meek and Hayden
    Numerous fish bones, phosphate nodules, and fragments of carbonized wood

SAGE BREAKS MEMBER

The Sage Breaks member was named by Rubey (1931, p. 4) for beds of grayish-black noncalcareous shale exposed at the Sage Breaks in T. 46 N., R. 63 W., Weston County, Wyo. Rubey redefined the overlying Niobrara formation in the northwestern part of the Black Hills to include the Sage Breaks as a lower member; more recently the Sage Breaks has been considered the uppermost member of the Carlile (Cobban, 1951, p. 2187; Cobban and Reeside, 1952, chart 10b).

The Sage Breaks member is 250 feet thick near Pedro, in sec. 1, T. 45 N., R. 63 W., Weston County, Wyo., and it has about the same thickness in most parts of western Crook County, Wyo., and western Carter County, Mont. Knechtel and Patterson (1962, p. 924) reported a thickness of about 300 feet for the Sage Breaks member in secs. 34 and 35, T. 58 N., R. 61 W., northeastern Crook County, and Cobban (1951, p. 2189) measured a total of 195 feet for the Sage Breaks a few miles farther to the east in T. 9 N., R. 2 E., Butte County, S. Dak.

The Sage Breaks member is characterized by abundant light-gray-weathering septarian limestone concretions containing veins of brown, yellow, and white calcite. Most of the concretions are about 1 foot in diameter, but some may be as much as 5 feet. Individual concretion beds are persistent for many miles and are useful locally for correlation. The shale weathers dark gray to black and forms gentle slopes and flats that at many places are nearly bare of soil or vegetation.

Fossils are scarce in the Sage Breaks member, and those that have been found are commonly poorly preserved. The fossils collected by W. W. Rubey and others in 1922 to 1924 are tabulated below:

697-728—64——6

Fossils collected from the Sage Breaks member of the Carlile shale

[Fossils identified by J. B. Reeside, Jr.]

1. Sec. 6, T. 45 N., R. 62 W., half a mile south of Pedro siding, Wyoming.
   Loc. 12679, about middle of Sage Breaks member of the Carlile shale.
   Yoldia cf. *Y. scitula* (Meek and Hayden)
   Ostrea sp.
   Inoceramus cf. *I. deformis* Meek
   Anchura ruida White
2. Sec. 8, T. 45 N., R. 62 W., south of Pedro siding, Wyoming.
   Loc. 12058, near middle of Sage Breaks member of Carlile shale.
   Inoceramus sp., thick shelled, cf. *I. deformis* Meek
3. Sec. 4, T. 45 N., R. 63 W., Weston County, Wyo.
   Loc. 11225, lower part of Sage Breaks member of Carlile shale.
   Inoceramus cf. *I. deformis Meek*
   Ostrea congesta Conrad
   Baculites sp.
4. Sec. 4, T. 48 N., R. 66 W., railroad cut about 2 miles northwest of Thornton, Wyo.
   Loc. 12627, lower part of Sage Breaks member of Carlile shale.
   Inoceramus sp.
   Lucina? sp.
5. Sec. 4, T. 48 N., R. 66 W.
   Loc. 11925, west of Thornton, Wyo.
   Callista tenuis (Hall and Meek)
   Corbula nematophora Meek
   Anchura cf. *A. ruida* White
   Fossil wood
6. NW¼ sec. 14, T. 57 N., R. 67 W., Crook County, Wyo.
   Loc. 12738, upper part of Sage Breaks member of Carlile shale.
   Inoceramus sp.
   Callista? sp.
   Loc. 12736, from about middle of Sage Breaks member of Carlile shale.
   Veniella goniophora Meek
   Baculites sp.
7. Sec. 4, T. 8 S., R. 57 E., Carter County, Mont.
   Loc. 12632, middle of Sage Breaks member of Carlile shale.
   Inoceramus n. sp.
   Veniella goniophora Meek
   Fusus n. sp.
   Anisomyon n. sp.
   Scaphites convensis Cobban
8. N½ sec. 5, T. 8 S., R. 58 E., Carter County, Wyo.
   Loc. 12637, 20 ft above base of Sage Breaks member of Carlile shale.
   Scaphites corvensis Cobban
9. N½ sec. 34, T. 7 S., R. 58 E., Carter County, Mont.
   Loc. 12670.
   Globigerina? sp.
   Inoceramus n. sp.
   Anchura sp.
   Anisomyon n. sp.
   Baculites sp.
   Scaphites sp.

Following are seven sections of the different members of the Carlile shale measured on the northern and western flanks of the Black Hills. Some of these sections are shown graphically on figure 7.

Sage Breaks and Turner sandy members of the Carlile shale on the east side of the Colony anticline in secs. 34 and 35, T. 58 N., R. 61 W., and secs. 3 and 4, T. 57 N., R. 61 W., Crook County, Wyo.

[After Knechtel and Patterson, 1962, p. 923–925]

	Feet
Niobrara formation (part):	
1. Marl, brownish-gray, weathers very light gray.	
Carlile shale (part):	
Sage Breaks member:	
2. Shale, gray, fissile; grades into overlying marl through a zone about 10 in. thick	48
3. Shale, gray, fissile; zone of limestone concretions at top which are veined with black calcite and are 8 in. thick and 10 ft long	6
4. Shale, gray, weathers light gray	2
5. Shale, gray, weathers light gray; zone of light-gray limestone concretions at top which are veined with brown calcite and average 2 ft thick and 4 ft long; fossil fragments abundant in concretions	10
6. Shale, gray, weathers light gray; zone of light-gray limestone concretions at top which are veined with brown and yellow calcite and average 3 ft thick and 4½ ft long	8
7. Shale, gray, fissile; zone of limestone concretions at top which are veined with brown calcite and average 1½ ft thick and 3½ ft long	31½
8. Shale, gray, fissile; zone of limestone concretions at top which weather very light gray, are veined with brown calcite, and are as much as 14 in. thick and 5 ft long	14
9. Shale, gray, fissile; zone of light-gray limestone concretions at top which are veined with light-yellow calcite and average 1 ft thick and 2½ ft long	16
10. Shale, gray, fissile; zone of limestone concretions at top which are veined with dark-brown calcite and average 10 in. thick and 1½ ft long	3
11. Shale, gray, fissile; zone of limestone concretions at top which are veined with dark-brown calcite and average 10 in. thick and 1 ft long	7
12. Shale, gray, fissile; zone of limestone concretions at top which are veined with white and brown calcite and average 2½ ft thick and 5½ ft long; concretions make prominent ridge	54
13. Shale, gray, fissile; zone of light-gray limestone concretions at top which are veined with white calcite and average 3 ft thick and 8 ft long; concretions make prominent ridge	26

Sage Breaks and Turner sandy members of the Carlile shale on the east side of the Colony anticline in secs. 34 and 35, T. 58 N., R. 61 W., and secs. 3 and 4, T. 57 N., R. 61 W., Crook County, Wyo.—Continued

	Feet
Carlile shale (part)—Continued	
Sage Breaks member—Continued	
14. Shale, gray, fissile; zone of limestone concretions at top which are veined with dark-brown calcite and average 8 in. thick and 1½ ft long	40½
15. Shale, gray, fissile; zone of light-gray limestone concretions at top which are veined with yellow and brown calcite and average 2 ft thick and 4 ft long	22½
16. Shale, gray, fissile; zone of gray limestone concretions at top which are veined with yellow calcite and average 2 ft thick and 3 ft long	10
Thickness (rounded) of Sage Breaks member	298
Turner sandy member:	
17. Shale, gray, very sandy, weathers yellowish gray	3
18. Shale, gray, very sandy, weathers yellowish gray; at top a zone of calcareous concretions that weather light brown and average 1½ ft thick and 3 ft long	11
19. Shale, gray, very sandy, weathers yellowish gray; many large calcareous concretions that weather light orange brown; concretions form low ridge	13
20. Shale, dark-gray; many calcareous concretions that weather reddish brown and average 10 in. thick and 1 ft long	11
21. Shale, dark-gray, fissile; at top, zone of calcareous concretions that weather light buff and average 1 ft thick and 1½ ft long	8
22. Shale, gray, fissile; at top, zone of brown clayey ironstone concretions that are very fossiliferous and average about 1½ ft thick and 2½ ft long	4
23. Shale, dark-gray; at top, zone of fossiliferous calcareous concretions that weather light brown and average 2 ft thick and 3 ft long	7
24. Shale, dark-gray, fissile; at top, zone of calcareous concretions that weather reddish brown and average 8 in. thick and 1 ft long	4½
25. Shale, same as unit 24	14
26. Shale, dark-gray, lower part sandy; at top zone of gray limestone concretions that weather light yellowish brown and average 4 ft thick and 6 ft long	31½
27. Poorly exposed; mostly dark-gray shale; at top, zone of fossiliferous limestone concretions which weather light buff and average 2 ft thick and 3 ft long; thin calcareous cone-in-cone lenses above most of the concretions	51
28. Sandstone, gray, medium-grained, cross-bedded, calcareous, concretionary; many calcareous cone-in-cone lenses in upper part	2½

Sage Breaks and Turner sandy members of the Carlile shale on the east side of the Colony anticline in secs. 34 and 35, T. 58 N., R. 61 W., and secs. 3 and 4, T. 57 N., R. 61 W., Crook County, Wyo.—Continued

Carlile shale (part)—Continued

Turner sandy member—Continued

	Feet
29. Shale, dark-gray; interbedded light-gray calcareous sandstone in beds as much as 1½ in. thick	47
Thickness (rounded) of Turner sandy member	208

Lower unnamed member.

Parts of the Carlile shale and Greenhorn formation in sec. 21, T. 9 S., R. 57 E., Carter County, Mont.

Carlile shale (part):

Turner sandy member (part):

	Feet
5. Shale, dark-gray; about 20 ft above base, a bed of cone-in-cone limestone concretions; weathers yellowish gray	30
4. Sandstone, light-gray, fine- to medium-grained, calcareous; numerous dark grains give a speckled appearance	½
Partial thickness of Turner sandy member	30½

Lower unnamed member:

3. Shale, dark-gray; a few laminae of very fine grained sandstone; a bed of rusty-weathering limestone concretions about 90 ft above base	132
Partial thickness (rounded) of Carlile shale	162

Greenhorn formation (part):

2. Limestone, light-gray, platy, slightly bituminous	8
1. Shale, gray, weathers grayish brown, noncalcareous; several beds of limestone concretions that weather light gray	55
Partial thickness of Greenhorn formation	63

Carlile shale near Mud Creek in sec. 30, T. 56 N., R. 67 W., Crook County, Wyo. (see fig. 7)

Niobrara formation.

Carlile shale:

Sage Breaks member:

	Feet
17. Partly covered; appears to be mostly grayish-black noncalcareous shale; scattered septarian limestone concretions that weather light gray and contain veins of yellowish-brown calcite	93
16. Shale, grayish-black, noncalcareous; at top, a prominent bed of septarian limestone concretions that weather light gray, contain veins of brown and yellow calcite, and are 4 to 10 ft long and 2 to 4 ft thick; smaller gray limestone concretions about 8 ft below top	29

Carlile shale near Mud Creek in sec. 30, T. 56 N., R. 67 W., Crook County, Wyo. (see fig. 7)—Continued

Carlile shale—Continued

Sage Breaks member—Continued

	Feet
15. Shale, grayish-black, noncalcareous; scattered septarian limestone concretions that weather light gray	49
14. Shale, grayish-black, noncalcareous; at top, a prominent bed of septarian limestone concretions that weather light gray and are as much as 10 ft long and 4 ft thick; smaller light-gray septarian limestone concretions about 17 ft above base	76
13. Shale, grayish-black to brownish-gray, noncalcarous; at top, a bed of septarian limestone concretions that weather light gray, contain veins of brown and yellow calcite, and are 1 to 2 ft long and about ½ ft thick	26
Thickness of Sage Breaks member	273

Turner sandy member:

12. Shale, gray and brownish-gray with a few thin laminae of gray sandy shale; scattered dark-gray sandy septarian limestone concretions that weather yellowish brown, contain veins of dark- and light-brown calcite, and are 2 to 4 ft long and 1 to 2 ft thick	42
11. Shale, brownish-gray to medium-gray, sandy and silty; 3 ft below top, a bed of tan limestone concretions ½ to 1 ft long and ½ to ¾ ft thick	12
10. Sandstone, brown to light reddish-brown, very fine grained to silty, thin-bedded, calcareous; a few shale partings; scattered limestone concretions that weather yellowish gray	1
9. Shale, brownish-gray to medium-gray, silty; beds of dark-gray silty limestone concretions 12 and 16 ft below top; concretions weather yellowish brown to reddish brown and are 1 to 5 ft long and ¼ to 2 ft thick; a few similar concretions scattered throughout unit	23
8. Shale, dark-gray to brownish-gray, sandy and silty; at base, a bed 3 in. thick of dark reddish-brown calcareous siltstone that contains numerous dark-gray sandy and silty fossiliferous limestone concretions; concretions are ½ to 5 ft long and ¼ to 2 ft thick; similar concretions at top and 10 ft below top of unit	31
7. Shale, dark-gray to black, silty; stained with iron oxides on the bedding surfaces; 11 ft below top, a bed of yellowish-gray silty limestone concretions 1 to 3 ft long and ½ to 2 ft thick	36

Carlile shale near Mud Creek in sec. 30, T. 56 N., R. 67 W., Crook County, Wyo. (see fig 7)—Continued

Carlile shale—Continued

Turner sandy member—Continued

	Feet
6. Sandstone, dark reddish-brown, fine to very fine grained, shaly; contains silty limestone concretions that weather yellowish gray, are 1 to 3 ft long and ½ to 1 ft thick, and yield *Inoceramus* sp., *Baculites* sp., and *Prionocyclus wyomingensis* Meek (fossils identified by W. A. Cobban)	1
5. Shale, dark-gray to black, weathers dark and brownish gray, slightly silty; a few scattered dark-gray limestone concretions 1 to 3 ft long and ½ to 2 ft thick	45
Thickness of Turner sandy member	191

Lower unnamed member:

4. Poorly exposed; appears to be mostly grayish-brown bentonitic shale; numerous veins ½ to 1 in. thick of aragonite in lower part	9
3. Shale, dark-gray to grayish-black; red-weathering concretions at base 2 to 4 ft long and ½ to 1 ft thick; concretions contain fragments of *Inoceramus* and *Scaphites*	72
2. Shale, dark-gray to grayish-black	41
Thickness of lower unnamed member	122
Thickness of Carlile shale	586

Greenhorn formation (part):

1. Shale, dark-gray, weathers medium gray and brownish gray; contains gray septarian limestone concretions as much as 4 ft long cut by veins of light-gray and brown calcite	10

Turner sandy member and lower unnamed member of the Carlile shale at Thornton dome in sec. 18, T. 48 N., R. 65 W., Weston County, Wyo.

Carlile shale (part):

Sage Breaks member (part):

	Feet
7. Shale, grayish-black, a few septarian limestone concretions that weather light gray and have veins of dark-brown calcite	20

Turner sandy member:

6. Mostly covered; dark-gray shale in scattered exposures; a few chips of yellowish-gray sandy limestone in float	80±
5. Shale, dark-gray; laminae and a few thin slabby beds of yellowish-gray very fine grained sandstone; scattered silty limestone concretions that weather yellowish gray; about 20 ft above base, a bed of silty limestone concretions that weather dark red	75
4. Shale, dark-gray, a few laminae of yellowish-gray very fine grained sandstone	28

Turner sandy member and lower unnamed member of the Carlile shale at Thornton dome in sec. 18, T. 48 N., R. 65 W., Weston County, Wyo.—Continued

Carlile shale (part)—Continued

Turner sandy member—Continued

	Feet
3. Sandstone, very light gray, mostly fine- to medium-grained; granules and small pebbles of gray chert and black phosphatic material, calcareous, crossbedded; forms slabby ledges; contains numerous fish teeth including *Ptychodus whipplei* Marcou, *Ptychodus* sp., *Isurus appendiculata* (Agassiz), and *Squalicorax falcatus* (Agassiz) (loc. D415, fossils identified by W. A. Cobban)	4
Thickness of Turner sandy member	187±

Lower unnamed member:

2. Partly covered; mostly dark-gray shale; a few laminae of light-gray siltstone and very fine grained sandstone; very sandy in top 3 ft; near middle, scattered septarian limestone concretions that weather light gray, have veins of yellow calcite, and are ½ to 1½ ft in diameter	50
Partial thickness of Carlile shale	257±

Greenhorn formation (part):

1. Shale, dark-gray, weathers medium gray, silty and sandy, at top, tabular gray-weathering limestone concretions 1 to 3 ft thick and as much as 20 ft long; forms hogback	10

Turner sandy member and lower unnamed member of the Carlile shale near Osage in sec. 20, T. 46 N., R. 63 W., Weston County, Wyo. (see fig. 7)

Carlile shale (part):

Sage Breaks member (part):

	Feet
14. Shale, grayish-black, noncalcareous; at top, a bed of dark-gray septarian limestone concretions that weather light gray and contain veins of brown calcite	25

Turner sandy member:

13. Shale, interbedded and interlaminated with sandstone; shale is dark gray, noncalcareous; sandstone is light gray to light yellowish gray, very fine grained to silty; less sandy in upper half; at top, a prominent bed of closely spaced brown-weathering calcareous sandstone and siltstone concretions about 3 ft thick; similar concretions 45 and about 60 ft below top of unit; concretions 45 ft below top contain *Inoceramus perplexus* Whitfield *Inoceramus lamarcki* Parkinson, *Gyrodes* sp., ?*Fusus gabbi* Meek, *Baculites* cf. *B. besairiei* Collignon, *Scaphites nigricollensis* Cobban, and *Prionocyclus wyomingensis* Meek (loc. D412, fossils identified by W. A. Cobban)	64

Turner sandy member and lower unnamed member of the Carlile shale near Osage in sec. 20, T. 46 N., R. 63 W., Weston County, Wyo. (see fig. 7)—Continued

Carlile shale (part)—Continued

Turner sandy member—Continued

	Feet
12. Sandstone, light-gray, very fine grained, thin-bedded, crossbedded; some interlaminated gray shale; contains a few brown-weathering calcareous sandstone concretions	9
11. Shale and sandstone as in unit 13; a few slabby red-weathering calcareous sandstone concretions in upper part	18
10. Sandstone, light-gray, very fine grained, calcareous, very thin bedded; interlaminated dark-gray silty shale; contains brown-weathering calcareous sandstone concretions as much as 5 ft thick and 20 ft long; concretions form prominent lenticular ledges	17
9. Shale, dark-gray, noncalcareous, silty; some interbedded light-gray very fine grained sandstone; grades into units above and below	36
8. Sandstone, very light gray, mostly fine-grained, many grains and locally some granules of gray and black phosphatic material and chert; in beds 1 in. to 1 ft thick separated by partings of dark-gray shale; calcareous; forms slabby ledges; unit contains *Scaphites corvensis* Cobban; fish scales, probably *Hypsodon lowii* (Stewart) Cockerell; *Prionocyclus wyomingensis* Meek; *Ptychodus* sp.; *Isurus*? sp.; and *Corax* sp. (loc. 11200 and 11214, fossils collected by W. W. Rubey and identified by J. B. Reeside, Jr.)	5½
Thickness (rounded) of Turner sandy member	150

Lower unnamed member:

7. Shale, dark-gray, silty; laminae of light-gray siltstone	40
6. Bentonite, light-gray, nonswelling	.3
5. Shale, dark-gray, silty	5
4. Bentonite, light-gray, nonswelling	.9
3. Shale, dark-gray, silty; slightly calcareous in bottom 5 ft; two beds of gray-weathering silty limestone concretions about middle of unit; concretions contain *Inoceramus fragilis* Hall and Meek, *Pecten* sp., *Scaphites larvaeformis* Meek and Hayden, *Collignoniceras woollgari* (Mantell), and *Tragodesmoceras* sp. (loc. D411, fossils identified by W. A. Cobban); concretions at about same horizon nearby contain in addition "*Puzosia*" n. sp. (loc. 11199, fossil collected by W. W. Rubey and identified by J. B. Reeside, Jr.)	15

Turner sandy member and lower unnamed member of the Carlile shale near Osage in sec. 20, T. 46 N., R. 63 W., Weston County, Wyo. (see fig. 7)—Continued

Carlile shale (part)—Continued

Lower unnamed member—Continued

	Feet
2. Poorly exposed; appears to be mainly light-gray to tan calcareous shale	30
Thickness (rounded) of lower unnamed member	91
Partial thickness (rounded) of Carlile shale	266

Greenhorn formation (part):

1. Limestone, light-gray, interbedded light- to dark-gray marl; forms a ridge	10

Sage Breaks member of the Carlile shale near Pedro in sec. 1, T. 45 N., R. 63 W., Weston County, Wyo.

Niobrara formation (part):

	Feet
5. Shale, dark-gray, weathers light yellowish gray and dark gray; alternately calcareous and noncalcareous near base; calcareous in upper part; contains three beds of limestone concretions that weather light gray to yellowish orange	30

Carlile shale (part):

Sage Breaks member:

4. Shale, grayish-black; contains several beds of septarian limestone concretions that weather light gray and have veins of orange and brown calcite	73
3. Shale, grayish-black, weathers dark gray to dark brownish gray, alternately slightly calcareous and noncalcareous; a few thin seams and stringers of light-gray aragonite	22
2. Shale, grayish-black, noncalcareous; contains several beds of septarian limestone concretions that weather light gray, contain veins of dark-brown calcite, and average about 1½ ft in diameter; lowest bed of concretions about 20 ft above base of unit; concretions about middle of this unit nearby contain *Ostrea congesta* Conrad, *Baculites* sp., and fragments of a thick-shelled *Inoceramus* that resembles *I. deformis* Meek (loc. 11225, fossils collected by W. W. Rubey and identified by J. B. Reeside, Jr.)	160
Thickness of Sage Breaks member	255

Turner sandy member:

1. Shale, dark-gray, noncalcareous; a few laminae of yellowish-gray very fine grained sandstone; a bed of fossiliferous calcareous sandstone concretions that weather yellowish brown about 20 ft below top of unit, concretions about 6 ft in diameter	30
Partial thickness of Carlile shale	285

Lower part of the Carlile shale near Newcastle in the SW¼ sec. 31, T. 45 N., R. 61 W., Weston County, Wyo.

[Measured by W. A. Cobban, written communication, 1959]

	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 beds at top of unit; forms hogback	10
13. Shale, dark-gray, sandy; increasingly sandy upward	10
12. Sandstone, light-gray; many dark-gray chert grains; calcareous, massive	½
Partial thickness of Turner sandy member	20½
Lower unnamed member:	
11. Shale, dark-gray; a few thin partings of light-gray siltstone	33
10. Bentonite, light yellowish-gray	.1
9. Shale, dark-gray; contains a bed of limestone concretions that weather light gray and contain *Collignoniceras woollgari*	3
8. Bentonite, light-gray	.2
7. Shale, dark-gray	.6
6. Bentonite, light-gray	.2
5. Shale, dark-gray; contains limestone concretions about 1 ft long that weather light gray; locally abundant *Collignoniceras woollgari*	2
4. Bentonite, light-gray; shaly at top	1
3. Shale, dark-gray; some light-gray siltstone	5
2. Shale, dark bluish-gray, weathers gray brown, variably calcareous; contains a few thin limestone lenses and some soft yellowish-gray limestone concretions	55
Thickness (rounded) of lower unnamed member	100
Partial thickness (rounded) of Carlile shale	120
Greenhorn formation (part):	
1. Shale, gray, calcareous; numerous thin lenticular beds of finely crystalline light-gray limestone that contain fragments of *Inoceramus labiatus;* forms prominent hogback	20

NIOBRARA FORMATION

The Niobrara formation is between 150 and 200 feet thick at most places along the northwestern side of the Black Hills, although it thickens locally to as much as 225 feet. The formation consists mainly of dark- to light-gray calcareous shale and marl but contains some noncalcareous shale near the base, and many thin beds of bentonite, mostly in the middle and upper parts. The formation weathers to shades of light gray and light yellow in contrast to darker weathering shale of the underlying and overlying formations. It erodes easily and commonly forms a shallow valley.

The basal part of the Niobrara formation consists of alternating beds of calcareous and noncalcareous shale that weather to alternating light and dark bands. At some places the basal beds contain a few light-gray limestone concretions a foot or so in maximum dimension. Some of the concretions are septarian, with veins of brown calcite. The contact of the formation with grayish-black noncalcareous shale at the top of the underlying Sage Breaks member of the Carlile shale appears to be fairly sharp. At places, the contact is marked by a layer of phosphatic nodules.

Shale and marl composing most of the formation are dark gray when fresh and light gray to yellow when weathered. Much of the rock contains very small white calcareous specks which, according to Goodman (1951, p. 2429), may be mostly algal remains.

Bentonite beds in the Niobrara formation are mostly an inch or two thick. Cobban (1951, p. 2192) reports 60 beds of bentonite in a section 180 feet thick at the northern end of the Black Hills.

Inoceramus fragments encrusted with *Ostrea congesta* Conrad are commonly found in the Niobrara formation, but other invertebrate megafossils are rare. M. N. Bramlette found vertebrae of Mosasaurs in the Niobrara formation in sec. 28, T. 7 S., R. 57 E., and sec. 12, T. 8 S., R. 56 E., Carter County, Mont.

The four sections of the Niobrara formation that follow illustrate the lithology and thickness of this formation. Graphic sections of the Niobrara formation are shown on figure 7.

Niobrara formation on the north side of Owl Creek in sec. 24, T. 9 S., R. 61 E., Carter County, Mont. (see fig. 7.)

[After Knechtel and Patterson, 1962, p. 926–927]

	Feet
Niobrara formation:	
1. Marl, yellowish-gray, weathers light orange gray, fissile; a few platy limestone lenses; many fragments of *Inoceramus* in lower part	38
2. Bentonite, gray, waxy, stained with limonite	.5
3. Marl, yellowish-gray, weathers very light gray, fissile	3.5
4. Bentonite, yellowish-brown, waxy	.2
5. Marl, light brownish-gray, weathers very light gray, fissile	1.5
6. Bentonite, gray, waxy	.3
7. Marl, light brownish-gray, weathers light yellowish-gray, fissile	2.5
8. Shale, dark-gray, noncalcareous	1.0
9. Bentonite, light-gray, waxy	.1
10. Shale, dark-gray, noncalcareous	3.5
11. Bentonite, light-gray, hard	.2
12. Shale, dark-gray, fissile, noncalcareous	6.5

Niobrara formation on the north side of Owl Creek in sec. 24, T. 9 S., R. 61 E., Carter County, Mont. (see fig. 7)—Continued

Niobrara formation—Continued	Feet
13. Marl, brownish-gray, weathers light yellowish gray, fissile; at top, a bed of septarian limestone concretions that have veins of white calcite and average 6 in. thick and 1½ ft long	6
14. Poorly exposed; appears to be mostly brownish-gray marl that weathers light orange gray; a bed of septarian limestone concretions that have veins of brown calcite and average 1 ft thick and 1½ ft long. Base of unit is about the base of the Niobrara formation	132
Approximate thickness (rounded) of Niobrara formation	196

Alluvium.

Niobrara and parts of adjacent formations near Mud Creek, about the center of the N½ sec. 30, T. 56 N., R. 67 W., Crook County, Wyo. (see fig. 7)

Pierre shale (part):	Feet
Gammon ferruginous member (part):	
24. Shale, dark-gray, noncalcareous; contains thin tabular red-weathering siderite concretions in beds about 5 ft apart	25
23. Shale, dark-gray, noncalcareous	25
Partial thickness of Pierre shale	50

Niobrara formation:		
22. Shale, weathers light brown, calcareous; a few large fossil vertebrae		8.0
21. Shale and bentonite as follows:		
Bentonite, pale-yellow, nonswelling	0.3	
Shale, weathers brown, calcareous; contains five thin partings of bentonite	1.6	
Bentonite, light-gray, nonswelling	1.8	
Shale, weathers dark brown, calcareous	.2	
Bentonite, pale-yellow, nonswelling	.4	
Shale, weathers dark brown, calcareous	1.1	
Bentonite, light-gray, nonswelling	.5	
Shale, dark-gray	.3	
Bentonite, pale-yellow, nonswelling	.1	
Shale, weathers gray brown, noncalcareous at base; calcareous at top	1.1	
Bentonite, light-orange, nonswelling; contains limonite and jarosite	.1	
Shale, dark-gray, noncalcareous	.2	
Bentonite, pale-yellow, nonswelling	.8	
Total		8.5
20. Shale, weathers brown to grayish-yellow, very calcareous; contains a few thin partings of bentonite		10.0

Niobrara and parts of adjacent formations near Mud Creek, about the center of the N½ sec. 30, T. 56 N., R. 67 W., Crook County, Wyo. (see fig. 7)—Continued

Niobrara formation—Continued		Feet
19. Shale and bentonite as follows:		
Bentonite, light-gray nonswelling	0.3	
Shale, weathers light brown, very calcareous	2.0	
Bentonite, light-orange, nonswelling	.2	
Shale, weathers olive gray, noncalcareous	1.0	
Shale, dark-gray, noncalcareous; abundant fish scales	1.5	
Bentonite, pale-yellow, nonswelling	.1	
Total		5.1
18. Shale, dark-gray to black, calcareous; numerous noncalcareous black bands 0.2 to 0.3 ft thick		11.8
17. Bentonite, light-gray, nonswelling		.2
16. Shale, weathers gray and brown, very calcareous; numerous white specks on bedding surfaces; abundant fish scales in top 5 ft; a few thin lenses of limestone composed of oyster shells		23.0
15. Bentonite, yellowish-gray, nonswelling		.3
14. Shale, weathers light gray, very calcareous; contains a few thin lenses of limestone composed of oyster shells		5.0
13. Bentonite, yellowish-gray, nonswelling		.3
12. Shale, weathers light gray and tan, very calcareous		2.8
11. Bentonite, pale-yellow, nonswelling		.1
10. Shale, as in unit 12 above		8.0
9. Bentonite, pale-yellow, nonswelling		.1
8. Shale, as in unit 12 above; a few thin partings of bentonite and thin lenses of limestone composed of oyster shells		12.3
7. Bentonite, pale-yellow, nonswelling		.1
6. Shale, as in unit 12 above		9.0
5. Bentonite, pale-yellow, nonswelling		.2
4. Shale, as in unit 12 above		4.0
3. Poorly exposed; appears to be mostly calcareous shale; forms yellow to tan soil		50
Thickness (rounded) of Niobrara formation		159

Carlile shale (part):	
Sage Breaks member (part):	
2. Mostly covered; appears to be mostly dark-gray shale; black phosphatic pebbles weathering out in soil about top of unit	10
1. Shale, dark-gray to black, noncalcareous; contains septarian limestone concretions that weather light gray, have veinlets of white crystalline calcite, and are 1 to 3 ft in diameter	20
Partial thickness of Carlile shale	30

Niobrara and parts of adjacent formations 7 miles southeast of Upton in the NE¼ sec. 32, T. 47 N., R. 64 W., Weston County, Wyo.

	Feet
Pierre shale (part):	
Gammon ferruginous member (part):	
17. Shale, grayish-black, weathers medium to light gray; noncalcareous except for a zone about 5 ft thick near middle of unit	25
16. Shale, brownish-gray to dark-gray, weathers medium to light gray with a few tan bands, calcareous	125
Partial thickness of Pierre shale	150

	Feet	
Niobrara formation:		
15. Bentonite and shale as follows:		
Bentonite, light-gray, nonswelling	0.3	
Shale, weathers brown, noncalcareous	1.0	
Bentonite, light-gray, nonswelling	.1	
Shale, brown, noncalcareous	.1	
Bentonite, light-gray, nonswelling	.2	
Shale, dark-gray, noncalcareous	.5	
Bentonite, gray, nonswelling	.2	
Shale, weathers brownish gray, calcareous	1.0	
Bentonite, yellowish-gray, nonswelling	.2	
Total		3.6
14. Shale, grayish-black, noncalcareous, abundant fish scales		3
13. Shale, weathers tan, very calcareous		9
12. Bentonite, light-gray, nonswelling		.1
11. Shale and marl, weathers tan, very calcareous		23
10. Shale, grayish-black, noncalcareous; bed 0.2 ft thick of light-gray bentonite about middle of the unit		1
9. Marl, weathers tan and orange; contains *Ostrea* concentrated in a few thin platy masses; thin beds of grayish-black noncalcareous shale in top 15 ft		163
8. Bentonite, light-gray, nonswelling		.1
7. Marl, weathers tan and orange		1.0
6. Bentonite, light-gray, nonswelling		.1
5. Marl, weathers tan and orange; sharp contact with underying unit		6.5
Thickness (rounded) of Niobrara formation		210

Carlile shale (part):	
Sage Breaks member (part):	
4. Shale, grayish-black, noncalcareous; abundant fish scales	5
3. Shale, grayish-black, calcareous	48
2. Shale, grayish-black, noncalcareous; black phosphatic nodules as much as ½ in. long weathering out about top of the unit	40

Niobrara and parts of adjacent formations 7 miles southeast of Upton in the NE¼ sec. 32, T. 47 N., R. 64 W., Weston County, Wyo.—Continued

	Feet
Carlile shale (part)—Continued	
Sage Breaks member (part)—Continued	
1. Shale, black, flaky; contains seven beds of septarian limestone concretions mostly 1 to 3 ft in diameter that weather light gray and contain veins of coarsely crystalline white and brown calcite and some barite; forms low ridge	45
Partial thickness of Carlile shale	138

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

[Measured by J. R. Gill, written communication, 1958]

	Feet	
Pierre shale (part):		
10. Bentonite (Pedro bed), pale greenish-gray, swelling; fairly abundant flakes of biotite; about 12 ft above base, a hard light-gray bed 1.3 ft thick composed of the mineral clinoptilolite; rests sharply on underlying unit		19.5
Niobrara formation:		
9. Marl, dark gray-brown, weathers yellowish brown; top 1 to 2 ft hard and massive		6.0
8. Bentonite and shale as follows:		
Bentonite, yellowish-gray, nonswelling	0.2	
Shale, weathers brown, very calcareous	1.1	
Bentonite, yellowish-gray, nonswelling	.1	
Shale, weathers gray, calcareous	2.5	
Bentonite, yellowish-gray, nonswelling	.1	
Total		4.0
7. Shale, dark-gray to black, calcareous		4.0
6. Shale, weathers orange brown, very calcareous		7.0
5. Shale and bentonite as follows:		
Shale, dark-gray, noncalcareous	0.3	
Bentonite, gray, nonswelling	.1	
Shale, weathers tan, 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

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

	Feet	Feet
Niobrara formation—Continued		
4. Shale, black, noncalcareous		3.6
3. Shale, weathers orange brown and tan, very calcareous; white specks on bedding planes; a bed of red-weathering siderite concretions 0.1 to 0.2 ft in diameter at about top of 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) of Niobrara formation		155
Carlile shale (part):		
Sage Breaks member (part):		
1. Shale, grayish-black, locally calcareous; small black phosphatic pebbles weathering out at top of unit; at bottom of unit, bed of septarian limestone concretions that weather light gray, have veinlets of white and brown calcite, and are as much as 4 ft in diameter		40

PIERRE SHALE

The Pierre shale consists of dark-gray shale, some sandy shale and sandstone, and many beds of bentonite. It overlies the Niobrara formation conformably and is conformably overlain by the Fox Hills sandstone. Electric logs of holes drilled for oil and gas indicate that the formation is about 2,700 feet thick in T. 47 N., R. 66 W., Weston County, Wyo., and that it thins irregularly northwestward to about 2,050 feet in northern Campbell County, Wyo. (See fig. 5.)

The Pierre shale is divided into several units on the basis of differences in the shale and the presence of sandy or bentonitic units. In ascending order, these are the Gamman ferruginous member (including the Groat sandstone bed), the Mitten black shale member, and an unnamed upper part of the Pierre shale that includes near the top the Monument Hill and Kara bentonitic members. The Gammon ferruginous member and Mitten black shale member can be traced throughout most of the mapped area. The Monument Hill bentonitic member was recognized only in Carter County, Mont., and northern Crook County, Wyo. The Kara bentonitic member, which is somewhat younger than the Monument Hill, crops out in Weston County and in parts of Crook County, Wyo. Plate 5 shows the correlation of these units between Ridge, Mont., and Newcastle, Wyo., and fig. 4 the correlation in various parts of Wyoming, Montana, and South Dakota.

GAMMON FERRUGINOUS MEMBER

The Gammon ferruginous member of the Pierre shale was named by Rubey (1931, p. 4) for exposures along Gammon Prong in T. 57 N., Rs. 67 and 68 W., Crook County, Wyo. The member was traced across the northern end of the Black Hills and along the west side as far south as Beaver Creek in Weston County.

Logs of oil and gas wells indicate that the Gammon ferruginous member is 850 to about 1,000 feet thick in parts of Campbell County, Wyo., north of Gillette. It thins gradually southeastward to between 700 and 800 feet near its outcrop in Crook County, Wyo., and Carter County, Mont., and 500 and 600 feet in wells near Upton, Weston County, Wyo. The member thins rapidly southeastward across the Osage oil field southeast of Upton at as much as 100 feet per mile, and near Pedro in sec. 1, T. 45 N., R. 63 W. and in sec. 9 of the township to the east, the Gammon ferruginous member is absent. Southeast of Pedro, a sequence of dark shale 35 to 70 feet thick that lies between the Niobrara formation and a prominent zone of bentonite beds near the base of the Pierre has been correlated with the Gammon ferruginous member (J. R. Gill, written commun., 1959; Mapel and Pillmore, 1963), this unit was too thin to map separately and on plates 1 and 5 is included with the overlying Mitten black shale member of the Pierre. Changes in thickness in the Gammon ferruginous member in northeastern Wyoming and adjacent areas are given by Gill and Cobban (1961, fig. 352.2).

The Gammon ferruginous member mostly forms gentle slopes and flats only thinly covered by soil and vegetation.

The Gammon ferruginous member consists mostly of dark-gray shale that weathers light gray and contains numerous red-weathering ferruginous concretions. The contact of the member with the underlying Niobrara formation appears to be conformable. It is marked by a fairly abrupt change from yellow-weathering calcareous shale or marl at the top of the Niobrara formation to noncalcareous or slightly calcareous light-gray-weathering shale at the base of the Gammon ferruginous member. Except for the basal few feet of the member locally, shale and mudstone of the Gammon are not calcareous. In outcrops in the Osage oil field in T. 46 N., Rs. 63 and 64 W., the Gammon is very silty and contains many laminae and thin beds of very fine grained locally glauconitic sandstone.

Dark-gray sideritic concretions that weather red characterize the Gammon ferruginous member. They weather out in small chips in the soil, so that locally outcrops of the member appear grayish red when viewed from a distance. The concretions commonly are 1 to 6 inches thick, a few inches to several feet long, and are closely spaced in layers 5 to 10 feet apart stratigraphi-

cally. The middle and upper parts of the member contain, in addition, a few beds of dark-gray septarian limestone concretions with veins of brown calcite.

A partial analysis was made of a sample of a sideritic or ironstone concretion from the Gammon ferruginous member collected by W. W. Rubey from the N½ sec. 17, T. 49 N., R. 66 W. The results are tabulated below, and have previously been published by Wells (1937, p. 65, column D). Thin-section examination by W. W. Rubey showed the presence of fairly numerous carbonate oolites.

Analysis of ironstone concretion of the Gammon ferruginous member of the Pierre shale from N½ sec. 17, T. 49 N., R. 66 W., Crook County, Wyo.

[Analyst, J. G. Fairchild]

Fe_2O_3	7.07
FeO	11.25
CaO	26.64
CO_2	29.00
	73.96

A bed of bentonite, 1 to 2 feet thick, crops out about 75 feet below the top of the Gammon ferruginous member in northeastern Crook County, Wyo., and southern Carter County, Mont. (bed H of Knechtel and Patterson, 1962, p. 989). This bed makes a distinctive light yellowish-gray band that may be followed for many miles, and consequently it is an excellent marker for correlation.

Groat sandstone bed.—About 35 to 125 feet of sandstone, siltstone, and silty and sandy shale crops out 150 feet below the top of the Gammon ferruginous member of the Pierre shale in the northern part of the mapped area. These sandy strata were named the Groat sandstone bed by Rubey (1931, p. 4) for exposures at Groat Creek in T. 7 S., R. 56 E., Carter County, Mont. The Groat sandstone bed may be traced westward and southward across the northern end of the Black Hills as far as T. 55 N., R. 67 W., Crook County, Wyo. Farther southward, the Groat apparently is represented in outcrops by light-gray shale or silty shale similar to adjacent parts of the Gammon member. Sandy or silty beds at the stratigraphic position of the Groat can be identified in electric logs of drill holes in most parts of western Crook County and eastern Campbell County, Wyo.

The Groat sandstone bed consists of light-gray to light yellowish-gray medium- to fine-grained glauconitic and ferruginous sandstone interbedded with siltstone and gray shale. A bed of sandstone about 10 feet thick forms a low scarp at the top of the unit at most exposures. Glauconite is particularly abundant in the upper part of the Groat and at some places it tints the rock greenish. The sandstone is friable, calcareous, ripple marked, and crossbedded. The Groat becomes very silty and shaly in its lower part, and it grades downward into the underlying part of the Gammon ferruginous member almost imperceptibly through an interval of as much as 50 feet. The contact with the overlying part of the Gammon ferruginous member also apears to be gradational, although at most places the contact is concealed by slope wash on a broad dip slope formed by the uppermost beds of the Groat.

Fossils collected from the Gammon ferruginous member of the Pierre shale are common to the Telegraph Creek formation and Eagle sandstone of south-central Montana. The following collections were made by W. W. Rubey and others in 1922 and 1924, and the fossils identified by J. B. Reeside Jr.; other fossils are listed with the measured sections, page 80. Ammonites collected by Rubey from the Groat sandstone are no longer available for study; however, according to W. A. Cobban (oral communication, 1963), *Baculites haresi* identified by Reeside from the Groat (collections 12633, 12723, and 12719, pl. 5 and listed below) is probably the same form more recently identified as *Baculites* sp. (smooth) (Zapp and Cobban, 1962, zone F3, p. D54).

Fossils collected from the Gammon ferruginous member of the Pierre shale

[Fossils identified by J. B. Reeside, Jr.]

1. Sec. 4, T. 48N., R. 66 W., 2½ miles northwest of Thornton, Wyo.
   Loc. 11922, 150 ft. above Niobrara formation.
   Titanosarcolites coraloidea (Hall and Meek)
   Ostrea cf. *O. congesta* Conrad
   Loc. 11926, 300 ft. above Niobrara formation.
   Anchura cf. *A. sublevis* (Meek and Hayden)
   Acteon sp.
   Baculites sp.
2. SE¼ sec. 32, T. 49 N., R. 66 W., Crook County, Wyo.
   Loc. 12730.
   Ostrea sp. small simple form
   Baculites aquilaensis Reeside
   Haresiceras placentiforme Reeside
   Scaphites hippocrepis (DeKay)
3. NW¼ sec. 33, T. 54 N., R. 67 W., 3 miles north of Oshoto, Wyo.
   Loc. 12726, 50 ft. above Niobrara formation.
   Baculites haresi Reeside
   Ptychodus sp.
   Fish scales
4. E½ sec. 25, T. 56 N., R. 68 W., north of Mud Creek on New Haven-Rocky Point road, Wyoming.
   Loc. 12054, zone of calcareous concretions in lower part of Gammon ferruginous member of Pierre shale.
   Serpula? sp.
   Nucula n. sp.
   Nucula sp.
   Ostrea? sp.
   Crenella? n. sp.
   Cuspidaria moreauensis (Meek and Hayden)

Titanosarcolites coraloidea (Hall and Meek)
Lucina n. sp.
Callista? sp
Dentalium n. sp.
Drepanochilus evansi Cossman
Fusus? sp.
Glyptoxoceras? rubeyi (Reeside)
Baculites haresi Reeside
Baculites sp., small individuals with initial coil
Scaphites hippocrepis (DeKay) var. *tenuis* Reeside
Scaphites aquilaensis var. *nanus* Reeside
Fish teeth

Loc. 12718, about 120 ft below Groat sandstone bed of Gammon ferruginous member.
Lucina sp.
Protocardia subquadrata (Evans and Shumard)
Placenticeras sp.

Loc. 12719, about 80 ft below base of Groat sandstone bed of Gammon ferruginous member.
Nucula planimarginata Meek and Hayden
Yoldia? sp.
Lucina subundata Hall and Meek
Protocardia subquadrata (Evans and Shumard)
Dentalium sp. (n. sp.?)
Polinices concinna (Hall and Meek)
Anchura sp.
Fusus sp.
Baculites haresi Reeside

5. Sec. 26, T. 56 N., R. 68 W., Crook County, Wyo.

Locs. 12723 and 12656, upper 20 ft of Groat sandstone bed of Gammon ferruginous member.
Nucula sp.
Perrisonota protexta Conrad
Arca n. sp.
Yoldia? sp.
Pteria linquaeformis (Evans and Shumard)
Syncyclonema hallii (Gabb)
Lima n. sp. aff. *L. utahensis* Stanton
Cerithium n. sp.
Drepanochilus aff. *D. evansi* Cossman
Crenella elegantula Meek and Hayden
Lucina sp.
Xylophagella elegantula Meek and Hayden
Fusus sp.
Cinulia n. sp.
Acteon sp.
Baculites haresi Reeside
Baculites asper Morton
Scaphites aquilaensis Reeside
Scaphites hippocrepis (DeKay)
Placenticeras planum Hyatt

6. Sec. 1, T. 9 S., R. 56 E., Carter County, Mont.

Loc. 12631, 20 ft below base of Groat sandstone bed of Gammon ferruginous member.
Nucula n. sp.
Perissonota protexta Conrad
Yoldia n. sp.
Inoceramus cf. *I. sagensis* Owen
Syncyclonema hallii (Gabb)
Anomia sp.
Dentalim n. sp.
Turritella n. sp.
Drepanochilus evansi Cossman
Aporrhais meeki Whitfield
Fusus n. sp.
Acteon sp.
Baculites haresi Reeside
Scaphites aquilaensis Reeside
Haresiceras placentiforme Reeside

7. SW¼ sec. 8, T. 9 S., R. 56 E., 5 miles east of Ridge, Mont.

Loc. 12626, upper part of Groat sandstone bed of Gammon ferruginous member.
Inoceramus sp.
Ostrea n. sp.
Lucina subundata Hall and Meek
Baculites haresi Reeside
Placenticeras meeki Boehm

8. Sec. 11, T. 8 S., R. 56 E., Carter County, Mont.

Loc. 12633, upper part of Groat sandstone bed of Gammon ferruginous member.
Pinna cf. *P. lakesi* White
Inoceramus cf. *I. sagensis* Owen
Modiolus meeki (Evans and Shumard)
Baculites haresi Reeside
Placenticeras meeki Boehm

9. S½ sec. 12, T. 8 S., R. 56 E., Carter County, Mont.

Loc. 12639, Gammon ferruginous member 300 ft below Groat sandstone bed.
Haminea sp.
Scaphites hippocrepis (DeKay)
Haresiceras placentiforme Reeside

10. Sec. 26, T. 58 N., R. 61 W., Crook County, Wyo.

Loc. 12714, 120 ft above base of Gammon ferruginous member.
Ostrea? sp. very young shells
Polinices concinna (Hall and Meek)
Anchura aff. *A. sublevis* Meek and Hayden
Baculites haresi Reeside
Baculites aquilaensis Reeside
Scaphites hippocrepis (DeKay) var. *tenuis* Reeside
Haresiceras placentiforme Reeside
Aptychus, probably of *Scaphites*

The following sections illustrate the lithology of the Gammon ferruginous member, including the Groat sandstone bed, on the northwestern flank of the Black Hills.

Composite section of the Gammon ferruginous member of the Pierre shale along Owl Creek in T. 11 N., R. 2 E., Butte County, S. Dak., and in the SE¼SE¼ sec. 12 and the N½ sec. 13, T. 9 S., R. 61 E., Carter County, Mont.

[From thesis by W. A. Cobban, 1949, and available at The Johns Hopkins University, Baltimore, Md.]

	Feet
Pierre shale (part):	
Upper part of Gammon ferruginous member (part):	
27. Shale, gray; numerous ferruginous concretions that weather rusty brown; concretions contain the following fossils: *Inoceramus* sp., *Baculites* sp., *Hoploparia* sp.	20
26. Shale, gray; gray calcareous concretions	30
25. Shale, gray; numerous rusty brown ferruginous concretions with seams of yellow calcite; concretions contain the following fossils: *Caprinella coraloidea* Hall and Meek, *Inoceramus* sp., *Baculites* sp. (smooth)	20

Composite section of the Gammon ferruginous member of the Pierre shale along Owl Creek in T. 11 N., R. 2 E., Butte County, S. Dak., and in the SE¼SE¼ sec. 12 and the N½ sec. 13, T. 9 S., R. 61 E., Carter County, Mont.—Continued

Pierre shale (part)—Continued

Upper part of Gammon ferruginous member (part)—Continued

	Feet
24. Bentonite (bed H), yellowish-gray, shaly, hard; contains large flakes of biotite	1
23. Shale, gray	4
22. Bentonite, yellowish-gray	.2
21. Shale, gray	4.5
20. Bentonite, yellowish-gray	.7
19. Shale, gray; numerous dark-purplish-weathering ferruginous concretions with seams of yellow calcite	10
18. Shale, gray; rusty brown ferruginous concretions that contain the following fossil: *Baculites* sp. (smooth)	26
17. Shale, gray; a few brown ferruginous concretions that contain the following fossils: *Baculites* sp. (smooth) Reeside, *Placenticeras meeki* Boehm	16
16. Shale, gray; some gray calcareous concretions that contain *Baculites* sp. (smooth)	26
Thickness (rounded) upper part Gammon ferruginous member	158

Groat sandstone bed:

15. Sandstone, green to buff, massive to cross-bedded; rusty brown ferruginous concretions at top	34

Lower part of Gammon ferruginous member (part):

14. Shale, buff to gray, very sandy; grades upward into overlying sandstone; contains calcareous sandstone concretions	10
13. Shale, gray; gray calcareous concretions that contain the following fossils: *Inoceramus* sp., *Leda* sp., *Nemodon* sp., *Ostrea* sp., *Pteria* sp., *Nuculana* sp., *Cylichna* sp., *Baculites* sp. (smooth), *Placenticeras meeki* Boehm	25
12. Shale, gray; rusty-brown ferruginous concretions and gray calcareous concretions that contain the following fossils: *Nucula* sp., *Ostrea* sp., *Pecten* sp., *Pteria linguaeformis* (Evans and Shumard), *Nuculana* sp., *Fasciolaria* spp., *Entalis pauperculum* (Meek and Hayden), *Baculites* cf. *B. haresi* Reeside, *B.* cf. *B. minerensis* Landes, *Haresiceras* sp., *Placenticeras meeki* Boehm	10
11. Shale, gray; gray calcareous concretions that contain the following fossils: *Caprinella coraloidea* Hall and Meek, *Ostrea russelli* Landes, *Pteria linguaeformis* (Evans and Shumard), *Baculites* cf. *B. haresi* Reeside	28
10. Shale, gray; numerous rusty-brown ferruginous concretions that contain the following fossils: *Baculites* cf. *B. haresi* Reeside, *Campylostoma* cf. *C. pierrense* Rathbun	56

Composite section of the Gammon ferruginous member of the Pierre shale along Owl Creek in T. 11 N., R. 2 E., Butte County, S. Dak., and in the SE¼SE¼ sec. 12 and the N½ sec. 13, T. 9 S., R. 61 E., Carter County, Mont.—Continued

Pierre shale (part)—Continued

Lower part of Gammon ferruginous member (part)—Continued

	Feet
9. Shale, gray, slightly sandy; numerous calcareous concretions that weather bluish gray and contain the following fossils: *Ostrea* n. sp., *Nuculana* sp., *Baculites aquilaensis* Reeside, *B. aquilaensis* var. *obesus* Reeside, *B. aquilaensis* var. *separatus* Reeside, *Haresiceras placentiforme* Reeside, *Placenticeras meeki* Boehm, *Linuparus canadensis* (Whiteaves), *Homolopsis* sp., fish vertebrae, shark teeth, mosasaur teeth and bones	30
8. Shale, gray; some gray calcareous and rusty-brown ferruginous concretions that contain the following fossils: *Baculites aquilaensis* var. *separatus* Reeside, *B.* cf. *B. haresi* Reeside	45
7. Shale, gray; numerous rusty-brown shaly ferruginous concretions	230
6. Bentonite, yellowish-gray	1
5. Shale, gray; some parts slightly calcareous	78
4. Bentonite, gray	.2
3. Shale, gray	33
2. Bentonite, creamy	.2
1. Shale, gray, slightly calcareous, contains *Baculites* cf. *B. haresi* Reeside	44
Thickness (rounded) lower part of Gammon ferruginous member	590
Thickness (rounded) of Gammon ferruginous member	783

Part of the Gammon ferruginous member, including the Groat sandstone bed, of the Pierre shale in W½ sec. 17, T. 9 S., R. 62 E., Carter County, Mont.

Pierre shale (part):

Upper part of Gammon ferruginous member (part):

	Feet
8. Shale, medium-gray, weathers light gray; several thin red-weathering ferruginous siltstone seams; at top, limestone concretions that weather light gray; forms slope	15

Groat sandstone bed:

7. Sandstone, light-gray, silty to shaly, calcareous, massive; red-weathering ferruginous siltstone bed at top; forms slope	5.5
6. Sandstone, greenish-gray, medium to fine grained, calcareous, glauconitic; in beds 1 to 10 in. thick; red-weathering ferruginous siltstone layer ½ in thick at top; forms ledges	8.5
5. Sandstone, light-gray to light brownish-gray, medium- to fine-grained, glauconitic, massive, friable; contains brown-weathering calcareous sandstone concretions as much as 5 ft thick and 10 ft long	22.5

Part of the Gammon ferruginous member, including the Groat sandstone bed, of the Pierre shale in W½ sec. 17, T. 9 S., R. 62 E., Carter County, Mont.—Continued

Pierre shale (part)—Continued

	Feet
Groat sandstone bed—Continued	
4. Sandstone, gray to light brownish-gray, fine-grained to silty, glauconitic, locally calcareous; contains brown-weathering calcareous fossiliferous sandstone concretions about 4 ft thick and 6 ft long	35.5
3. Sandstone, dark-gray, weathers light gray, fine-grained to silty, very calcareous, glauconitic; contains *Baculites* sp.; forms bench	1
Thickness of Groat sandstone bed	73
Lower part of Gammon ferruginous members (part):	
2. Siltstone, medium- to dark-gray, weathers light gray, shaly	7
1. Shale, dark-gray weathers medium to light gray; scattered limestone concretions in upper half that weather light-gray, are about 1 to 3 ft in diameter, and contain *Baculites* locally; abundant selenite in lower part	55
Partial thickness lower part Gammon ferruginous member	62
Partial thickness of Gammon ferruginous member	150

Part of the Gammon ferruginous member, including the Groat sandstone bed, of the Pierre shale on the South Fork of Willow Creek in sec. 4, T. 9 S., R. 56 E., Carter County, Mont.

Pierre shale (part):

	Feet
Upper part of Gammon ferruginous member (part):	
7. Shale, gray and brownish-gray, weathers light gray, silty at base; a few tabular red-weathering siltstone concretions about 1 in. thick	15
Groat sandstone bed:	
6. Partly covered; mostly medium-gray fine-grained to silty sandstone; grades into overlying unit	5
5. Sandstone, medium-gray to light brownish-gray, a slight greenish tinge, fine- to medium-grained, glauconitic, calcareous, arkosic, micaceous; forms low scarp	6
4. Sandstone, medium-gray and yellowish-gray, friable; very fine grained in middle and upper parts; silty and clayey in lower 20 ft; a few brown-weathering siltstone concretions 1 to 4 in. in diameter; forms slope	70
Thickness of Groat sandstone bed	81
Lower part of Gammon ferruginous member (part):	
3. Claystone and shale, dark- to medium-gray, locally brownish gray, silty, becomes more silty near top; grades into overlying unit; forms slope	40

Part of the Gammon ferruginous member, including the Groat sandstone bed, of the Pierre shale of the South Fork of Willow Creek in sec. 4, T. 9 S., R. 56 E., Carter County, Mont.—Continued

Pierre shale (part)—Continued

	Feet
Lower part of Gammon ferruginous member (part)—Continued	
2. Claystone and shale, dark-gray to dark brownish-gray, slightly silty; contains red-weathering silty siderite concretions 1 to 4 in. thick and as much as 1 ft in diameter; a few red-weathering ferruginous siltstone beds about 1 in. thick	32
1. Shale, medium-gray, contains limestone concretions that weather light gray and are ½ to 1 ft in diameter	17
Partial thickness lower part Gammon ferruginous member	89
Partial thickness of Gammon ferruginous member	185

Lower part of the Gammon ferruginous member along the North Fork of Willow Creek in secs. 11 and 12, T. 8 S., R. 56 E., Carter County, Mont.

Pierre shale (part):

	Feet
Groat sandstone bed.	
Lower part of Gammon ferruginous member:	
5. Shale, gray, weathers medium to light gray, noncalcareous; numerous tabular red-weathering siderite concretions	220±
4. Shale, gray, weathers medium to light gray, slightly sandy, noncalcareous; contains light-gray-weathering limestone concretions	55±
3. Shale, gray, weathers medium- to light-gray, noncalcareous; a few discontinuous calcite beds 1 to 2 in. thick	90±
2. Shale, gray, weathers medium to light gray, noncalcareous, numerous tabular red-weathering siderite concretions	210±
1. Shale, gray, weathers medium to light gray; mostly noncalcareous, a few laminae of gray calcareous shale	25±
Thickness of lower part of Gammon ferruginous member	600±

Niobrara formation.

MITTEN BLACK SHALE MEMBER

The Mitten black shale member of the Pierre shale was named by Rubey (1931, p. 4) for a sequence of black fissile shale exposed along the South Fork of the Little Missouri River, which was known to Rubey as Mitten Prong, in sec. 22, T. 56 N., R. 68 W., Crook County, Wyo. The member is about 145 feet thick near its type locality, and Cobban (1952, p. 87) gives the thickness of the member as about 150 feet in central Carter County, Mont. The member thickens southward along the west flank of the Black Hills to about 500 feet near Thornton and nearly 1,000 feet in the subsurface near Newcastle, Weston County, Wyo. (Gill and

Cobban, 1961, p. D188). The Mitten commonly forms a low scarp or low rolling hills.

For most of the outcrop area shown by the geologic map (pl. 1) the Mitten lies on the Gammon ferruginous member of the Pierre shale; however, the Gammon thins southeastward and pinches out locally at Pedro in Weston County, Wyo. From Pedro southeastward, rocks belonging to the Gammon ferruginous member are less than 100 feet thick, and for purposes of mapping (pls. 1 and 5), they are included with the Mitten black shale member.

In much of its outcrop area, the Mitten black shale member consists of two lithologically distinct parts of about equal thickness. The lower part is fairly hard dark-gray shale that weathers brownish to silvery gray and contains much organic material including numerous fish scale and bones. Several bentonite beds crop out near the base, and large septarian limestone concretions that weather light gray characterize the upper half of the lower part. This part of the Mitten is about 400 to 425 feet thick in the Newcastle-Pedro area and is about 80 feet thick at the Rocky Point anticline in northern Crook County, Wyo. The upper part of the Mitten black shale member is soft grayish-black shale that weathers very dark gray to black. It contains numerous siderite concretions that weather dark-red and a few beds of large septarian limestone concretions that weather light gray or orange brown. The two parts of the member contrast markedly and are mapped separately (pl. 1) southeast of Pedro in Weston County, Wyo., and they are readily distinguished at places in northern Crook County, Wyo., and southern Carter County, Mont. They are less distinct, however, in the intervening area from about Upton northward to the Rocky Point anticline. In that area shale in both parts of the Mitten weathers mostly dark gray to black.

Where bentonite beds are present in the Mitten, they generally occur at or near the base of the member in a zone that is about 15 to 70 feet thick. West of Newcastle, the bentonite zone is 35 to 40 feet above the Niobrara formation and includes 13 bentonite beds, one about 6 feet thick, in an interval of about 60 feet. A few miles northwest of Newcastle in the SW¼ sec. 23, T. 45 N., R. 62 W., the bentonite zone is about 60 feet thick and contains 14 bentonite beds. At this locality the zone is about 70 feet above the Niobrara formation. Near Pedro in sec. 9 of the same township, the bentonite zone is at least 70 feet thick and has at least 20 bentonite beds, including one about 30 feet thick called the Pedro bed (Rubey, 1931, p. 4) that rests directly on the Niobrara formation. Bentonite appears to be absent locally southwest of Osage in the southeastern part of T. 46 N., R. 64 W., but the zone is present and is as much as 35 feet thick between Osage and Upton in T. 47 N., Rs. 64 and 65 W. From a point in sec. 22, T. 47 N., R. 65 W. near Upton in Weston County, Wyo., northward to the Wyoming-Montana boundary, little or no bentonite was found in the Mitten black shale member. Exposures of the base of the Mitten are poor in northern Weston and southern Crook Counties, Wyo., and it is not clear whether the bentonite beds thin and grade into shale in this area or whether the bentonite zone is truncated beneath an unconformity in the lower part of the Mitten. The bentonite zone becomes prominent in Carter County, Mont.; and at Indian Creek in T. 9 S., R. 62 E., the basal part of the Mitten contains 8 bentonite beds in a zone 14½ feet thick. Bentonite beds in the basal part of the Mitten at Newcastle in Weston County, Wyo., and at Indian Creek in Carter County, Mont., have been traced by J. R. Gill (oral communication, 1959) into the Sharon Springs member of the Pierre shale at the southern end of the Black Hills where they constitute a bentonite zone that includes the Ardmore bed of Spivey (1940, p. 3; Kepferle, 1959, p. 584, pl. 52). In the northern Black Hills, Knechtel and Patterson (1962, p. 990–992) referred to all the bentonites in the zone collectively as bentonite bed I.

Marine invertebrate fossils are abundant at many places in concretions in the upper part of the Mitten black shale member of the Pierre shale. The fossils collected are tabulated below. The first group of collections was made by W. W. Rubey, and the fossils identified by J. B. Reeside, Jr.; the other collections were made by the writers and their assistants and identified by W. A. Cobban. Fossils are also listed in the measured sections, pages 83–86.

Fossils collected from the Mitten black shale member of the Pierre shale

[Fossils identified by W. A. Cobban and J. B. Reeside, Jr.]

1. N½ sec. 15, T. 44 N., R. 61 W., about 1 mile northwest of Spencer siding, Wyoming, on divide between Blacktail and Stockade Beaver Creeks.

Loc. 11193.
Inoceramus barabini Morton
Fasciolaria culbertsoni (Meek and Hayden)
Baculites sp.
Scaphites (*Hoploscaphites*) n. sp.

Loc. 12023, 5 ft above preceding collection.
Lucina occidentalis (Morton)
Baculites sp.
Scaphites n. sp.

Loc. 13876, approximately same bed as preceding collection.
Inoceramus barabini Morton
Anisomyon borealis (Morton)

Loc. 12055, 30 to 50 ft above preceding collection.
Inoceramus sp.
Baculites sp.
Scaphites n. sp.

2. Near center SW¼ sec. 6, T. 45 N., R. 63 W.
   Loc. D424, near middle of Mitten black shale member.
   Inoceramus sublaevis Meek and Hayden
   Baculites perplexus Cobban
   Scaphites n. sp.
   Placenticeras cf. *P. meeki* Boehm
   Loc. D423, near top of Mitten black shale member.
   Inoceramus sublaevis Hall and Meek
   I. cf. *I. subcompressus* Meek and Hayden
   Baculites perplexus Cobban
3. NW¼ sec. 25, T. 49 N., R. 67 W., Crook County, Wyo.
   Loc. D460, near top of Mitten black shale member.
   Inoceramus cf. *I. subcompressus* Meek and Hayden
   Lucina occidentalis (Morton)
   Baculites perplexus Cobban
   Scaphites (*Hoploscaphites*) n. sp.
4. NE¼ sec. 23, T. 50 N., R. 67 W., Crook County, Wyo.
   Loc. D399, upper 20 ft. of Mitten black shale member.
   Inoceramus pertenuis Meek and Hayden
   I. sp.
   Pteria linguaeformis (Evans and Shumard)
   Lucina subundata Hall and Meek
   Baculites perplexus Cobban
5. NE¼ sec. 22, T. 56 N., R. 68 W., north side of South Fork of the Little Missouri River (type locality), Crook County, Wyo.
   Loc. D398, near top of Mitten black shale member.
   Inoceramus cf. *I. subcompressus* Meek and Hayden
   Anisomyon sexsulcatus (Meek and Hayden)
   Dentalium gracile Hall and Meek
   Baculites perplexus Cobban
   Scaphites (*Hoploscaphites*) n. sp.
6. SW¼ sec. 18, T. 9 S., R. 56 E.
   Loc. D856, near top of Mitten black shale member.
   Inoceramus sp.
   Baculites perplexus Cobban

Following are three stratigraphic sections of the Mitten black shale member of the Pierre shale, the second of which was measured near the type locality. Descriptions of the bentonite zone in the basal part of the Mitten near Pedro, sec. 9, T. 45 N., R. 62 W., and southeast of Upton, sec. 32, T. 47 N., R. 64 W., are given in the chapter on bentonite, pages 123–125.

Mitten black shale member of the Pierre shale along Indian Creek in the E½ sec. 1 and the NE¼ sec. 2, T. 9 S., R. 62 W., Carter County, Mont.

[Modified from thesis by W. A. Cobban, 1949, and available at The Johns Hopkins University, Baltimore, Md.]

	Feet
Pierre shale (part):	
Upper part (part):	
12. Shale, dark, medium-gray, weathers medium gray, silty to sandy; contains gray septarian limestone concretions that weather yellow tan to brown and have veins of brown or yellow calcite; unit contains the following fossils: *Inoceramus vanuxemi* Meek and Hayden, *I.* aff. *I. barabini* Morton, *Baculites gregoryensis* Cobban	20+

Mitten black shale member of the Pierre shale along Indian Creek in the E½ sec. 1 and the NE¼ sec. 2, T. 9 S., R. 62 W., Carter County, Mont.—Continued

	Feet	
Pierre shale (part)—Continued		
Mitten black shale member:		
11. Shale, dark-gray, weathers dark gray; at top, bed of septarian limestone concretions that weather bright tan and contain veins of yellow to dark-brown calcite		14
10. Bentonite, gray		.2
9. Shale, dark-gray; contains dark-gray septarian limestone concretions that weather brown and have veins of dark-brown botryoidal calcite; concretions contain the following fossils: *Cucullaea* sp., *Nucula* sp., *Ostrea* sp., *Pecten* n. sp., *Pteria linguaeformis* (Evans and Shumard), *Yoldia evansi* (Meek and Hayden), *Anisomyon borealis* Meek and Hayden, *A. patelliformis* Meek and Hayden?, *A.* aff. *A. sexsulcatus* Meek and Hayden, *Drepanochilus evansi* Cossman, *Entalis pauperculum* (Meek and Hayden), *Baculites perplexus* Cobban, *Scaphites* (*Hoploscaphites*) n. sp., fish scales, mosasaur bones		3
8. Shale, dark-gray		15
7. Shale, dark-gray; several beds of brown-weathering septarian limestone concretions		43
6. Shale, dark-gray		37
5. Bentonite, yellow		1
4. Shale, dark-gray		30
3. Bentonite and shale as follows (bed I):	Feet	
Bentonite, yellowish-gray	2	
Shale, dark-gray	.4	
Bentonite, yellowish-gray	1.3	
Shale, dark-gray	.8	
Bentonite, yellowish-gray	.2	
Shale, dark-gray	.5	
Bentonite, yellowish-gray	.4	
Shale, dark-gray	.5	
Bentonite, yellowish-gray	.7	
Shale, dark-gray	1.5	
Shale and bentonite, gray	.5	
Bentonite, yellowish-gray, contains aragonite-gypsum concretions (Ardmore bentonite bed of Spivey, 1940)	4.4	
Shale, dark-gray	.5	
Bentonite, yellowish-gray	.8	
Total		14.5
2. Shale, dark-gray		5
Thickness (rounded) of Mitten black shale member		163

Mitten black shale member of the Pierre shale along Indian Creek in the E½ sec. 1 and the NE¼ sec. 2, T. 9 S., R. 62 W., Carter County, Mont.—Continued

	Feet
Pierre shale (part)—Continued	
Gammon ferruginous member (part):	
1. Shale, medium-gray; at top, a bed of gray-weathering septarian limestone concretions with veins of brown and yellow calcite; numerous rusty-brown ferruginous concretions	6
Partial thickness (rounded) of Pierre shale	189

Composite section of the Mitten black shale member of the Pierre shale east of Monument Hill in the N½ sec. 22, T. 56 N., R. 68 W., and the NW¼ sec. 1, T. 55 N., R. 68 W., Crook County, Wyo.[1]

Section following measured in N½ sec. 22, T. 55 N., R. 68 W.

	Feet
Pierre shale (part):	
Upper part (part):	
12. Shale, dark-gray, weathers dark brownish gray, slightly bentonitic; contains dark-gray limestone concretions that weather light gray and contain *Inoceramus vanuxemi* Meek and Hayden, *Baculites* aff. *B. gregoryensis* Cobban, and *Placenticeras meeki* Boehm (loc. D869, fossils identified by W. A. Cobban)	10
Upper part of Mitten black shale member:	
11. Shale, grayish-black, weathers grayish-black, soft; contains dark-gray to black septarian limestone concretions that weather orange brown and have veins of yellow and brown calcite; concretions are irregularly shaped, as much as 6 ft long, and contain *Inoceramus* cf. *I. subcompressus* Meek and Hayden, *Anisomyon sexsulcatus* (Meek and Hayden), *Dentalium gracile* Hall and Meek *Baculites perplexus* Cobban, and *Scaphites* (*Hoploscaphites*) n. sp. (loc. D398, fossils identified by W. A. Cobban)	17
10. Shale, grayish-black, weathers grayish black, soft; scattered ferruginous concretions that weather dark red	12
9. Partly covered; mostly grayish-black shale, at top of unit, a bed of closely spaced dark-gray limestone concretions that weather light yellowish brown; scattered ferruginous concretions that weather dark red and are 1 to 2 ft in diameter; a few limestone cone-in-cone concretions that weather yellowish brown	12

[1] Stratigraphic section given previously at this locality by Robinson, Mapel, and Cobban (1959, p. 121) is here amended.

Composite section of the Mitten black shale member of the Pierre shale east of Monument Hill in the N½ sec. 22, T. 56 N., R. 68 W., and the NW¼ sec. 1, T. 55 N., R. 68 W., Crook County, Wyo.[1]—Continued

Pierre shale (part)—Continued	
Upper part of Mitten black shale member—Continued	
8. Shale, grayish-black, weathers grayish black, soft; near middle of unit, a bed of dark-gray limestone concretions 1 to 3 ft in diameter; scattered red-weathering ferruginous concretions mostly less than 1 ft in diameter	23
Thickness upper part of Mitten black shale member	64
7. Shale, dark-gray, weathers to hard light-gray and brownish-gray chips; top of unit is a bed 2 to 4 in. thick of ferruginous siltstone; limestone concretions that weather light gray and tan scattered in lower part	15
6. Bentonite, light yellowish-gray, nonswelling	1

Section following is offset 3 miles southeast to NW¼ sec. 1, T. 55 N., R. 68 W.

5. Shale, dark-gray; weathers to brownish-gray hard papery fragments; much organic material on bedding surfaces; contains two beds of large limestone concretions that weather light gray	35
4. Bentonite, light yellowish-gray, nonswelling	.1
3. Shale, dark-gray; weathers to brownish-gray hard papery fragments; about 15 ft above base, a bed of septarian limestone concretions that weather light gray and are as much as 3 ft in diameter; about 10 ft above base, a bed of cone-in-cone limestone concretions that weather tan; black phosphatic nodules and bone fragments weather out from base of unit	29
Thickness (rounded) lower part of Mitten black shale member	80
Thickness (rounded) of Mitten black shale member	144
Gammon ferruginous member (part):	
2. Shale, dark-gray, weathers light-gray; scattered septarian limestone concretions that weather light-gray to tan and have veins of orange calcite	10
1. Shale, dark-gray, weathers light gray; numerous thin seams and closely spaced tabular concretions of red-weathering siderite	20
Partial thickness of Gammon ferruginous member	30
Partial thickness of Pierre shale	184

Mitten black shale member of the Pierre shale and adjacent rocks south of Newcastle in the SW¼NE¼ and the SE¼ NW¼ sec. 6, T. 44 N., R. 61 W., Weston County, Wyo.

Pierre shale (part):

Upper part (part): *Feet*

24. Shale, dark-gray, weathers grayish brown; silty at 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 top of unit; the following fossils identified by W. A. Cobban:

    Loc. D417, from concretions about top or slightly above top of unit nearby to the south: *Inoceramus sublaevis* Hall and Meek, *Inoceramus* sp., *Eutrephoceras* sp., *Baculites scotti* Cobban, *Anapachydiscus* sp.

    Loc. D418, from gray-weathering concretions about middle of unit: *Inoceramus sublaevis* Hall and Meek, *Inoceramus* cf. *I. proximus* Tuomey, *Cuspidarea* cf. *C. moreauensis* (Meek and Hayden), *Anisomyon borealis* (Morton), *Baculites gregoryensis* Cobban, *Placenticeras* sp. 150

Upper part of Mitten black shale member:

23. Shale, grayish-black, weathers grayish black, scattered gray-weathering limestone concretions. Loc. D419, fossils from concretions in upper part of the unit, identified by W. A. Cobban: *Lucina subundata* Hall and Meek, *Baculites perplexus* Cobban, *Scaphites* (*Hoploscapthites*) n. sp. 45
22. Shale, dark-gray, weathers grayish brown, silty; several beds of rusty-weathering tabular limestone concretions 30
21. Shale, grayish-black, weathers grayish black; three beds of limestone concretions that weather light gray to grayish red and are about 1 ft in diameter. Loc. D420, fossils from concretions, identified by W. A. Cobban: *Inoceramus barabini* Morton, *Baculites* sp. (smooth) 25
20. Covered; deeply weathered bentonitic soil bare of vegetation 9
19. 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. Loc. D421, fossils from concretions about 25 ft below top of unit, identified by W. A. Cobban: *Baculites* cf. *B. haresi* Reeside 315
18. Bentonite, light yellowish-gray, nonswelling 5

Thickness (rounded) upper part of Mitten black shale member 425

Mitten black shale member of the Pierre shale and adjacent rocks south of Newcastle in the SW¼NE¼ and the SE¼ NW¼ sec. 6, T. 44 N., R. 61 W., Weston County, Wyo.—Con.

Pierre shale (part)—Continued

Lower part of Mitten black shale member: *Feet*

17. 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
16. Shale as in unit 17; 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 top 90 ft 160
15. Shale, medium- to dark-gray, weathers to fairly hard platy fragments; somewhat less fissile than shale in units 16 and 17; contains fish scales and organic fragments; supports relatively little vegetation 40
14. Mostly covered; bottom 5 ft is shale as in unit 15 45
13. Bentonite, very light gray, nonswelling 2
12. Shale as in unit 15 above 12
11. Bentonite, very light gray, nonswelling 1
10. Shale as in unit 15 above 74
9. Bentonite, very light gray, nonswelling; shaly at top 1.9
8. Shale, medium- to dark-gray, platy, organic-rich 6.6
7. Bentonite, very light gray, nonswelling 1.5
6. Shale, medium- to dark-gray, platy, organic-rich 6.1
5. Shale and bentonite as follows: *Feet*
    - 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

Mitten black shale member of the Pierre shale and adjacent rocks south of Newcastle in the SW¼NE¼ and the SE¼ NW¼ sec. 6, T. 44 N., R. 61 W., Weston County, Wyo.—Con.

	Feet	
Pierre shale (part)—Continued		
Lower part of Mitten black shale member—Continued		
5. Shale and bentonite as follows—Continued		
Bentonite, very light gray, nonswelling	0.9	
Total		20.8
4. Shale, medium- to dark-gray, platy, organic rich		9.7
3. Bentonite and shale as follows (Ardmore 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	
Shale, medium- to dark-gray, platy; weathers brown in bottom 2 ft, silicified in top 0.1 ft	3.6	
Bentonite, very light gray, nonswelling	.8	
Total		11.1
2. Shale, medium- to dark-gray, weathers to fairly hard platy chips; contains fish scales and other organic material; supports relatively little vegetation		35
Thickness lower part of Mitten black shale member		445
Thickness (rounded) of Mitten black shale member		870
Partial thickness (rounded) of Pierre shale		1,020
Niobrara formation (part):		
1. Marl, weathers yellow and light gray, fissile		10

UPPER PART OF THE PIERRE SHALE

The upper part of the Pierre shale includes light-gray to black shale, locally bentonitic and silty, that overlies the Mitten black shale member of the Pierre shale and underlies the Fox Hills sandstone. This sequence is about 800 feet thick in Carter County, Mont., and northern Crook County, Wyo.; it thickens southward to about 1,500 feet in Weston County, Wyo. It typically forms rolling grass- and sage-covered hills and flats. Beds of limestone concretions, commonly fossiliferous, form low ridges locally; and in the lower part, large limestone concretions hold up isolated low conical hills known as tepee buttes.

Five distinct lithologic units and many faunal zones are recognized in the upper part of the Pierre shale. Not all the lithologic units are recognizable throughout the mapped area, however, and only two of them were mapped separately; the Monument Hill bentonitic member in Carter County, Mont., and northern Crook County, Wyo., and the stratigraphically higher Kara bentonitic member in central and southern Crook County and Weston County, Wyo.

Cobban (1958, p. 117) noted 12 ammonite zones for this part of the Pierre shale along the west flank of the Black Hills uplift. These zones, with two changes (W. A. Cobban, oral communication, 1963), are as follows:

Baculites clinolobatus (youngest)
B. grandis
B. baculus
B. eliasi
B. reesidei
B. compressus
Didymoceras cheyennense
Exiteloceras jenneyi
Didymoceras stevensoni
D. nebrascense
B. scotti
B. gregoryensis (oldest)

At the base of the upper part of the Pierre shale is a sequence of gray to brownish-gray silty and sandy shale containing septarian limestone concretions that weather light gray and reddish gray. This unit rests sharply on black shale at the top of the underlying Mitten black shale member, which contains concretions that weather orange brown. The silty unit was named the Red Bird silty member of the Pierre shale by Gill and Cobban (1962). It is about 200 feet thick in central Carter County, Mont. (Cobban, 1952, p. 87), and it appears to be 200 to 300 feet thick farther south along the west side of the Black Hills, in Crook and northern Weston Counties, Wyo., although it was not measured because of poor exposures. Concretions in this unit yield fossils representing the zones of *Baculites gregoryensis* Cobban and *B. scotti* Cobban.

Overlying the basal silty unit with a fairly sharp contact is a sequence of dark-gray to black shale that contains beds of gray-weathering septarian limestone concretions and numerous red-weathering ferruginous concretions. This unit is about 250 feet thick in central Carter County (Cobban, 1952, p. 87). A zone of light-gray-weathering septarian limestone concretions with distinctive veins of dark-brown botyroidal calcite occurs about 5 to 15 feet below the top of the unit in Carter County, Mont., and northern Crook County, Wyo., and is a useful horizon marker. Concretions in the lower part of the black shale unit yield fossils representing the zones of *Didymoceras nebrascense* (Meek and Hayden) and *Didymoceras stevensoni* (Whitfield);

in northern Crook County, Wyo., and Carter County, Mont., concretions in the upper part yield fossils representing the lower part of the zone of *Exiteloceras jenneyi* (Whitfield).

The Monument Hill bentonitic member of the Pierre shale consists of 150 to 220 feet of light-gray-weathering bentonitic and silty shale and impure bentonite that overlies the black shale unit just described. The member is fairly well exposed in Carter County, Mont., and northern Crook County, Wyo., and the base of the member could be traced southward in Crook County to the northwest corner of T. 55 N., R. 67 W. Farther southward, the member appears to grade laterally into dark shale and could not be mapped separately. Fossils from the lower and middle parts of the Monument Hill member represent the upper part of the zone of *Exiteloceras jenneyi*, whereas fossils from the uppermost part mark the zone of *Didymoceras cheyennense* Elias. The Monument Hill bentonitic member is more fully described on pages 91–93.

In Carter County, Mont., and in northern Crook County, Wyo., the part of the Pierre shale overlying the Monument Hill bentonitic member consists of about 200 feet of dark-gray to black shale that contains gray and red-brown-weathering limestone concretions. The shale is locally bentonitic and contains a few beds of bentonite, most of which are only a few inches thick. At the top of this unit is a sequence of silty and sandy shale 10 to 50 feet thick that is transitional with the overlying standstone and sandy shale of the Fox Hills sandstone. Concretions in the lower part of the unit yield fossils representing the zone of *Baculites reesidei* Elias. The upper part is unfossiliferous in Carter County, Mont., but at the Rocky Point anticline (T. 56 N., R. 69 W.) in Crook County, Wyo., the upper part of the black shale and the overlying transition beds yield fossils belonging to the zone of *Baculites eliasi* Cobban.

Exposures of the upper part of the Pierre shale are poor from the Rocky Point anticline southward for several miles, and no division of the formation could be made. Near Oshoto, however, a zone about 100 feet thick of gray-weathering shale, bentonitic shale, and bentonite, belonging to the Kara bentonitic member, crops out about 700 feet above the base of the middle part of the Pierre shale. The Kara bentonitic member, described more fully on pages 93–95, may be traced from Oshoto southward to the southern edge of the mapped area.

Overlying the Kara bentonitic member and making up the remainder of the Pierre shale south of Oshoto is a sequence of dark-gray shale that is about 140 feet thick in sec. 6, T. 51 N., R. 67 W.; 300 feet thick in sec. 2, T. 48 N., R. 67 W.; and 300 to 325 feet thick in T. 44 N., R. 63 W. Light-gray-weathering septarian concretions 3 to 4 feet in diameter are abundant in the basal 40 feet of this unit, and a few gray- or grayish-yellow-weathering limestone concretions are scattered in the upper part. The unit becomes silty and sandy in its top 10 to 20 feet and appears to grade upward into the overlying Fox Hills sandstone. Concretions in the lower 40 feet of the unit contain fossils belonging to the zone of *Baculites eliasi* Cobban, those in the upper part, south of T. 52 N., R. 67 W., contain fossils representing the zones *Baculites baculus* Meek and Hayden and of *Baculites grandis* Hall and Meek.

Fossils collected from the upper part of the Pierre shale are tabulated below and given in the measured sections on pages 92–95.

Fossils collected from the upper part of the Pierre shale

[Fossils identified by W. A. Cobban and J. B. Reeside, Jr.]

Pierre shale overlying the Kara bentonitic member

1. Sec. 9, T. 44 N., R. 63 W., 11 miles southwest of Newcastle, Wyo., from silty sandstone transition zone between Pierre shale and Fox Hills sandstone.

Loc. 12696, 10 ft below top of Pierre shale.
Serpula sp.
Nucula planimarginata Meek and Hayden
Yoldia scitula (Meek and Hayden)
Pecten nebrascensis Meek and Hayden
Corbula? sp.
Fusus? sp.
Oligoptycha concinna (Hall and Meek)
Baculites sp.
Scaphites? sp. fragment

Loc. 12053, 15 ft below top of Pierre shale.
Yoldia evansi (Meek and Hayden)
Pecten nebrascensis Meek and Hayden
Protocardia subquadrata (Evans and Shumard)
Lunatia? sp.
Drepanochilus evansi Cossman
Baculites sp.

Loc. 12021 and 12707, 20 ft below top of Pierre shale.
Inoceramus sagensis Owen
Pecten nebrascensis Meek and Hayden
Baculites sp.

Loc. 12064, 24 ft below base of Fox Hills sandstone.
Nucula planimarginata Meek and Hayden
Yoldia evansi (Meek and Hayden)
Yoldia scitula (Meek and Hayden)
Polinices concinna (Hall and Meek)
Drepanochilus evansi Cossman
Fusus sp.
Baculites sp.
Ichthyodectes sp.

Loc. 12044, 37 ft below top of Pierre shale.
Inoceramus (*Actinoceramus*) *fibrosus* (Meek and Hayden)

2. SW¼ sec. 11, T. 44 N., R. 63 W., 9 miles southwest of Newcastle, Wyo.
   Locs. 11197 and 11215, from limestone capping tepee buttes in upper part of Pierre shale just above Kara bentonitic member.
   Inoceramus barabini Morton
   Opertochasma cuneata (Meek and Hayden)
   Lucina occidentalis (Morton)
   Oligoptycha concinna (Hall and Meek)
   Acanthoscaphites nodosus var. *quadrangularis* Meek
   Acanthoscaphites nodosus (Owen)
   Dentalium gracile Hall and Meek
3. SE¼ sec. 28, T. 46 N., R. 64 W., 7 miles southwest of Osage, Wyo.
   Loc. 11216, from limestone forming tepee buttes about 100 ft below top of Pierre shale.
   Nucula sp.
   Yoldia evansi (Meek and Hayden)
   Glycerimeris n. sp.
   Pteria nebrascana (Meek and Hayden)
   Pecten nebrascensis Meek and Hayden
   Modiolus meeki (Evans and Shumard)
   Lucina occidentalis (Morton)
   Lucina subundata Hall and Meek
   Dentalium gracile Hall and Meek
   Margarita nebrascensis (Meek and Hayden)
   Drepanochilus nebrascensis (Evans and Shumard)
   Ellipsoscapha subcylindrica (Meek and Hayden)
   Oligoptycha concinna (Hall and Meek)
   Oligoptycha? n. sp.
   Acanthoscaphites nodosus (Owen)
   Aptychus of *Acanthoscaphites* sp.
4. NE¼ sec. 1, T. 46 N., R. 65 W., 6.5 miles south of Upton, Wyo.
   Loc. 11217, from limestone concretions about 100 ft below top of Pierre shale.
   Pteria nebrascana (Evans and Shumard)
   Acirsa? *cerithiformis* (Meek and Hayden)?
   Acanthoscaphites nodosus (Owen)
   Baculites sp.
5. NW¼ sec. 35, T. 47 N., R. 65 W., 6 miles south of Upton, Wyo.
   Loc. 11220, about 30 ft below top of Pierre shale.
   Nucula cancellata Meek and Hayden
   Yoldia scitula (Meek and Hayden)
   Idonearca shumardi (Meek and Hayden)
   Inoceramus sagensis Owen
   Inoceramus fibrosus (Meek and Hayden)
   Pteria linguaeformis (Evans and Shumard)
   Pecten nebrascensis Meek and Hayden
   Anomia aff. *A. gryphorhynchus* Meek
   Crenella elegantula Meek and Hayden
   Protocardia subquadrata (Evans and Shumard)
   Dentalium gracile Hall and Meek
   Polinices concinna (Hall and Meek)
   Ellipsoscapha minor (Meek and Hayden)
   Baculites sp.
   Discoscaphites cf. *D. conradi* (Morton) of Meek
   Discoscaphites cf. *D. conradi* var. *intermedius* Meek
6. SW¼ sec. 8, T. 47 N., R. 65 W., Weston County, Wyo.
   Loc. D395, gray limestone concretions near top of Pierre shale.
   Nucula cancellata Meek and Hayden
   Yoldia evansi (Meek and Hayden)
   Idonearca shumardi (Meek and Hayden)
   Anomia argentaria Morton
   Anomia sp.
   Inoceramus barabini Morton
   Ellipsoscapha occidentalis (Meek and Hayden)
   Baculites grandis Hall and Meek
   Discoscaphites n. sp.
7. SW¼ sec. 17, T. 48 N., R. 66 W., west of Thornton, Wyo.
   Loc. 11224, within 20 ft of top of Pierre shale.
   Micarabcia americana Meek and Hayden
   Nucula planimarginata Meek and Hayden
   Pteria nebrascana (Evans and Shumard)
   Pecten nebrascensis Meek and Hayden
   Anomia aff. *A. gryphorhynchus* Meek
   Protocardia subquadrata (Evans and Shumard)
   Lunatia subcrassa (Meek and Hayden)
   Drepanochilus evansi Cossman
   Oligoptycha concinna (Hall and Meek)
   Baculites sp.
   Discoscaphites cf. *D. conradi* var. *intermedius* Meek
8. NW¼ sec. 11 and NE¼ sec. 10, T. 49 N., R. 67 W., Crook County, Wyo.
   Loc. 13878, highest concretion in Pierre shale below undoubtedly Fox Hills sandstone, 100 to 110 ft below prominent upper ledge of Fox Hills sandstone.
   Micrabacea? sp.
   Yoldia evansi (Meek and Hayden)
   Inoceramus fibrosus (Meek and Hayden)
   Pteria nebrascana (Evans and Shumard)
   Anomia aff. A. *gryphorhynchus* Meek
   Modiolus meeki (Evans and Shumard)
   Cuspidaria moreauensis (Meek and Hayden)
   Protocardia subquadrata (Evans and Shumard)
   Lunatia sp.
   Baculities sp.
   Disoscaphites conradi Morton var. *intermedius* Meek
   Discoscaphites n. sp.
9. SE¼ sec. 27, T. 50 N., R. 67 W., Crook County, Wyo.
   Loc. D396, gray limestone concretions near top of Pierre shale.
   Micrabacia sp.
   Nucula cancellata Meek and Hayden
   Yoldia evansi (Meek and Hayden)
   Idonearca shumardi (Meek and Hayden)
   Inoceramus n. sp.
   Pteria (*Oxtoma*) *nebrascana* (Evans and Shumard)
   Anomia sp.
   Dentalium pauperculum (Meek and Hayden)
   Ellipsoscapha occidentalis (Meek and Hayden)
   Baculites grandis Hall and Meek
   Discoscaphites n. sp.
10. NW¼ and SW¼ sec. 6, T. 51 N., R. 67 W., Crook County, Wyo.
   Loc. D869, yellowish-gray limestone concretions within 30 ft of top of Pierre shale.
   Idonearca shumardi (Meek and Hayden)
   Baculites grandis Hall and Meek

11. NE¼ sec. 32, T. 54 N., R. 67 W., Crook County, Wyo.
    Loc. D863, gray concretions in brown-weathering silty shale at top of Pierre shale, estimated 30 to 40 ft below base of Fox Hills sandstone.
    Inoceramus sp.
    Baculites eliasi Cobban
    Loc. 12710, 50 ft above Kara bentonitic member.
    Crassatella subquadrata Whitfield
    Baculites sp.
12. NE¼ sec. 23, T. 56 N., R. 69 W., Campbell County, Wyo.
    Loc. 12623, in sandy unit 20 ft below base of Fox Hills sandstone.
    Baculites sp.

Pierre shale overlying the Monument Hill bentonitic member

13. NE¼ sec. 24, T. 56 N., R. 69 W., Campbell County, Wyo.
    Loc. D440, gray limestone concretions in black shale estimated within 50 ft stratigraphically of top of Monument Hill bentonitic member.
    Trochocyathus? sp.
    Serpula? *lineata* (Weller)
    Nuculana sp.
    Inoceramus sagensis Owen
    Pecten (*Chlamys*) *nebrascensis* Meek and Hayden
    Anomia sp.
    Lucina subundata Hall and Meek
    Dentalium pauperculum Meek and Hayden
    Dentalium gracile Hall and Meek
    Polinices concinna (Hall and Meek)
    Drepanochilus nebrascensis (Evans and Shumard)
    Baculites reesidei Elias
    Acanthoscaphites nodosus (Owen)
    Acanthoscaphites brevis (Meek)
    Rhaeboceras albertense (Warren)
14. SW¼NW¼ sec. 24, T. 56 N., R. 69 W., Campbell County, Wyo.
    Loc. D442, reddish-gray-weathering limestone concretions in black shale estimated 50 ft below silty transition beds at top of Pierre shale.
    Inoceramus sp.
    Baculites cf. *B. eliasi* Cobban
15. NE¼ sec. 36, T. 8 S., R. 55 E., Carter County, Mont.
    Loc. D854, concretions about 50 ft above Monument Hill bentonitic member.
    Inoceramus vanuxemi Meek and Hayden
    Inoceramus sagensis Owen
    Anisomyon sp.
    Baculites reesidei Elias
    Acanthoscaphites cf. *A. quadrangularis* (Meek and Hayden)

Kara bentonitic member

16. SW¼ sec. 16, T. 46 N., R. 64 W., Weston County, Wyo.
    Locs. D426, D427, and D428, gray limestone concretions in middle and upper parts of Kara bentonitic member.
    Inoceramus n. sp.
    Lucina subundata Hall and Meek
    Baculites eliasi Cobban
    Acanthoscaphites n. sp.
17. SW¼ sec. 11, T. 49 N., R. 67 W., Crook County, Wyo.
    Loc. 12699, from tepee butte in upper part of Kara bentonitic member.
    Lucina occidentalis (Morton)
    Baculites eliasi Cobban
    Acanthoscaphites nodosus (Owen)

Monument Hill bentonitic member

18. NE¼ sec. 32, T. 54 N., R. 67 W., Crook County, Wyo.
    Loc. D461, concretions about 10 ft stratigraphically below a prominent bed of light-gray limestone concretions believed to be equivalent to ledge-forming concretions near base of Monument Hill bentonitic member at Rocky Point anticline to the north.
    Inoceramus vanuxemi Meek and Hayden
    Inoceramus (*Endocostea*) sp.
    Pteria linguaeformis (Evans and Shumard)
    Baculites rugosus Cobban
    Acanthoscaphites sp.
    Loc. D864, gray limestone concretions in black shale probably equivalent to upper part of Monument Hill bentonitic member.
    Inoceramus sp.
    Eutrephoceras sp.
    Baculites aff. *B. corrugatus* Elias
    Acanthoscaphites sp.
19. NE¼ sec. 32, T. 56 N., R. 68 W., Crook County, Wyo.
    Loc. 12051, limestone on Monument Hill.
    Inoceramus sagensis Owen
20. SW¼ sec. 32, T. 56 N., R. 68 W., Crook County, Wyo.
    Loc. D858, gray limestone concretions in dark-gray shale probably equivalent to middle or upper part of Monument Hill bentonitic member.
    Pteria linguaeformis (Evans and Shumard)
    Inoceramus vanuxemi Meek and Hayden
    Inoceramus (*Endocostea*) sp.
    Ostrea falcata Morton
    Ostrea inornata Meek and Hayden
    Anisomyon borealis Morton
    Eutrephoceras sp.
    Baculites rugosus Cobban
    Acanthoscaphites n. sp.
21. NW¼ sec. 23, T. 9 S., R. 55 E., Carter County, Mont.
    Loc. D855, sandy concretions about middle of Monument Hill bentonitic member.
    Nuculana sp.
    Inoceramus sp.
    Ostrea inornata Meek and Hayden
    Ostrea falcata Morton
    Anomia sp.
    Baculites rugosus Cobban
    Acanthoscaphites n. sp.
    Placenticeras meeki Boehm
22. SW¼ sec. 18, T. 8 S., R. 56 E., Carter County, Mont.
    Loc. D850, sandy concretions 40 ft above base of Monument Hill bentonitic member.
    Nucula n. sp.
    Inoceramus (*Endocostea*) sp.
    Inoceramus vanuxemi Meek and Hayden
    Ostrea sp.
    Baculites rugosus Cobban
    Acanthoscaphites n. sp.
    Exiteloceras jenneyi (Whitfield)
    Placenticeras meeki Boehm
    Eutrephoceras sp.

Pierre shale below the Kara and Monument Hill bentonitic members

Upper black shale unit

23. NE¼ sec. 9, T. 44 N., R. 62 W., 6 miles southwest of Newcastle, Wyo.
    Loc. 11188, small limestone concretions near base of upper black shale unit.
    Inoceramus sagensis Owen
    Crassatella subquadrata Whitfield
    Lucina ventricosa Hall and Meek
24. SW¼NE¼ and SE¼SE¼ sec. 16, T. 44 N., R. 62 W., Weston County, Wyo.
    Loc. D455, gray limestone concretions, stratigraphically above collection 25.
    Inoceramus cf. *I. sagensis* Owen
    Inoceramus cf. *I. vanuxemi* Meek and Hayden
    Anisomyon borealis (Morton)
    Baculites rugosus Cobban
    Exiteloceras jenneyi (Whitfield)
    Acanthoscaphites n. sp.
    Placenticeras meeki Boehm
25. SW¼ sec. 18, T. 44 N., R. 62 W., about 9 miles southwest of Newcastle, Wyo.
    Locs. 11195 and 11196, from concretion bed below Kara bentonitic member.
    Inoceramus barabini Morton
    Lucina occidentalis (Morton)
    Anisomyon borealis (Morton)
    Baculites sp.
26. NW¼ sec. 36, T. 45 N., R. 63 W., Weston County, Wyo.
    Loc. D457, red-weathering concretions estimated 50 ft stratigraphically below Kara bentonitic member.
    Inoceramus n. sp.
    Baculites eliasi Cobban
    Acanthoscaphites n. sp.
27. NW¼SE¼ sec. 19, T. 45 N., R. 62 W., Weston County, Wyo.
    Loc. D454, gray limestone concretions.
    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)
28. SE¼ sec. 11, T. 49 N., R. 67 W., Crook County, Wyo.
    Loc 12721, concretions about 230 ft below Kara bentonitic member.
    Yoldia scitula (Meek and Hayden)
    Perissonta protexta Conrad
    Inoceramus sagensis Owen
    Pteria linguaeformis (Evans and Shumard)
    Dentalium sp., (n. sp?)
    Polinices concinna (Hall and Meek)
    Drepanochilus evansi Cossman
    Fusus dakotensis Meek and Hayden
    Baculites rugosus Cobban
    Exiteloceras jenneyi (Whitfield)
    Acanthoscaphites nodosus var. *quadrangularis* (of Whitfield, not Meek)
    Aptychus, probably *Scaphites* sp.
29. SE¼ sec. 14, T. 49 N., R. 67 W., Crook County, Wyo.
    Loc. 12722, tepee butte concretions, lower of two layers, about 200 ft below Kara bentonitic member.
    Bryozoan?
    Nucula planimarginata Meek and Hayden
    Yoldia scitula (Meek and Hayden)
    Inoceramus sagensis Owen
    Inoceramus barabini Morton
    Pteria linguaeformis (Evans and Shumard)
    Pteria nebrascana (Evans and Shumard)
    Cuspidaria ventricosa (Meek and Hayden)
    Lucina subundata Hall and Meek
    Anchura sp.
    Fasciolaria sp.
    Solenoceras? mortoni (Meek and Hayden)
    Baculites sp.
    Didymoceras sp.
    Acanthoscaphites n. sp.
    Placenticeras sp., fragment
30. NW¼ sec. 28, T. 56 N., R. 68 W., 1 mile northeast of Monument Hill, Crook County, Wyo.
    Loc. 12715, top of ferruginous concretions below Monument Hill bentonitic member.
    Inoceramous barabini Morton
    Solenoceras? mortoni (Meek and Hayden)
31. NE¼ sec. 32, T. 56 N., R. 68 W., Crook County, Wyo.
    Loc. D439, gray limestone concretions at same stratigraphic position as collection 30.
    Inoceramus vanuxemi Meek and Hayden
    Inoceramus (*Endocostea*) *sulcatus* Roemer
    Pteria linguaeformis (Evans and Shumard)
    Pteris (*Oxytoma*) *nebrascana* (Evans and Shumard)
    Eutrephoceras sp.
    Baculites rugosus Cobban
    Exiteloceras jenneyi (Whitfield)
    Acanthoscaphites n. sp.
    Placenticeras meeki Boehm
32. SW¼ sec. 13, T. 56 N., R. 69 W., Crook County, Wyo.
    Loc. 12717, about 425 ft above Mitten Black shale member of Pierre shale.
    Lucina occidentalis (Morton)
    Protocardia subquadrata (Evans and Shumard)
    Acanthoscaphites nodosus (Owen)
33. SE¼ sec. 18, T. 8 S., R. 56 E., Carter County, Mont.
    Locs. D849 and D397, gray limestone concretions 10 to 15 ft stratigraphically below Monument Hill bentonitic member.
    Inoceramus tenuilineatus Hall and Meek
    Baculites rugosus Cobban
    Placenticeras meeki Boehm
    Placenticeras intercalare Meek
    Exiteloceras jenneyi (Whitfield)
34. SW¼ sec. 19, T. 8 S., R. 56 E., Carter County, Mont.
    Loc. D851, gray limestone concretions at same stratigraphic position as collection 33.
    Inoceramus (*Endocostea*) sp.
    Baculites rugosus Cobban
    Acanthoscaphites n. sp.
    Exiteloceras jenneyi (Whitfield)
    Placenticeras meeki Boehm

35. NE¼ sec. 30, T. 8 S., R. 56 E., Carter County, Mont.
Loc. D848, red-weathering concretions in the lower part of upper black shale unit.
Nucula cancellata Meek and Hayden
Inoceramus (*Endocostea*) *sulcatus* Roemer
Ostrea inornata Meek and Hayden
Baculites pseudovatus Elias
Acanthoscaphites n. sp.

36. NW¼ sec. 31, T. 8 S., R. 56 E., Carter County, Mont.
Loc. D852, limestone concretions in upper part of upper black shale unit.
Nuculana sp.
Inoceramus cf. *I. sublaevis* Hall and Meek
Inoceramus (*Endocostea*) sp.
Pteria aff. *P. linguaeformis* (Evans and Shumard)
Pecten nebrascensis Meek and Hayden
Dentalium gracile Hall and Meek
Polinices sp.
Baculites crickmayi Williams
Didymoceras sp.

37. SW¼NW¼ sec. 6, T. 44 N., R. 61 W., Weston County, Wyo.
Loc. D418, gray limestone concretions estimated 50 ft above top of Mitten black shale member of Pierre shale.
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.

38. SE¼ SW¼ NW¼ sec. 6, T. 44 N. R. 61 W., Weston County, Wyo.
Loc. D417, limestone concretions estimated 50 to 100 ft stratigraphically above collection 37.
Inoceramus sublaevis Hall and Meek
Inoceramus sp.
Eutrephoceras sp.
Baculites scotti Cobban
Anapachydiscus sp.

39. SW¼ sec. 7, T. 45 N., R. 62 W., Weston County, Wyo.
Loc. D870, gray limestone concretions estimated not more than 50 ft stratigraphically above top of Mitten black shale member of Pierre shale.
Inoceramus cf. *I. barabini* Morton
Lucina subundata Hall and Meek
Drepanochilus n. sp.
Baculites cf. *B. gregoryensis* Cobban

Lower gray silty shale unit

40. W½ sec. 18, T. 45 N., R. 62 W., 8 miles west of Newcastle, Wyo., on divide between Skull and Beaver Creeks.
Loc. 11191, lower half of upper part of Pierre shale.
Inoceramus sagensis Owen
Inoceramus barabini Morton
Pecten (*Chlamys*) *nebrascensis* Meek and Hayden
Polinices concinna (Hall and Meek)
Anisomyon borealis (Morton)
Oxybeloceras crassum (Whitfield)
Acanthoscaphites nodosus (Owen)
Didymoceras nebrascense (Meek and Hayden)

41. SE¼ sec. 32, T. 45 N., R. 62 W. 6½ miles southwest of Newcastle, Wyo., on divide between Skull and Beaver Creeks.
Loc. 11212, same stratigraphic horizon as 40.
Nucula sp.
Arca n. sp.
Inoceramus barabini Morton
Ostrea sp., smooth simple form
Lucina subundata Hall and Meek
Acirsa? *cerithiformis* (Meek and Hayden)
Vanikora ambigua (Meek and Hayden)
Ellipsoscapha subcylindrica (Meek and Hayden)
Anisomyon borealis (Morton)
Eutrephoceras dekayi (Morton)
Baculites sp.
Acanthoscaphites nodosus var. *quadrangularis* Meek Hayden

42. SE¼ sec. 3, T. 56 N., R. 68 W., Crook County, Wyo.
Loc. 112629, north side of South Fork of Little Missouri River just above Mitten black shale member of Pierre shale.
Inoceramus sagensis Owen
Protocardia subquadrata (Evans and Shumard)
Baculites sp.

43. NW¼ sec. 22, T. 56 N., R. 68 W., Crook County, Wyo.
Loc. D861 gray limestone concretions about 10 ft stratigraphically above top of Mitten black shale member of Pierre shale.
Inoceramus vanuxemi Meek and Hayden
Baculites aff. *B. gregoryensis* Cobban
Placenticeras meeki Boehm

44. SE¼ sec. 21, T. 8 S., R. 62 E., Carter County, Mont.
Loc. 12641, 250 ft above Mitten black shale member of Pierre shale.
Inoceramus sagensis Owen
Baculites sp.

Above, in, and below Monument Hill bentonitic member

45. NW¼ T. 56 N., R. 69 W., Campbell County, Wyo.
Loc. 12700, from 75 to 375 ft below Fox Hills sandstone.
Parasmilia? n. sp.
Serpula sp.
Yoldia scitula (Meek and Hayden)
Arca n. sp.
Inoceramus sagensis Owen
Pecten nebrascensis Meek and Hayden
Cuspidaria ventricosa (Meek and Hayden)
Lucina occidentalis (Morton)
Thetis circularis (Meek and Hayden)
Natica dakotensis Henderson
Ellipsoscapha subcylindrica (Meek and Hayden)
Baculites compressus Say
Acanthoscaphites nodosus (Owen)

MONUMENT HILL BENTONITIC MEMBER

The Monument Hill bentonitic member of the Pierre shale was named by Rubey (1931, p. 3) for exposures at Monument Hill in sec. 32, T. 56 N., R. 68 W., Crook County, Wyo. This member is fairly well exposed in Carter County, Mont., and parts of it are exposed locally in northwestern Crook County, Wyo. It consists of 150 to 220 feet of gray bentonitic shale, silty shale, and impure bentonite that weathers light gray in contrast to the dark-gray-weathering shale above and below. In Carter County, Mont., the top of the Monu-

ment Hill bentonitic member is about 200 feet below the base of the Fox Hills sandstone, and the base is estimated to be about 450 feet above the Mitten black shale member and 1,500 feet above the base of the Pierre shale. In southern Crook and in Weston Counties, Wyo., rocks of the same age as the Monument Hill bentonitic member apparently are represented by dark-gray shale indistinguishable from the other dark shale underlying the Kara bentonitic member.

Shale in the lower half of the Monument Hill bentonitic member is more bentonitic than that in the upper half, and the shale in the upper half differs, further, by being silty. Interbedded with the bentonitic shale are beds of bentonite ranging from less than ¼ inch to 3 feet in thickness; the average being less than half a foot. Most of the bentonite beds contain barite nodules that range from ¼ to 4 inches in diameter. Gray limestone concretions that weather reddish brown occur locally in the basal 30 feet of the member in Carter County, Mont. From Monument Hill southward to the northwest corner of T. 55 N., R. 67 W., a bed of closely spaced light-gray limestone concretions crops out 30 to 50 feet above the base. The limestone is dense to fine grained, faintly laminated, and unfossiliferous. The concretions are 2 to 4 feet thick and 2 to 5 feet long. They make up a ledge, or weather out in large fragments, and are therefore useful in mapping and correlation in grass-covered areas near the Rocky Point anticline. Similar concretions at about the same stratigraphic position crop out north of Oshoto for about a mile in secs. 29 and 32, T. 54 N., R. 67 W.

In the middle of the member is a bed 5 to 10 feet thick of silty and sandy shale that contains light-gray sandy and silty fossiliferous limestone concretions. At the top of the member in Carter County, Mont., and northern Crook County, Wyo., is a bed of hard medium-gray fine-grained unfossiliferous concretionary limestone, which, like the limestone concretions near the base farther south, forms a ledge that is easily traced. The limestone is in tabular lenses 1 to 3 feet thick and several feet long, and they occur at about the change from gray silty and bentonitic shale below to dark-gray shale above. An analysis was made of a sample of one of these concretions collected by W. W. Rubey 4 miles north of Ridge, Mont., and is given in the following table. Rubey examined thin sections of these concretions and attributes their hardness to an abnormally high amount of secondary silica, which may have been derived from the associated bentonitic shales.

Fossils collected from the lower and middle parts of the Monument Hill bentonitic member represent the zone of *Exiteloceras jenneyi*.

Analysis of calcareous concretion from top of Monument Hill bentonitic member of the Pierre shale about 4 miles north of Ridge, Mont.

[Analyst, J. G. Fairchild]

SiO_2	40.98
Al_2O_3	8.04
Fe_2O_3	1.10
MgO	[1] 1.47
CaO	[1] 22.06
CO_2	[1] 18.24
SO_3	.11
	[2] 92.00

[1] Previously published by Wells (1937, p. 65, column B).
[2] Difference mainly due to water.

The following section was measured on an eastward-facing escarpment in the SW¼ sec. 12, T. 9 S., R. 55 E., about 4 miles east of Ridge, Mont., and is the best complete exposure of this member in the area.

Monument Hill bentonitic member in SW¼ sec. 12, T. 9 S., R. 55 E., Carter County, Mont. (see pl. 5)

	Feet
Pierre shale (part):	
Pierre shale overlying Monument Hill bentonitic member (part):	
14. Shale, dark brownish-gray to grayish-brown; upper half bentonitic; a few thin bentonite seams locally; a bed of manganese-stained limestone concretions 20 ft below top; overlying beds covered by slumped blocks of Fox Hills sandstone; base of the Fox Hills is estimated to be within 25 ft above top of unit	92
13. Shale, brownish-gray; swells slightly on weathering; contains a few brownish-gray limestone concretions as much as 3 ft in diameter; at base a bed 2- to 5-ft thick of grayish- and yellowish-white nonswelling bentonite	110
Partial thickness of Pierre shale overlying Monument Hill bentonitic member	202
Monument Hill bentonitic member:	
12. Limestone, light-gray, fine-grained, massive, nonfossiliferous; forms ledge	2
11. Shale, brownish-gray, bentonitic	15
10. Bentonite, grayish-white and light yellowish-gray, powdery, nonswelling	3
9. Partly covered; mostly brownish medium-gray bentonitic silty shale	60
8. Shale, brownish-gray, silty; contains medium-gray silty and sandy limestone concretions 2 to 5 ft in maximum dimension. Concretions contain the following fossils (identified by W. A. Cobban, loc. D463): *Inoceramus* (*Endocostea*) sp., *Baculites rugosus* Cobban, *Acanthoscaphites* cf. *A. nodosus* (Owen)	6

Monument Hill bentonitic member in SW¼ sec. 12, T. 9 S., R. 55 E., Carter County, Mont. (see pl. 5)—Continued

	Feet
Pierre shale (part)—Continued	
Monument Hill bentonitic member—Continued	
7. Partly covered; mostly brownish-gray shale; silty in upper part	30
6. Shaly bentonite and bentonitic shale, dark-gray and brownish-gray; weathers to a medium-gray "popcorn" surface; contains barite concretions ¼ to 2 in. in diameter	63
5. Partly covered; mostly dark-gray and brownish-gray shale; a few dark-gray limestone concretions 1 to 2 ft in diameter that contain *Inoceramus* fragments	35
4. Bentonite, dark-gray, shaly; middle part contains barite concretions as much as 4 in. in diameter	5
Thickness of Monument Hill bentonitic member	219
Pierre shale underlying the Monument Hill bentonitic member (part):	
3. Partly covered, mostly dark grayish-brown shale	11
2. Shale, dark-gray; contains dark-gray septarian limestone concretions that weather light gray and are 1 to 3 ft in diameter; concretions cut by numerous ¼- to 1-in.-thick yellowish-brown calcite veins. Concretions contain the following fossils (identified by W. A. Cobban, loc. D464): *Nucula planimarginata* Meek and Hayden, *Inoceramus* cf. *I. vanuxemi* Meek and Hayden, *Eutrephoceras* sp. (a nautiloid), *Baculites rugosus* Cobban, *Acanthoscaphites* sp., *Exiteloceras jenneyi* (Whitfield), *Placenticeras meeki* Boehm	29
1. Partly covered; mostly dark-gray to black shale that weathers dark gray; in lower half a few red-weathering ferruginous limestone concretions containing *Inoceramus* fragments	60
Partial thickness of Pierre shale underlying Monument Hill bentonitic member	100
Partial thickness of Pierre shale	521

KARA BENTONITIC MEMBER

The Kara bentonitic member of the Pierre shale is a sequence of gray shale and gray bentonitic shale about 100 feet thick that was mapped along the west flank of the Black Hills from the vicinity of Oshoto in T. 54 N., R. 67 W., southward to the edge of the mapped area in T. 44 N., R. 62 W.—a distance of about 75 miles. The member takes its name from exposures in sec. 2, T. 48 N., R. 67 W., about 1½ miles south of Kara, a siding on the Chicago, Burlington, and Quincy Railroad. At this locality, the top of the member is about 300 feet stratigraphically below the base of the Fox Hills sandstone, and the base of the member is estimated to be about 2,000 feet above the base of the Pierre shale and about 700 feet above the Mitten black shale member of the Pierre. The interval between the Fox Hills sandstone and the Kara bentonitic member of the Pierre shale thins to about 140 feet 18 miles to the north in sec. 6, T. 51 N., R. 67 W. In northwestern Crook County, Wyo., and in Carter County, Mont., rocks of the same age as the Kara bentonitic member are apparently represented either by the upper part of the black shale unit that overlies the Monument Hill bentonitic member, or possibly by the lower part of the Fox Hills sandstone.

Outcrops of the Kara bentonitic member are commonly free of vegetation, and the member typically makes a light-gray band of gumbo soil that contrasts markedly with adjacent grass-covered slopes and flats. The member is particularly prominent west of the Oil Butte-Pine Ridge anticline where it is nearly continuously exposed on a low ridge for several miles.

The basal 20 to 30 feet of the member consists of gray shale containing scattered gray-weathering limestone concretions. This unit rests gradationally on an underlying sequence of grayish-black shale containing concretions that weather dark red. Gray shale at the base of the member grades upward into about 40 to 60 feet of light-gray bentonitic shale or shaly bentonite that swells and flows on weathering. Barite nodules an inch or two in diameter are locally abundant in the middle and lower parts of the bentonitic sequence, and a few gray-weathering limestone concretions 1 to 2 feet in diameter are scattered throughout. The top 10 to 15 feet of the member becomes much less bentonitic, and the top is picked at the base of a prominent ridge-forming zone of gray-weathering septarian limestone concretions commonly 3 to 4 feet in diameter, which characterize the base of the overlying sequence.

Fossils collected from concretions in the Kara bentonitic member, and from concretions in the adjacent beds, represent the zone of *Baculites eliasi.*

The following section, measured 1½ miles south of Kara siding, is the type section (Robinson and others, 1959).

Kara bentonitic member and overlying part of the Pierre shale 1½ miles south of Kara in the NW¼ sec. 2, T. 48 N., R. 67 W., Weston County, Wyo. (see pl. 5)

	Feet
Fox Hills sandstone (part):	
9. Sandstone and interbedded shale; sandstone is very light gray, weathers light yellowish gray, fine grained, in beds as much as 1 ft thick; thicker beds are calcareous and form slabby ledges; shale is dark gray, noncalcareous, slightly sandy; forms ridge	50+

Kara bentonitic member and overlying part of the Pierre shale 1½ miles south of Kara in the NW¼ sec. 2, T. 48 N., R. 67 W., Weston County, Wyo. (see pl. 5)—Continued

	Feet
Pierre shale (part):	
Pierre shale overlying the Kara bentonitic member:	
8. Shale, dark-gray weathers medium gray, noncalcareous; lower half poorly exposed; upper half contains several beds of dark gray limestone concretions that weather light gray and range from 1 to 4 ft in diameter; some concretions are septarian with veins of orange and brown calcite; a few laminae of fine-grained sandstone in top 20 ft. Unit yields the following fossils (identified by W. A. Cobban): concretions within top 50 ft (locs. D407, D435, D436, and D437), *Nucula cancellata* Meek and Hayden, *Yoldia evansi* (Meek and Hayden), *Idonearca shumardi* (Meek and Hayden), *Gervillia* sp., *Inoceramus balchi* Meek and Hayden, *Inoceramus* n. sp., *Pteria linguaeformis* (Evans and Shumard), *Pteria* (*Oxytoma*) *nebrascana* (Evans and Shumard), *Ostrea* sp., *Pecten* (*Syncyclonema*) *halli* Gabb, *Pecten* (*Chlamys*) *nebrascensis* Meek and Hayden, *Anomia* sp., *Crenella elegantula* (Meek and Hayden), *Protocardia subquadrata* (Evans and Shumard), *Cuspidaria moreauensis* (Meek and Hayden), *Dentalium* sp., *Ellipsoscapha minor* (Meek and Hayden), *Baculites grandis* Hall and Meek, *Discoscaphites* n. sp.; concertions about 125 ft below top (loc. D434), *Idonearca shumardi* (Meek and Hayden), *Inoceramus sp.*, *Protocardia subquadrata* (Evans and Shumard), *Baculites* cf. *B. baculus* Meek and Hayden, *Discoscaphites* n. sp	230
7. Shale, dark-gray, weathers medium gray, noncalcareous; upper and lower parts contain prominent beds of dark-gray limestone concretions that weather light gray; a few scattered light-gray-weathering limestone concretions in middle; concretions at base as much as 10 ft in diameter. Concretions in basal 35 ft. yield the following fossils (identified by W. A. Cobban, locs. D406 and D433): *Nucula cancellata* Meek and Hayden, *Yoldia evansi* (Meek and Hayden), *Inoceramus* (*Endocostea*) *typicus* (Whitfield), *Pteria* (*Oxytoma*) *nebrascana* (Evans and Shumard), *Lucina occidentalis* (Morton), *Dentalium* sp., *Baculites eliasi* Cobban, *Acanthoscaphites* n. sp	70
Thickness of Pierre shale overlying Kara bentonitic member	300

Kara bentonitic member and overlying part of the Pierre shale 1½ miles south of Kara in the NW¼ sec. 2, T. 48 N., R. 67 W., Weston County, Wyo. (see pl. 5)—Continued

	Feet
Pierre shale (part)—Continued	
Kara bentonitic member:	
6. Shale, dark-gray, weathers dark gray to dark olive gray, slightly silty; slightly bentonitic locally; a few small scattered limestone concretions like those in unit 7. Concretions yield the following fossils (identified by W. A. Cobban, locs. D405 and D432): *Inoceramus* n. sp., *Lucina subundata* Hall and Meek, *Protocardia subquadrata* (Evans and Shumard), *Baculites eliasi* Cobban, *Acanthoscaphites* n. sp	25
5. Partly covered; mostly bentonite and bentonitic shale; bentonite is yellowish gray; shale is dark gray; middle part more shaly than upper and lower parts and contains scattered small dark-gray limestone concretions like those in unit 7; a few fragments of barite weathering out on slopes; unit forms bare slopes on which the bentonite swells and flows. Concretions near middle of unit yield the following fossils (identified by W. A. Cobban, locs. D404 and D431): *Inoceramus* cf. *I. subcircularis* Meek, *Inoceramus* n. sp., *Lucina subundata* Hall and Meek, *Baculites eliasi* Cobban, *Acanthoscaphites* n. sp	38
4. Shale, dark-gray, weathers dark olive gray, noncalcareous, slightly bentonitic locally; a few dark-gray limestone concretions that weather light gray and are 1 to 2 ft. in diameter	13
3. Shale, dark-gray, weathers dark olive gray, noncalcareous; a few scattered dark-gray limestone concretions that weather light gray and are about 1 ft in diameter; a few lenses of fibrous aragonite and barite as much as 1 ft thick. Concretions yield the following fossils (identified by W. A. Cobban, loc. D403): *Inoceramus* sp., *Lucina occidentalis* (Morton), *Baculites eliasi* Cobban	17
Thickness of Kara bentonitic member	93
Pierre shale underlying the Kara bentonitic member (part):	
2. Shale, very dark gray, weathers dark gray to black, noncalcareous; several beds of dark-gray limestone concretions that weather dark red and are about 1 to 3 ft in diameter; a few scattered light-gray-weathering limestone concretions	80

Kara bentonitic member and overlying part of the Pierre shale 1½ miles south of Kara in the NW¼ sec. 2, T. 48 N., R. 67 W., Weston County, Wyo. (see pl. 5)—Continued

Pierre shale (part)—Continued

Pierre shale underlying the Kara bentonitic member part)—Continued — *Feet*

1. Shale, dark-gray, weathers medium gray, noncalcareous; contains a few dark-gray limestone concretions that weather light gray. Concretions near top yield the following fossils (identified by W. A. Cobban, locs. D402 and D429): *Micrabacia*? sp., *Nuculana bisulcata* (Meek and Hayden), *Idonearca shumardi* (Meek and Hayden), *Nemodon* sp., *Yoldia evansi* (Meek and Hayden), *Inoceramus* cf. *I. barabini* Morton, *Inoceramus* cf. *I. balchi* (Meek and Hayden), *Pteria linguaeformis* (Evans and Shumard), *Pecten* (*Chlamys*) *nebrascensis* (Meek and Hayden), *Crenella elegantula* (Meek and Hayden), *Periploma* sp., *Cuspidaria* cf. *C. ventricosa* (Meek and Hayden), *Thetis*? *circularis* (Meek and Hayden), *Protocardia subquadrata* (Evans and Shumard), *Amonia* sp., *Ellipsoscapha occidentalis* (Meek and Hayden), *Anisomyon* sp., *Drepanochilus nebrascensis* (Evans and Shumard), *Baculites eliasi* Cobban, *Discoscaphites*? sp., *Acanthoscaphites* n. sp. — 20

Partial thickness of Pierre shale underlying Kara bentonitic member — 100

Partial thickness of Pierre shale — 493

A complete section of the Kara bentonitic member was also measured about 14 miles farther north as follows:

Kara bentonitic member of the Pierre shale near the Texas Trail road in the SE¼ sec. 6, T. 51 N., R. 67 W., Crook County, Wyo. (see pl. 5)

Pierre shale (part): — *Feet*

Pierre shale overlying the Kara bentonitic member (part):

6. Shale, dark-gray, weathers dark gray to dark olive gray, noncalcareous; prominent beds of dark-gray limestone concretions 3 to 5 ft in diameter that weather light gray and contain veins of brown and yellow calcite. Concretions at top of unit yield the following fossils (identified by W. A. Cobban, loc. D868): *Inoceramus* cf. *I. subcircularis* Meek, *Eutrephoceras* sp., and *Baculites baculus* Meek and Hayden — 45

Kara bentonitic member of the Pierre shale near the Texas Trail road in the SE¼ sec. 6, T. 51 N., R. 67 W., Crook County, Wyo. (see pl. 5)—Continued

Pierre shale (part)—Continued

Kara bentonitic member of the Pierre shale: — *Feet*

5. Shale, dark-gray to dark olive gray, locally bentonitic; a few scattered dark-gray limestone concretions smaller but otherwise similar to those at the base of unit 6. Concretions in this unit and in the lower third of unit 6, yield the following fossils (identified by W. A. Cobban, loc. D408): *Nucula cancellata* Meek and Hayden, *Inoceramus* (*Endocostea*) *typicus* (Whitfield), *Inoceramus* sp., *Pteria* (*Oxytoma*) *nebrascana* (Evans and Shumard), *Pteria* aff. *P. linguaeformis* (Evans and Shumard), *Polinices* sp., *Ringicula* sp., *Baculites eliasi*, Cobban, and *Acanthoscaphites* n. sp. — 10
4. Bentonitic shale and impure bentonite; shale is gray; bentonite is grayish yellow; swells and flows on weathering; forms bare slopes; upper part of unit contains a few scattered limestone concretions similar to those at base of unit 6; lower part contains scattered light-gray barite concretions as much as 6 in. in diameter — 30
3. Shale, dark-gray; slightly bentonitic at base becoming more bentonitic upward; a few gray limestone concretions similar to those at the base of unit 6, and scattered barite concretions similar to those at base of unit 4 — 40
2. Partly covered, appears to be mostly dark-gray shale containing a few scattered gray limestone concretions — 16

Thickness of Kara bentonitic member — 96

Pierre shale underlying the Kara bentonitic member (part):

1. Shale, very dark gray to black, very soft and fissile; contains a few scattered dark-gray limestone concretions that weather gray to dark red — 20+

Partial thickness of Pierre shale — 161

FOX HILLS SANDSTONE

The Fox Hills sandstone is a sequence of sandstone and shale that ranges in thickness from about 125 to 200 feet and includes the youngest known marine deposits of the mapped area. The formation is fairly well exposed in Montana and in Wyoming south of the Belle Fourche River, where it forms a scarp standing 100 feet or more above low rolling hills underlain by the Pierre shale. From the Montana-Wyoming line

southward about to the Belle Fourche River, the Fox Hills sandstone is poorly exposed and has no pronounced topographic expression.

Two members can be recognized in the Fox Hills sandstone in Montana. The lower member is about 50 to 100 feet thick and consists of gray to brownish-gray fine-grained thin-bedded sandstone interbedded with gray sandy shale and siltstone. The sandstone contains a few ferruginous and calcareous sandstone concretions and locally forms slabby ledges. Beds of shale become abundant at the base of the formation and the Fox Hills grades downward through an interval of about 10 to 50 feet into dark-gray sandy shale in the upper part of the Pierre shale.

The upper member of the formation is equivalent to the Colgate sandstone member of the Fox Hills sandstone as redefined by Thom and Dobbin (1924, p. 485–486). It consists of very light gray fine- to medium-grained more or less massive sandstone 50 to slightly more than 100 feet thick. This member forms prominent white bluffs 50 feet or more high near Ridge, Mont., and it is well exposed from Ridge northward to the northern limit of the mapped area. In Wyoming, the Colgate member pinches out or grades laterally into sandstone and shale similar to that in the lower member.

Fossils from the Fox Hills sandstone are scarce in the northwestern part of the Black Hills, and none was found by the authors. The following fossils were collected by W. W. Rubey and others in 1922 to 1924, and identified by J. B. Reeside, Jr.

Fossils collected from the Fox Hills sandstone

[Fossils identified by J. B. Reeside, Jr.]

1. Sec. 30, T. 45 N., R. 63 W., about 13 miles west of Newcastle, Wyo.
   Loc. 11213, from sandstone near middle of Fox Hills sandstone.
   Fish scales, sugggesting *Cyclolepis stenodinus* Cockerell
2. Sec. 21, 27, or 28, T. 47 N., R. 65 W., about 5 miles south-southwest of Upton, Wyo.
   Loc. 11219, probably near top of Fox Hills sandstone.
   Veniella humilis (Meek and Hayden)
3. NE¼ sec. 12, T. 47 N., R. 66 W., about 5 miles west-southwest of Upton, Wyo.
   Loc. 11924, sandstone near top of Fox Hills sandstone.
   Nucula sp.
   Yoldia evansi (Meek and Hayden)
   Veniella humilis (Meek and Hayden)
   Tellina scitula Meek and Hayden
   Dentalium sp.
   Fusus newberryi Meek and Hayden
   Ellipsoscapha subcylindrica (Meek and Hayden)
   Discoscaphites sp.
   Fish vertebra
4. Sec. 7 or 8, T. 48 N., R. 66 W., 9 miles southeast of Moorcroft, Wyo.
   Loc. 11339, concretionary bed 60 ft above base of Fox Hills sandstone.
   Yoldia scitula (Meek and Hayden)
   Tellina scitula Meek and Hayden
   Lunatia subcrassa (Meek and Hayden)
   Discoscaphites sp.
5. Sec. 6, T. 51 N., R. 67 W., about 12 miles north of Moorcroft, Wyo.
   Loc. 12039, about 50 ft above base of Fox Hills sandstone.
   Ophiomorpha major (Lesquereux)

In northern Weston and southern Crook Counties, Wyo., the Fox Hills sandstone rests on shale that contains *Baculites grandis* Hall and Meek in its uppermost 100 feet. Near Oshoto and on the south flank of the Rocky Point anticline in northern Crook County, the uppermost part of the Pierre shale contains the older ammonite *Baculites eliasi* Cobban. This relation suggests that the Fox Hills sandstone might become older northward, so that in northern Crook County some part of the Fox Hills makes up the zone of *Baculites grandis*. It is also possible, however, that the Fox Hills is everywhere about the same age, and rocks representing the zone of *Baculites grandis* are very thin or missing in the northern area because of nondeposition—perhaps as a result of local uplift of the sea floor prior to deposition of the Fox Hills. No evidence was found to indicate which of these two possibilities is more likely.

The following sections illustrate the lithology of the Fox Hills sandstone. The first section, measured northeast of Ridge, Mont., is a good example of the Fox Hills sandstone including the Colgate sandstone member in the northern part of the area. The second section was measured near Upton in Weston County, Wyo., and is typical of the Fox Hills sandstone south of the Belle Fourche River. The third section, taken from Dobbin and Reeside (1929, p. 19), was measured west of Newcastle, Wyo., near the southern limit of the mapped area.

Fox Hills sandstone and part of the Lance formation near Ridge in sec. 11, T. 9 S., R. 55 E., Carter County, Mont.

	Feet
Lance formation (part):	
17. Sandstone, gray, weathers brownish to yellowish gray, medium-grained, arkosic, micaceous; upper 11 ft forms massive ledge; lower 3 ft forms slope	14
16. Claystone, dark-gray, weathers light gray; swells slightly on weathering	8
15. Sandstone, light-gray, weathers brownish gray, slightly carbonaceous	4
14. Claystone, dark-gray, weathers light gray	7

Fox Hill sandstone and part of the Lance formation near Ridge in sec. 11, T. 9 S., R. 55 E., Carter County, Mont.—Continued

Lance formation (part)—Continued	Feet
13. Claystone, gray, sandy; swells slightly on weathering; a few brown-weathering sandstone concretions about 1 ft thick and as much as 3 ft long	29
12. Sandstone, light-gray, weathers yellowish gray and light gray, fine-grained, micaceous; numerous dark grains; abundant fossil wood; scattered brown-weathering sandstone concretions as much as 2 ft in diameter	76
11. Partly covered; mostly light-gray to light-brown fine-grained sandstone	17
Partial thickness of Lance formation	155
Fox Hills sandstone:	
Colgate sandstone member:	
10. Sandstone, grayish-white, medium-grained, arkosic, micaceous, massive; contains numerous yellow limonite specks	15
9. Covered	20±
8. Sandstone, light-gray to light greenish-gray, weathers grayish white, medium-grained, arkosic, micaceous, friable; contains small clay pellets; beds 2 to 6 in. thick	28
7. Sandstone, gray to light greenish-gray, weathers light gray, medium-grained; a few small yellow ferruginous sandstone nodules in upper part; beds 4 to 15 ft thick separated by lenticular partings of gray shale; forms cliff	49
Thickness of Colgate sandstone member	112
Lower part:	
6. Claystone, very light greenish-gray, silty to sandy	2
5. Sandstone, light to dark greenish-gray, medium-grained, micaceous; beds about 1 to 10 in. thick separated by partings of siltstone and silty claystone; a bed of brown-weathering calcareous sandstone concretions as much as 8 ft long at base; forms slope	10
4. Sandstone, medium-gray, weathers light gray to light brownish gray, fine-grained, silty, crossbedded, friable; beds 1 to 6 ft thick; a few thin partings of gray shale; forms slope	30
3. Sandstone and siltstone, medium- to dark gray, weathers light gray to light yellowish gray, calcareous; beds 1 to 6 in. thick; thinner bedded at base; forms ledge	5½
2. Siltstone, medium-gray, weathers brownish gray, sandy	3
Thickness of lower part (rounded)	50
Thickness of Fox Hills sandstone	162

Fox Hill sandstone and part of the Lance formation near Ridge in sec. 11, T. 9 S., R. 55 E., Carter County, Mont.—Continued

Pierre shale (part):	Feet
1. Shale, dark- to medium-gray; weathers light gray to light greenish gray; upper third slightly silty; lower third swells slightly on weathering	29

Part of the Fox Hills sandstone northwest of Upton in sec. 17, T. 48 N., R. 66 W., Weston County, Wyo.

Top of ridge.

Fox Hills sandstone (part):	Feet
13. Sandstone, yellowish-gray, fine-grained, locally crossbedded; a few thin partings of gray sandy shale	40
12. Shale, gray	17
11. Sandstone, light-gray to yellowish-gray, fine-grained	1
10. Shale, gray	8
9. Sandstone, light-gray, fine-grained; gray sandy shale in middle part	8
8. Shale, gray; some yellowish-gray sandy shale	20
7. Sandstone, brownish-gray, fine-grained	1
6. Shale, gray, sandy	22
5. Sandstone, light-gray, fine-grained	½
4. Shale, gray	11
3. Shale, gray, sandy; a few thin light-gray fine-grained sandstone beds in upper part; a bed 1 ft thick of light-gray fine-grained friable sandstone at base	6
2. Shale, gray; thin partings of yellowish-gray sandy shale	17
Partial thickness (rounded) of Fox Hills sandstone	152
Pierre shale (part):	
1. Shale, dark-gray; a few gray limestone concretions near base	25

Fox Hills sandstone and parts of the Lance formation and Pierre shale 13 miles west of Newcastle, Weston County, Wyo.

[After Dobbin and Reeside, 1929, p. 19]

Lance formation (part):	Feet
Sandstone, yellow-brown; contains flat hard brown sandstone concretions; weathers into "toadstools"	30
"Somber shale"; composed of dark-gray sandy clay with small botryoidal masses of limonite sand, brown concretions, and a little hard sandstone in thin layers; turtle and dinosaur bones at top	50
Slope; probably underlain by gray sandy clayey shale	70
Sandstone, light-gray, soft; and dark-gray shale; alternating in thin layers; contains a little hard brown platy sandstone; no fossils found, assignment arbitrary	30
Partial thickness of the Lance formation	180

Fox Hills sandstone and parts of the Lance formation and Pierre shale 13 miles west of Newcastle, Weston County, Wyo.—Continued

	Feet
Fox Hills sandstone:	
Sandstone, dark-brown, hard, platy; forms cap rock of many small buttes	3
Sandstone, yellow to light-gray, rather soft; weathers to a slope	62
Sandstone, argillaceous, very soft, slope-forming; contains a few somewhat harder layers, some thin layers, and a few siderite concretions; marine fossils 44 ft above base	60
Thickness of Fox Hills sandstone	125
Pierre shale (part):	
Limestone concretions, gray; 3 to 4 ft in diameter; most are septarian and without fossils; a few marine fossils	3
Shale, greenish-gray, sandy; a few small calcareous concretions	20
Concealed under grassy flat that extends eastward from Fox Hills escarpment; probably in large part gray sandy shale	150±
Partial thickness of Pierre shale	173

LANCE FORMATION

The Lance formation is a variable nonmarine sequence of sandstone, sandy shale, and claystone that overlies the Fox Hills sandstone and underlies the Tullock member of the Fort Union formation. Exposures of the formation are poor; it typically forms grasslands dotted with a few buttes and ridges held up by the more resistant beds of sandstone. The Lance formation is about 1,600 feet thick in northern Weston County, Wyo., but it thins gradually northward to about 500 feet in southern Powder River County, Mont.

The formation consists of alternating beds of sandstone, sandy shale, and claystone. The sandstone weathers light gray to yellowish gray, is fine to medium grained, friable, and commonly crossbedded, and occurs in beds that range from less than 1 inch to more than 25 feet in thickness. The thicker sandstone beds locally contain calcareous sandstone concretions that are spherical, roughly cylindrical, or large tabular masses several feet thick and tens of feet wide. The sandy shale and claystone are medium to dark gray and plastic and swell slightly when wet. Beds of carbonaceous shale usually occur at or near the base of the formation and locally in the middle and upper parts.

The contact between the Lance formation and underlying Fox Hills sandstone is gradational and is picked at a change in lithology thought to represent the change from marine rocks below the contact to nonmarine rocks above (Dobbin and Reeside, 1929, p. 9–25). In Montana, where the Colgate sandstone member is present at the top of the Fox Hills sandstone, the contact is marked by a comparatively abrupt change upward from light-gray cliff-forming sandstone of the Colgate to thin-bedded darker sandstone, sandy shale, and claystone of the Lance formation. South of the Montana-Wyoming State line, the Colgate sandstone member cannot be recognized, and the beds of sandstone in the Fox Hills and Lance formations do not differ appreciably as seen in isolated outcrops. The contact in this area is arbitrarily placed at the base of the lowest bed of brown carbonaceous shale or gray plastic swelling clay. Locally, bone fragments weather from beds near the base of the overlying sequence, and, rarely, fragmentary marine fossils occur in the underlying beds.

No fossils were collected from the Lance formation during the present work. W. W. Rubey and others in 1922 to 1924 collected the following invertebrate and vertebrate fossils:

Fossils collected from the Lance formation

[Invertebrate fossils identified by J. B. Reeside, Jr.; vertebrate fossils identified by C. W. Gilmore]

1. Sec. 7, T. 49 N., R. 67 W., 1 mile south of Moorcroft, Wyo.
   Loc. 12056.
   Sphaerium subellipticum (Meek and Hayden)
   Thaumastus limnaeiformis (Meek and Hayden)
2. Sec. 2, T. 54 N., R. 68 W., 8 miles north of Oshoto, Wyo.
   Loc. 12043, brownish-gray sandstone 300 ft above base of Lance formation.
   Unio covesi White
3. Sec. 5, T. 54 N., R. 68 W., E. side of Prairie Creek 9 miles northwest of Oshoto, Wyo.
   Loc. 12646, 100 ft below top of Lance formation.
   Unio letsoni Whitfield
   Unio sp.
   Viviparus sp.
   Campeloma sp.
4. SW¼ sec. 6, T. 46 N., R. 65 W., 8 miles southwest of Upton, Wyo.
   Part of dinosaur foot bone
   Epioccipital bone probably pertaining to genus *Triceratops*
   Fragments of soft-shelled turtles

No complete sections of the Lance formation were measured because of poor exposures and the wide area of outcrop. The following section illustrates the lithology of the middle part of the formation; partial sections of the base are given on pages 96–97 and the top on pages 101–102.

Part of the Lance formation in the SW¼ sec. 7, T. 54 N., R. 67 W., Crook County, Wyo.

Top of hill.

Lance formation (part):	Feet
10. Sandstone, light yellowish-gray to light-gray, medium- to fine-grained, friable; a few partings and laminae of gray and brown carbonaceous shale; scattered gray- to brown-weathering calcareous sandstone concretions in middle and upper parts; a few layers 1 to 2 in. thick of yellowish-gray cone-in-cone sandstone concretions; 3 beds about 1 ft thick of brown carbonaceous shale about equally spaced in the unit	60+
9. Shale, medium-gray, silty, slightly carbonaceous; grades in upper 2 to 3 ft into brown carbonaceous shale	8
8. Sandstone, light gray, weathers olive-gray, fine-grained, crossbedded, very friable; a few laminae of gray and brown shale	2
7. Shale, brown, carbonaceous	8
6. Sandstone as in unit 8	20
5. Claystone, medium-gray, sandy, carbonaceous	16
4. Sandstone, light-gray, weathers light brownish gray, fine- to medium-grained, friable; a few thin partings of medium-gray sandy shale	15
3. Shale, medium-gray to olive-gray, slightly sandy; selenite and bone fragments weather out on slope	3
2. Sandstone, light-gray, weathers light yellowish brown, fine- to medium-grained, friable, crossbedded; abundant dark-colored minerals; scattered dark-brown-weathering calcareous sandstone concretions as much as 10 ft long	95
1. Shale, medium-gray, slightly carbonaceous; lower half brown locally; a few seams of coal about ⅛ in. thick	12+
Partial thickness of Lance formation	239

Base of exposures.

TERTIARY SYSTEM

PALEOCENE SERIES

FORT UNION FORMATION

The Fort Union formation crops out in much of the western third of the mapped area and consists of 1,500 to 2,100 feet of interbedded nonmarine sandstone, shale, and coal. The formation can be divided into three members in Powder River County, Mont., and in northern Campbell County, Wyo.

At the base is the Tullock member, which is characterized by many thin lenticular beds of coal and carbonaceous shale and relatively large amounts of sandstone. The Lebo shale member overlies the Tullock member and consists mostly of dark-gray shale, some sandstone, and only a few thin beds of coal. The Tongue River member, at the top of the formation, consists mostly of sandstone, some shale, and several thick coal beds. The lithologic distinction between the Lebo and Tongue River members becomes less pronounced as they are traced southward in Campbell County, and in the southwestern part of the mapped area these two members were not differentiated.

TULLOCK MEMBER

The Tullock member of the Fort Union formation crops out mostly east of the Little Powder River or its tributary Cottonwood Creek in a northward-trending band ranging from 5 to 20 miles in width. The member forms a line of high intricately dissected ridges, in contrast to more subdued rolling topography formed on the underlying Lance formation to the east. The Tullock member is between 1,000 and 1,100 feet thick near Rozet in Campbell County, Wyo.; it is estimated to be 950 feet thick in the Trigood Oil Co. Government 1 north of Adon in sec. 28, T. 53 N., R. 70 W.; and it is about 500 feet thick near the Wyoming-Montana State line.

The Tullock member consists of fine-grained sandstone, gray sandy or silty shale, and numerous beds of brown carbonaceous shale and coal. The sandstone weathers to light shades of yellow and gray, which together with darker weathering carbonaceous shale and coal beds give outcrops of the member a striking, banded appearance from a distance. Much of the sandstone is soft and friable although thin layers of calcareous brown-weathering sandstone form a few hard resistant ledges at most outcrops. The beds of coal usually are lenticular and less than 2 feet thick.

The Tullock member of the Fort Union formation is of Tertiary age, and rests conformably on the Lance formation of Late Cretaceous age. The Tullock is distinguished from the Lance by its lighter colors, somewhat more even bedding and its coal beds. The base of the Tullock was mapped at the bottom of the stratigraphically lowest coal bed above a thick sequence of massive channel sandstone and dark-gray shale in the upper part of the Lance found by Rubey to contain locally abundant bone fragments.

LEBO SHALE MEMBER

The Lebo shale member of the Fort Union formation is 200 to 250 feet thick. It crops out along the valley of the Little Powder River north of White Tail Creek in northern Campbell County, Wyo., and in Powder River County, Mont. South of White Tail Creek, the Lebo shale and overlying Tongue River members were not differentiated. The member typically forms badlands in which the prevailing color is dark gray.

The Lebo shale member consists mostly of light- to dark-gray claystone and shale, subordinate light-gray fine-grained sandstone in the discontinuous lenses, and beds of brown carbonaceous shale. Calcareous siltstone concretions that weather purplish red are abundant and locally give outcrops of the member a reddish-gray appearance from a distance. The member is conformable on the Tullock member of the Fort Union formation; the contact being marked by a fairly abrupt change from light yellowish-gray sandstone and gray shale at the top of the Tullock to dark-gray claystone and gray sandstone containing abundant red-weathering concretions at the base of the Lebo. A persistent coal bed, a few inches to as much as 4 feet thick, crops out at the base of the Lebo shale member at many outcrops, but the remainder of the member contains little or no coal.

TONGUE RIVER MEMBER

The Tongue River member of the Fort Union formation was mapped separately north of White Tail Creek in northern Campbell County, Wyo., and in Powder River County, Mont. It is fairly well exposed on the sides of steep bluffs that border the Little Powder River on the west. The Tongue River member consists of about 800 feet of interbedded light-gray fine-grained sandstone, gray siltstone, gray sandy shale, and coal. The prevailing colors of the member are light gray and yellowish gray in contrast to the much darker colors of the underlying Lebo shale member. The middle and upper parts of the Tongue River member contain several coal beds that, according to Davis, (1912, pls. 31, 32, and 33), locally attain thicknesses of 5 to 10 feet of clean coal free of shale partings. Some of the coal beds were traced by Davis (1912) for several miles. The lowest thick coal bed, bed J of Davis (1912, p. 429), is about 300 to 350 feet above the base of the member.

According to Olive (1957, p. 24) the Tongue River member is 1,200 to 1,300 feet thick in the Spotted Horse coal field a few miles west of the mapped area. Olive (1957, p. 26) noted that the stratigraphic interval between coal beds at the top of the Tongue River and those at the base of the overlying Wasatch formation decreases eastward under the divide between the Powder and Little Powder Rivers. He suggested that this is due, in part at least, to a slight angular unconformity at or near the top of the Tongue River member.

LEBO SHALE AND TONGUE RIVER MEMBERS UNDIFFERENTIATED

The Lebo shale and Tongue River members of the Fort Union formation were mapped as a single unit south of White Tail Creek in Campbell County, Wyo. The two members make up a sequence 900 to 1,000 feet thick, which may be divided into a lower part 250 to 400 feet thick composed of dark-gray shale and light-gray sandstone resembling in general the Lebo shale member in the adjoining area to the north, and an upper part 500 to 700 feet thick composed of gray shale, light-gray sandstone, and a few coal beds resembling in general the Tongue River member of the area to the north. Rusty-weathering ferruginous siltstone concretions are abundant in the lower part of the sequence and appear in the upper part in increasing numbers going southward. Beds of sandstone in the upper part tend to weather light gray rather than yellowish gray, as is characteristic of the Tongue River member in northern Campbell County. Coal beds in the upper part are thinner and less persistent than the coal beds in the equivalent rocks farther to the north where the Tongue River member is differentiated.

Details of the lithology of various parts of the Fort Union formation are given in the following measured sections:

Parts of the Tullock member of the Fort Union formation and the Lance formation on the west side of the Rocky Point anticline in sec, 35, T. 56 N., R. 69 W., Campbell County, Wyo.

Top of hill.
Fort Union formation (part):
Tullock member (part):

	Feet
43. Sandstone, very light gray, medium- to fine-grained, friable; contains calcareous sandstone concretions as much as 5 ft thick, 25 ft wide, and 50 ft long	10
42. Shale, dark-brown to black coaly	2
41. Sandstone, light-gray, weathers yellowish gray, very fine grained, friable	9
40. Claystone, medium-gray; a bed of brown carbonaceous shale 2 ft thick near top	11
39. Siltstone, light yellowish-gray, shaly	3
38. Claystone, medium-gray to brown; a few brown-weathering ferruginous siltstone concretions	7
37. Sandstone, very light gray, very fine grained; locally shaly; a few brown-weathering siltstone concretions as much as 6 in. long; forms local slabby ledges	21
36. Shale, gray to brown, carbonaceous	5
35. Sandstone and siltstone, light-gray, very fine grained	8
34. Claystone, light- to medium-gray; sandy at top	2
33. Shale, dark-brown to black; a few thin stringers of coal	1
32. Claystone, gray, sandy	3
31. Shale, brown and gray, silty, carbonaceous; seam of coal 1 in. thick near top	3
30. Shale, gray, carbonaceous	3
29. Sandstone, light-gray, weathers yellowish gray, fine-grained, friable	6
28. Shale, gray to brownish-gray, silty	2
27. Sandstone, light-gray, weathers light yellowish gray, fine-grained, micaceous, friable	3

Parts of the Tullock member of the Fort Union formation and the Lance formation on the west side of the Rocky Point anticline in sec. 35, T. 56 N., R. 69 W., Campbell County, Wyo.—Continued

Fort Union formation (part)—Continued

Tullock member (part)—Continued

	Feet	Feet
26. Shale, medium-gray; carbonaceous near middle		3½
25. Sandstone, light-gray, weathers yellowish gray to brownish gray, fine-grained; contains nodules of orange-brown-weathering siltstone as much as 3 in. in diameter; slabby to friable		8
24. Shale and coal, as follows:		
Shale, gray, slightly carbonaceous	1.8	
Shale, brown, carbonaceous	1.6	
Coal	.7	
Shale, brown, carbonaceous	.9	
Coal	.7	
Shale, dark-brown, carbonaceous	.9	
Coal	1.4	
Shale, dark-brown to black, carbonaceous	5.0	
Total		13
Partial thickness (rounded) of the Tullock member of Fort Union formation		124

Lance formation (part):

23. Sandstone, medium- to light-gray, medium- to fine-grained, slightly carbonaceous	5
22. Claystone, light- to dark-gray, sandy, slightly carbonaceous	6
21. Sandstone, gray, weathers brownish gray, medium- to fine-grained, friable; slightly carbonaceous at base	5
20. Shale, brown, carbonaceous	1
19 Claystone, gray, slightly carbonaceous; sandy at base	10
18. Sandstone, gray, medium- to fine-grained, friable; slightly carbonaceous at base	8
17. Shale, brown to gray, carbonaceous	1½
16. Claystone, gray, silty	4
15. Sandstone, light gray, weathers yellowish brown, medium-grained, friable	1
14. Claystone, medium-gray, sandy	4½
13. Sandstone, light brownish-gray, fine-grained, friable	5
12. Claystone, dark-gray, silty; carbonaceous in lower part	7
11. Shale, dark-brown, carbonaceous	2
10. Claystone, gray; sandy at base; slightly carbonaceous at top	9
9. Sandstone, light-gray, fine-grained, very friable	2
8. Claystone, light- to dark-gray; sandy near base; carbonaceous at top	11

Parts of the Tullock member of the Fort Union formation and the Lance formation on the west side of the Rocky Point anticline in sec. 35, T. 56 N., R. 69 W., Campbell County, Wyo.—Continued

Lance formation (part)—Continued

	Feet
7. Sandstone, light-gray, weathers brownish gray, medium- to fine-grained; partings of gray sandy shale and brown carbonaceous shale; scattered brown-weathering siltstone concretions as much as 1½ ft thick and 3 ft long	46
6. Sandstone, light-gray, weathers yellowish gray, medium-grained, friable; elongate sandstone concretions several feet long	40
5. Covered	6
4. Siltstone, gray, sandy	2
3. Shale, gray	1
2. Shale, brown, carbonaceous	1½
1. Claystone, gray	10
Partial thickness (rounded) of Lance formation	188

Base of exposures.

Parts of the Tullock member of the Fort Union formation and the Lance formation in secs. 9 and 10, T. 47 N., R. 67 W., Weston County, Wyo.

Fort Union formation (part):

Tullock member (part):

	Feet
41. Sandstone and interbedded shale; sandstone is very light gray, weathers light gray, fine grained, friable; shale is gray	12+
40. Shale, gray to dark grayish-purple; silty and sandy in middle and upper parts	15
39. Sandstone, very light gray, weathers light yellowish gray, fine-grained, friable, carbonaceous; a brown-weathering calcareous concretionary ledge-forming sandstone bed about 1 ft thick in lower part	15
38. Shale, greenish-gray	3
37. Shale, brown, carbonaceous; a coal seam 6 in. thick near middle	9
36. Sandstone, very light gray, fine-grained, friable	3
35. Shale, medium- to dark-gray, carbonaceous; a dark-brown to black carbonaceous shale bed 3 in. thick near top	10
34. Shale, brown, carbonaceous; a seam of coal 2 in. thick near middle	3
33. Partly covered; in part very light gray fine-grained sandstone	8
32. Shale, brown, carbonaceous; coal seam 6 in. thick near top	2
31. Sandstone, very light gray, fine-grained, carbonaceous, friable, crossbedded; shaly near top	20
30. Shale, brown, carbonaceous	1
29. Sandstone, very light gray to very light yellowish gray, fine-grained, friable, slightly carbonaceous, crossbedded; many partings of gray shale	5

Parts of the Tullock member of the Fort Union formation and the Lance formation in secs. 9 and 10, T. 47 N., R. 67 W., Weston County, Wyo.—Continued

Fort Union formation (part)—Continued

Tullock member (part)—Continued

	Feet
28. Shale and interbedded siltstone light-gray and light greenish-gray; a few thin beds of very light gray fine-grained sandstone near middle; brown carbonaceous shale bed 3 in. thick at top	5
27. Partly covered; lower and middle parts mostly very light gray fine-grained friable sandstone	33
26. Shale, gray, silty and sandy	4
25. Sandstone, very light gray, fine-grained, friable, crossbedded, slightly carbonaceous; a few thin gray shaly and silty beds near middle	25
24. Shale, brown, carbonaceous; a coaly shale bed 4 in. thick at top	6
23. Sandstone, very light gray, fine-grained; a few thin beds of gray sandy carbonaceous shale; scattered calcareous orange-yellow siltstone nodules about 1 in. in diameter	18
22. Shale, brown and gray, carbonaceous	2
21. Sandstone, very light gray, fine-grained, friable, crossbedded, slightly carbonaceous; a few calcareous orange-yellow siltstone nodules	13
20. Shale, brown, carbonaceous; a few coal lenses 1 to 2 in. thick	6
19. Sandstone, very light gray, fine-grained, crossbedded, mostly friable; a few calcareous hard slabby beds; upper 1 ft concretionary and weathers yellowish gray	6
18. Shale, gray, carbonaceous; a coal seam 2 in. thick at top	1
17. Sandstone, very light gray, fine-grained, friable, crossbedded	17
16. Shale, gray and brown, carbonaceous	3
15. Sandstone, very light gray, fine-grained, friable, crossbedded, locally calcareous and slabby; a few orange-brown calcareous sandstone nodules near base	15
14. Shale, gray and brown, carbonaceous; very dark brown at top	4
13. Sandstone, very light gray, fine-grained, friable, crossbedded; ledge-forming bed of tabular brown-weathering calcareous sandstone concretions near top	8
12. Shale, gray to greenish-gray; a few thin sandstone partings near base; a thin seam of dark-brown carbonaceous shale about 1 ft from top	8
11. Shale carbonaceous, sandy; gray in lower part; dark brown in upper 6 in	3
10. Sandstone, light-gray, fine-grained, friable, shaly at base and top; a few scattered orange-yellow calcareous sandstone concretions about 6 in. long and 2 in. thick	24
9. Shale, gray; sandy at base; a bed 1 ft thick of brown carbonaceous shale near top	4
8. Sandstone, very light gray, fine to very fine grained, carbonaceous, crossbedded	9
7. Shale, gray, very sandy	5
6. Very poorly exposed; scattered outcrops of light yellowish-gray fine-grained sandstone	80
Partial thickness of Tullock member of Fort Union formation	405

Lance formation (part):

5. Shale, medium-gray, sandy; a few fossilized plant fragments	10
4. Sandstone, very light gray, fine-grained, crossbedded, friable, a few loglike brown-weathering calcareous sandstone concretions 2 to 3 ft thick and several feet long	6
3. Mostly covered; gray sandy soil	20
2. Sandstone, like unit 4; brown-weathering calcareous sandstone concretions 3 to 4 ft thick and as much as 30 ft long	12
1. Shale, medium-gray to greenish-gray, sandy	10+
Partial thickness of Lance formation	58

Parts of the Lebo shale and Tullock members of the Fort Union formation in sec. 23, T. 54 N., R. 70 W., Campbell County, Wyo.

Top of hill

Fort Union formation (part):

Lebo shale member (part):

	Feet
27. Claystone and sandstone in alternating beds, very light gray, weathers white; claystone is silty, massive, and locally slightly carbonaceous; sandstone is fine to medium grained, friable, and massive to thin bedded; several beds of hard tabular calcareous dark-brown to dark reddish-brown fine-grained sandstone concretions as much as 40 ft long and 1½ ft thick; forms badlands	33
26. Sandstone, very light gray, weathers white, fine-grained; a few lenses of medium-grained sandstone	5
25. Claystone, very light gray, weathers white, silty, massive; a few dark-red silty calcareous concretions	6
24. Sandstone, very light gray, weathers white, fine-grained, friable; a few partings of brown carbonaceous shale near top; several calcareous dark reddish-brown sandstone and siltstone concretions	5
23. Siltstone, very light gray, weathers white, clayey, massive; scattered carbonized plant fragments; beds of brown to dark reddish-brown calcareous sandstone concretions; dark gray and carbonaceous in upper 1 ft	7
22. Shale and siltstone; brown, carbonaceous; thin coaly seams at top and base	3

Parts of the Lebo shale and Tullock members of the Fort Union formation in sec. 23, T. 54 N., R. 70 W., Campbell County, Wyo.—Continued

For Union formation (part)—Continued

	Feet
Lebo shale member (part)—Continued	
21. Sandstone, very light gray, fine- to medium-grained; a few tabular reddish-brown calcareous sandstone concretions	12
20. Shale, medium-gray, slightly carbonaceous	2
19. Claystone, very light gray; lower part sandy and silty; scattered dark reddish-brown calcareous siltstone concretions as much as 3 ft long and ½ ft thick	15
18. Sandstone, very light gray, weathers very light yellowish gray; many partings of light-gray and brown carbonaceous shale	27
17. Shale, brown, carbonaceous; a seam of coal 4 in. thick at base and a few thinner seams near middle; a few thin partings of very light gray carbonaceous siltstone	8
16. Siltstone, light-gray, slightly carbonaceous; grades upward to very light gray fine-grained sandstone	4
15. Shale, brown, carbonaceous; a few black coaly partings	2
14. Sandstone, very light gray, medium-grained, massive to crossbedded, friable; many laminae of brown carbonaceous shale; a few scattered dark reddish-brown to purplish-red calcareous sandstone concretions as much as 1½ ft long	2
13. Shale, brown, carbonaceous; a lenticular bed of coal as much as 6 in. thick near top	4
12. Sandstone as in unit 14	3½
11. Coal, shale, and sandstone; as follows:	
Shale, brown, carbonaceous (Feet: 1.2)	
Coal; a parting of brown carbonaceous shale ½ in. thick near top (Feet: 1.8)	
Shale, brown, carbonaceous; a few coaly streaks (Feet: .5)	
Sandstone, very light gray fine-grained, crossbedded, carbonaceous (Feet: 3.5)	
Shale, brown, carbonaceous (Feet: 6.0)	
Coal (Feet: 2.8)	
Shale, brown, carbonaceous (Feet: .2)	
Total	16
Partial thickness (rounded) of Lebo shale member	154
Tullock member (part):	
10. Sandstone, light-gray to light yellowish-gray, fine-grained, thin-bedded, slightly carbonaceous; several calcareous siltstone beds about ½ in. thick that weather orange brown; 4 lenticular gray silty shale beds as much as 2 ft thick	30
9. Shale, light-gray to light-brown, carbonaceous; contains orange-brown calcareous siltstone nodules	5
8. Shale, dark-brown, carbonaceous	½

Parts of the Lebo shale and Tullock members of the Fort Union formation in sec. 23, T. 54 N., R. 70 W., Campbell County, Wyo.—Continued

Fort Union formation (part)—Continued

	Feet
Tullock member (part)—Continued	
7. Shale, light-gray; some interbedded light greenish-gray siltstone	2
6. Shale, light to very dark brown, silty, carbonaceous	2
5. Sandstone light-gray to light yellowish-gray, fine to very fine grained, thin- to medium-bedded, friable; a few calcareous beds that form platy ledges; a few orange-brown-weathering calcareous siltstone nodules as much as 4 in. in diameter	6
4. Shale, light purplish-gray, carbonaceous	2
3. Sandstone, as in unit 5; some interbedded light yellowish-gray siltstone; slightly carbonaceous	10
2. Shale, greenish-gray; brown carbonaceous shale bed 6 in. thick near base	7
1. Shale, brown, carbonaceous; a coal bed 1 ft thick near top	3+
Partial thickness (rounded) of Tullock member	68

Parts of the Lebo shale and Tullock members of the Fort Union formation near the Wyoming-Montana boundary in sec. 23, T. 58 N., R. 71 W., Campbell County, Wyo.

Top of hill.

Fort Union formation (part):

	Feet
Lebo shale member (part):	
48. Claystone, light-gray, weathers light brownish-gray; tabular ferruginous siltstone concretions as much as 2 ft thick and 10 ft long	11
47. Sandstone, gray to yellowish-gray, very fine grained, silty and clayey; red-weathering sandstone concretions	3
46. Shale, gray and brownish-gray, carbonaceous; a few thin partings of yellowish-gray fine-grained sandstone	17
45. Shale, grayish-brown, silty; a few ferruginous siltstone beds as much as 4 in. thick	7½
44. Shale, medium-gray and brownish-gray; swells slightly on weathering	17
43. Shale, medium- to dark-brown, carbonaceous; coal seams at top and base that are 2 in. and 1 in. thick, respectively	2½
42. Shale, very dark gray; swells slightly on weathering	1½
41. Shale, dark-brown, carbonaceous; a coal seam 1 in. thick at base	1
40. Claystone, medium- to dark-gray; swells slightly on weathering	6
39. Shale, gray to brownish-gray; a few dark-red-weathering siltstone concretions as much as 5 ft long and 1 ft thick	7
38. Coal	2
37. Claystone, dark-gray to brownish-gray, carbonaceous; forms ledge	1
36. Sandstone, grayish-white, very fine grained, clayey	3

Parts of the Lebo shale and Tullock members of the Fort Union formation near the Wyoming-Montana boundary in sec. 23, T. 58 N., R. 71 W., Campbell County, Wyo.—Continued

	Feet
Fort Union formation (part)—Continued	
Lebo shale member (part)—Continued	
35. Shale, medium-gray to brownish-gray; swells slightly on weathering	2
34. Sandstone, grayish-brown, fine- to medium-grained; ferruginous at top	2
33. Shale, light brownish-gray; swells slightly on weathering	5
32. Claystone and interbedded siltstone, medium-gray to brownish-gray; sandy at top	6
31. Shale, medium-gray, weathers light gray; swells slightly on weathering	1½
30. Claystone, very dark gray; swells slightly on weathering	3
29. Claystone, very light brownish-gray, hard	3
28. Coal, shaly	1½
27. Claystone, brownish-gray, hard	1
26. Coal	3½
25. Shale, dark-brown, carbonaceous; coal seam 2 in. thick at base	2
Partial thickness of Lebo shale member	110
Tullock member (part):	
24. Sandstone, medium-gray, very fine grained, shaly	1½
23. Shale, medium-gray and dark-brown, carbonaceous; coal seam 2 in. thick at top	2½
22. Claystone, medium-gray, silty	1½
21. Sandstone, light-gray, weathers yellowish gray, very fine-grained to silty	5
20. Shale, medium- to dark-gray; tabular ferruginous siltstone cone-in-cone concretions at top	5
19. Shale, brown, carbonaceous; a coal seam 2 in. thick at top	1½
18. Partly covered; mostly yellowish-gray fine-grained sandstone	10
17. Sandstone, very light gray, fine-grained, micaceous, crossbedded, thin bedded; calcareous and slabby in upper few inches; remainder friable	6
16. Shale, gray and dark-brown, carbonaceous; a coal seam 2 in. thick at top	1½
15. Sandstone, light-gray, weathers yellowish-gray to brown, fine-grained, friable	6
14. Shale, gray and brown, carbonaceous	2
13. Sandstone, light-gray, weathers yellowish gray to brown; upper 1 to 2 in. slabby; remainder friable	3½
12. Shale, carbonaceous; gray at base grades to brown at top	1½
11. Sandstone, very light gray, fine-grained, friable	3
10. Shale, gray at base grades to brown near top; a coal seam 2 in. thick at top	2½
9. Sandstone, light-gray, weathers yellowish gray to brown, very fine-grained, friable	3

Parts of the Lebo shale and Tullock members of the Fort Union formation near the Wyoming-Montana boundary in sec. 23, T. 58 N., R. 71 W., Campbell County, Wyo.—Continued

	Feet
Fort Union formation (part)—Continued	
Tullock member (part)—Continued	
8. Shale, medium-gray, silty; contains fine-grained sandstone lenses as much as 2 in. thick	1½
7. Shale, brown, carbonaceous; a coal seam 1 in. thick near middle	1
6. Party covered; mostly light yellowish-gray fine-grained sandstone	7
5. Shale, light-gray, silty; thin coal seam near base	3
4. Sandstone, light-gray, weathers light yellow to light brown, fine-grained, friable, cross-bedded, calcareous; slabby in upper part, friable near base; forms ledge	11
3. Shale, dark-brown, carbonaceous	1
2. Claystone, light-gray to medium-gray	½
1. Sandstone, grayish-white, very fine grained, friable	3
Partial thickness of Tullock member	84

EOCENE SERIES

WASATCH FORMATION

The Wasatch formation crops out near Gillette, Campbell County, Wyo., and along the west side of the Little Powder River as far north as southern Powder River County, Mont. Only the lowermost 200 to 300 feet of the formation is exposed in the mapped area.

The base of the formation as mapped during the present investigation is the base of the thick and persistent Roland coal bed, or coal bed D of the Gillette coal field (Dobbin and Barnett, 1927, p. 14) and coal bed C of the Little Powder River coal field (Davis, 1912, p. 428). This coal bed is burned at most places along its outcrop, and the resulting heat has altered the overlying rocks for several tens of feet into resistant masses of red clinker. The clinker holds up a prominent eastward-facing escarpment or line of ridges for many miles north and east of Gillette. The overlying part of the formation consists of brownish-gray to light-gray sandstone and gray shale, and forms low rolling grass-covered hills in the southwestern corner of the area.

Fossil plants and fresh-water mollusks have been found in the Wasatch formation at many places in the western part of the Powder River Basin, and vertebrate remains have been found locally in the southeastern part. These fossils indicate that the middle and upper parts of the formation are Eocene in age. Brown (1948, p. 1273) suggested that the lower 200 feet of strata lying just above supposed equivalents of the Roland coal bed in the Powder River coal field, a few miles west of Gillette, may be Paleocene.

OLIGOCENE SERIES

WHITE RIVER FORMATION

Rocks assigned to the White River formation cap a few high divides in the vicinity of Missouri Buttes and along the northern and western side of the Bear Lodge Mountains. The deposits are remnants of a much more extensive sheet of rock that may once have covered much of the western and northern Black Hills. At present, they cover areas ranging from an acre or two to slightly more than a square mile in extent, and they range from a few feet to at least 150 feet in thickness. At most places, the White River formation rests unconformably on the Fall River formation or the Skull Creek shale, but near the head of Lytle Creek, the formation rests unconformably on the Lakota, Morrison, Sundance, or Spearfish formations.

Near Missouri Buttes and at the northern end of the Bear Lodge Mountains, the basal part of the White River formation is a bed of light-gray coarse to very coarse grained quartzose to slightly feldspathic sandstone as much as 30 feet thick that locally forms slabby ledges and weathers to large talus blocks several feet across. The sandstone may be stained pink locally. A clay parting an inch or two thick separates the sandstone from the underlying Fall River formation or Skull Creek shale where the contact could be observed, and in the NE¼ sec. 11, T. 54 N., R. 66 W., the Skull Creek shale is bleached shades of light gray and pink for several feet below the contact. At most places, the bed of sandstone constitutes the whole formation; however, at Missouri Buttes, in sec. 33, T. 54 N., R. 66 W., the sandstone is overlain by 50 feet or more of poorly exposed grayish-white calcareous claystone. Fragments of dense nodular light-gray limestone weather out on the slopes, but none was found in place.

In a partial exposure near the head of Lytle Creek east of the mapped area in sec. 12, T. 52 N., R. 64 W., strata assigned to the White River formation are at least 150 feet thick and consist mainly of tan to light-gray silty claystone containing numerous closely spaced silty limestone concretions about 1 foot in diameter. A lenticular bed of conglomerate near the base of the exposure contains angular to subangular fragments of igneous rock, limestone, and chert such as might be derived from older formations that crop out in the core of the Bear Lodge Mountains. The claystone is capped by about 15 feet of conglomeratic strata that were mapped as part of the White River formation, but which might be younger pediment or terrace gravel.

A tooth fragment of a large brontothere of indeterminate genus and species was found in the lower part of the White River formation in the NW¼NE¼ sec. 27, T. 55 N., R. 65 W. (G. A. Izett, oral communication, 1956). According to G. Edward Lewis, who examined the specimen, it is early Oligocene in age, and indicates that the White River formation in this vicinity is equivalent in age to the Chadron formation of Nebraska and South Dakota. Brown[2] reported finding a *Merycoidon* tooth from an exposure at the head of Lytle Creek east of the mapped area, and concluded that beds here are equivalent to the Brule formation of Oligocene age of northwestern Nebraska and South Dakota. The Brule formation overlies the Chadron formation southeast of the Black Hills and the two formations constitute the White River group. Brown further reported finding the seed *Biorbia fossilia* near the top of the Lytle Creek section, which would indicate that some of uppermost White River, as mapped, may be Pliocene in age and equivalent to the Ogallala formation of South Dakota and Nebraska. Vertebrate remains of Oligocene age have also been found in rocks assigned to the White River formation near Lead, South Dakota, a few miles east of the mapped area (Darton, 1909, p. 59), and by Rubey north of Belle Fourche, S. Dak.

The following measured sections give some details of the lithology of the White River formation.

Part of the White River formation near the head of Lytle Creek in sec. 12 (approximately), T. 52 N., R. 64 W., Crook County, Wyo.

Top of hill.

	Feet
White River (?) formation:	
4. Conglomerate interbedded with siltstone; conglomerate in discontinuous lenses as much as 2 ft. thick consisting of angular to subangular fragments of igneous rocks, limestone, and chert as much as 6 in. in maximum dimension in a matrix of sand and silt; siltstone is pale brownish white, friable, and crudely bedded; sharp contact with underlying unit. This unit possibly is a post-White River pediment or terrace deposit	15
White River formation (part):	
3. Claystone, silty, very pale orange to brownish-white, tuffaceous(?), crudely bedded; upper half contains closely spaced silty limestone concretions as much as 1 ft in diameter in beds 1 ft to 5 ft apart	105
2. Conglomerate as in unit 1; forms lenticular ledge; may be traced for about 100 ft	2–4
1. Claystone, pale-orange to brownish-white, silty, slightly calcareous, crudely bedded; a few grit-sized fragments of igneous rock and chert in upper 5 ft	30
Partial thickness of White River formation	154

Base of exposure.

[2] Brown, B. W., 1952, A study of the Bear Lodge Mountains intrusives: Master's thesis, University of Nebraska, Lincoln, Nebr.

Part of the White River formation in SW¼ sec. 3, T. 56 N., R. 63 W., Crook County, Wyo.

	Feet
White River formation (part):	
3. Sandstone, light- to medium-gray, slightly greenish, medium- to coarse-grained; some interstitial clay and a few thin calcareous claystone beds 1 to 4 in. thick; forms gentle receding slope; poorly exposed	20+
2. Sandstone, light- to medium-gray, slight greenish tinge, medium- to coarse-grained, crossbedded, poorly sorted; grains subrounded, mostly quartz, some feldspar, mica, magnetite, and small clay pellets; beds 1 to 4 ft thick; plastic clay seam ¼ to 1 in. thick at base	8
Partial thickness of White River formation	28
Fall River formation (part):	
1. Quartzite, grayish-white to brown, fine- to medium-grained, highly silicified, ripple-marked; in beds ¼ to 3 in. thick separated in upper 3 in. of unit by clay seams ¼ to ½ in. thick	1

TERTIARY(?) AND QUATERNARY SYSTEMS

STREAM TERRACE DEPOSITS

Stream terrace deposits of silt, sand, and gravel occur locally along most of the major stream valleys. They are most extensive along the Belle Fourche River in the northern part of the mapped area, and along divides adjacent to Skull Creek, in the southern part. Only the largest deposits are shown on plate 1.

Knechtel and Patterson (1955; 1962, p. 932) recognized six terrace levels in the area drained by the Belle Fourche and Little Missouri Rivers. The five youngest were assigned to the Quaternary, and the sixth was considered of possible Tertiary age. According to Knechtel and Patterson (1962, p. 932) the terraces range from 30 to 450 feet above the present level of the Belle Fourche River, and the deposits have a maximum thickness of about 40 feet.

QUATERNARY SYSTEM

LANDSLIDE DEPOSITS

Landslide deposits cover areas ranging from a few acres to several square miles along the valleys of the Belle Fourche River and its tributaries in the east-central part of the mapped area, and at several places along the southeastern edge of the area between Inyan Kara Mountain and Newcastle. Most of the landslides consist of rock waste, from the thick competent sandstone beds of the Sundance, Lakota, or Fall River formations, that has slid downward on slopes underlain by soft plastic shale or claystone in the Sundance or Morrison formations.

Landslides are associated with faults northeast of the junction of Inyan Kara Creek and the Belle Fourche River in sec. 19 and parts of adjoining sections T. 52 N., R. 65 W., and along Left Creek in secs. 21, 27, and 28, T. 53 N., R. 66 W. East of the junction of Inyan Kara Creek and the Belle Fourche River, a ridge composed of the Sundance and Morrison formations is faulted along its crest; but because of several coalescing landslides along the flanks of the ridge, the amount of faulting is almost impossible to determine. The south side of the landslide along Left Creek is bordered by faults, and other faults may be covered by the slide.

TALUS DEPOSITS

Broad aprons of talus surround the base of Devils Tower and the Missouri Buttes in the central part of the area and Inyan Kara Mountain in the southeastern part. The deposits consist of angular blocks of igneous rock derived from adjacent outcrops. The talus fragments range from pieces an inch or two in maximum dimension to boulders 20 feet long.

Small talus deposits have accumulated at the base of cliffs formed by resistant sandstone beds in the Hulett sandstone member of the Sundance formation, and in the Lakota, Fall River, and Newcastle formations, but most of the deposits are too small to show on the geologic map, plate 1.

ALLUVIAL DEPOSITS

Alluvial deposits of silt, sand, and gravel cover the flood plains of all of the larger streams. At places along the Belle Fourche, Little Missouri, and Little Powder Rivers, and some of their major tributaries, the deposits form a band as much as 5 miles wide. Some of the deposits cover benches too high to have been flooded during recent times and probably should be classified as low stream terraces. The maximum thickness of the alluvium is not known, but presumably most of the deposits are less than 50 feet thick.

A notable example of an alluvial deposit is Stoneville Flats near the Montana-Wyoming State line. Here a gravel-strewn flat merges with the flood-plain deposits of the Little Missouri River to the north, but is about 100 feet above the present flood plain of the Belle Fourche River to the south. Darton and O'Harra (1905, p. 1), and Rubey (1927, p. 120) noted that the northeastward-flowing part of Belle Fourche River probably once crossed Stoneville Flats to join the Little Missouri River. The part of the stream formerly tributary to the Little Missouri was tapped at the south end of Stoneville Flats by a relatively small eastward-flowing tributary of the Cheyenne River, and the present course of the Belle Fourche River is the result of this stream capture.

Another striking example of recent stream capture is west of Inyan Kara Mountain in T. 49 N., R. 63 W.,

Crook County, Wyo. A low southward-sloping terrace deposit along Sheldon Creek was laid down by a much larger stream at a time when the headwaters of the present Inyan Kara Creek probably connected southward with Mason Creek through the broad, open valley occupied by the deposit. Inyan Kara Creek has since been diverted northwestward. Subsequent erosion has left the upper end of the old stream deposit about 20 feet higher than the present level of Inyan Kara Creek in sec. 17, T. 49 N., R. 63 W.

IGNEOUS ROCKS

Igneous rocks crop out at Devils Tower, Missouri Buttes, and Barlow Canyon in Tps. 53 and 54 N., Rs. 65 and 66 W.; near the heads of Lytle and Miller Creeks in Tps. 52 and 53 N., R. 64 W., and at Inyan Kara Mountain in T. 49 N., Rs. 62 and 63 W. Except for some small outcrops of agglomerate near the Missouri Buttes, the igneous rocks consist of sills, dikes, and small plugs of nepheline syenite. They intrude sedimentary rocks ranging in age from Mississippian (Pahasapa limestone) to Early Cretaceous (Mowry shale). Darton and O'Harra (1907, p. 6, 7), Darton (1909, p. 66–73), Darton and Paige (1925, p. 19–24), and Robinson (1956, 1960) have described the field relations and petrology of the igneous rocks in various parts of these or nearby areas in some detail.

Devils Tower (sec. 7, T. 53 N., R. 65 W.) is an isolated plug of igneous rock that crops out as a nearly vertical column about 800 feet in diameter at its base and 600 feet high. The Redwater shale member of the Sundance formation is the youngest rock exposed on the slopes surrounding the base.

The Missouri Buttes (secs. 33 and 34, T. 54 N., R. 66 W., and secs. 3 and 4, T. 53 N., R. 66 W.) are four igneous plugs that stand about 400 feet above the surrounding country. They form a rectangular pattern and are separated from each other at the surface by broad talus slopes, but probably they are apophyses of a single intrusion at depth. Remnants of Mowry shale are exposed south of the northwest and southwest Buttes.

Agglomerate crops out at three places near Missouri Buttes. The largest outcrop, and the only one shown on plate 1, is between the northeast and northwest Buttes. Two other outcrops are about 300 feet due south and 1,300 feet southeast of the northwest Butte, respectively.

A sill crops out at the base of the Hulett sandstone member of the Sundance formation in Barlow Canyon (sec. 23, T. 54 N., R. 66 W.). The sill may be traced laterally for about 1,000 feet and has a maximum exposed thickness of about 60 feet.

Igneous rocks exposed near the head of Lytle Creek comprise several sills, one set of dikes, and one plug, all of which are apparently related to the igneous intrusions in the main part of the Bear Lodge Mountains 2 or 3 miles to the east (Darton, 1909, p. 67). The thickest and most continuous sills are grouped in the NE¼ of T. 52 N., R. 64 W., and the SE¼ of T. 53 N., R. 64 W. One, exposed in the bottom of Lytle Creek, is at least 50 feet thick. This sill is in the Spearfish formation of Triassic age; others occur in the Spearfish formation, at the base and top of the Hulett sandstone member of the Sundance formation, near the contact of the Morrison and Lakota formations, and in the lower part of the Fall River formation. A sill at the base of the Hulett sandstone member near the head of the North Fork of Miller Creek, sec. 11, T. 52 N., R. 64 W., is about 40 feet thick, and others in the Fall River formation in and adjacent to sec. 27, T. 52 N., R. 64 W., and sec. 9, T. 51 N., R. 64 W. are probably about the same thickness.

A series of closely spaced dikes, trending west-northwest and dipping almost vertically, extend for about 3 miles in the northwest part of T. 52 N., R. 64 W. (shown as one dike on pl. 1). The maximum observed thickness of any one of the dikes is about 6 feet. The dikes cut the Morrison and the upper part of the Sundance formations.

The greater part of Inyan Kara Mountain in secs. 19 and 30, T. 49 N., R. 62 W., and adjacent parts of the township to the west is an intrusive body roughly circular in plan view and about a mile in diameter. Within this area, the igneous rock makes bold, nearly vertical cliffs and jagged peaks that rise several hundred feet above the nearby countryside. The igneous mass cuts across all formations in turn from the Spearfish (Permian and Triassic) to the Pahasapa (Mississippian).

Most of the igneous rocks, except for the agglomerate near Missouri Buttes, are porphyries. In the larger masses, such as Devils Tower, Missouri Buttes, and Inyan Kara Mountain, the phenocrysts range from 1 to 15 mm long. In the dikes and sills the phenocrysts are, in general, from 1 to 5 mm long, but some dikes and sills are microporphyritic. The most common phenocrysts, listed in approximate order of their abundance, are: feldspar (anorthoclase and sanidine), aegirite-augite and augite, nepheline, sphene, and magnetite or ilmenite. Also present in some of the igneous rocks are phenocrysts of biotite, hornblende, and apatite. The groundmass consists of lath-shaped crystals of feldspar, aegirite-augite and augite, and nepheline; accessory minerals of magnetite or ilmenite, sphene, and apatite; and alteration products including zeolites

(analcite), calcite, kaolin, chlorite, and possibly other unidentified alteration products. Mineral grains in the groundmass of the coarser grained rock range from 0.01 to 1 mm in diameter. The groundmass of most dikes and sills is too fine grained for positive identification of most of the constituent minerals; generally present is a considerable amount of isotropic material, probably glass. These igneous rocks all fall within the classification of nepheline syenite porphyry or phonolite porphyry (Darton, 1909, p. 67–70; Darton and O'Harra, 1907, p. 5–6).

The agglomerate, which crops out in the vicinity of Missouri Buttes, consists of rounded to subrounded fragments of sedimentary and igneous rocks, from less than 1 to 30 mm in diameter, and rounded to angular mineral grains, in a vesicular aphanitic groundmass. The fragments consist of gray limestone; greenish-gray argillite; yellowish- to reddish-brown siltstone; reddish-brown fine-grained sandstone; rounded quartz and chert pebbles and grains; angular grains of feldspar including orthoclase, microcline, sanidine, anorthoclase, and plagioclase; biotite granite; and a grayish-white aphanitic porphyry with phenocrysts of feldspar. The groundmass is so fine grained and altered that the constituent minerals could not be identified. At least half the groundmass is isotropic and is probably glass. Some of the vesicles are lined with zeolites and calcite, and possibly unidentified alteration products.

The White River formation of Oligocene age is deposited on an erosion surface cut on a phonolite porphyry body in sec. 35, T. 53 N., R. 64 W. The youngest formation intruded by igneous rock is the Mowry shale of Early Cretaceous age, at Missouri Buttes. There is no evidence of any fragments from these intrusive rocks in any of the sedimentary rocks younger than the Mowry shale and older than the White River formation. If it is assumed that all the igneous rocks were introduced at about the same time, then their age is Late Cretaceous or early Tertiary. Darton (1909, p. 76) states that the igneous intrusions probably occurred in early Tertiary time in connection with the general uplift of the Black Hills. Rocks of similar composition in the Rattlesnake Hills near Casper, Wyo. (fig. 8), are reported by Carey (1954) to be of middle and late Eocene age.

STRUCTURE

The Black Hills is a broad northward-trending anticlinal uplift about 200 miles long that flanks the Powder River Basin to the west and southwest and the Williston basin to the northeast. The area described in this report lies across the plunging north end of the uplift and extends westward and southwestward into the Powder River Basin. Figure 8 shows the outline of the mapped area in relation to the Black Hills uplift and nearby structural features.

The major structural feature of the mapped area is a steep westward-dipping northwestward-trending monocline that extends across the central part of the area and marks the west flank of the Black Hills uplift (pl. 1). This fold, called here the Black Hills monocline, separates gently dipping rocks of the uplift from gently dipping rocks in the trough of the Powder River Basin to the west.

The sedimentary rocks on the eastern or uplifted side of the Black Hills monocline are deformed by northward- or northwestward-trending anticlines and synclines and by nearly circular domes and depressions. Several of the largest of these folds are adjacent and parallel to the Black Hills monocline. A group of anticlines and synclines with the same general trend occupy a belt about 40 miles long on the opposite and much less steeply dipping eastern flank of the Black Hills uplift, near the northeastern margin of the mapped area. The nose of the uplift between the two folded belts plunges northwestward and is gently crenulated. Sharply folded domes or depressions in various parts of the area are the result of the intrusion of igneous rocks. The largest of these domes makes up the highest part of the Bear Lodge Mountains, the center of which is a few miles east of the mapped area in T. 52 N., R. 63 W. (Darton, 1909, pl. IV). Its steeply dipping western flank crosses the mapped area in the eastern part of T. 52 N., R. 64 W.

Steeply dipping normal faults cut the sedimentary rocks locally. Most of the faults have less than 100 feet of displacement; few can be traced for more than a mile.

The top of the Fall River formation was used as a datum plane in drawing the structure contours shown on plate 1. The contour interval at most places east of the Black Hills monocline is 100 feet, and the interval west of the monocline is 200 feet. Structure contours in the western part of the area are somewhat generalized because the changes in the thickness of the younger rocks that overlie the Fall River formation are known only from scattered drill holes. Structural relief of the area is about 10,000 feet; the structurally lowest part being near Gillette in the southwestern corner, and the structurally highest part on the west flank of the Bear Lodge Mountains along the east-central edge.

Several writers have described the structure of the northern Black Hills, principally Darton (1909, p. 62–73; *in* Darton and Paige, 1925, p. 17–23) and Noble (1952, p. 31–37). Other writers who have described the structure of small parts of the mapped area are cited at appropriate places in the following pages.

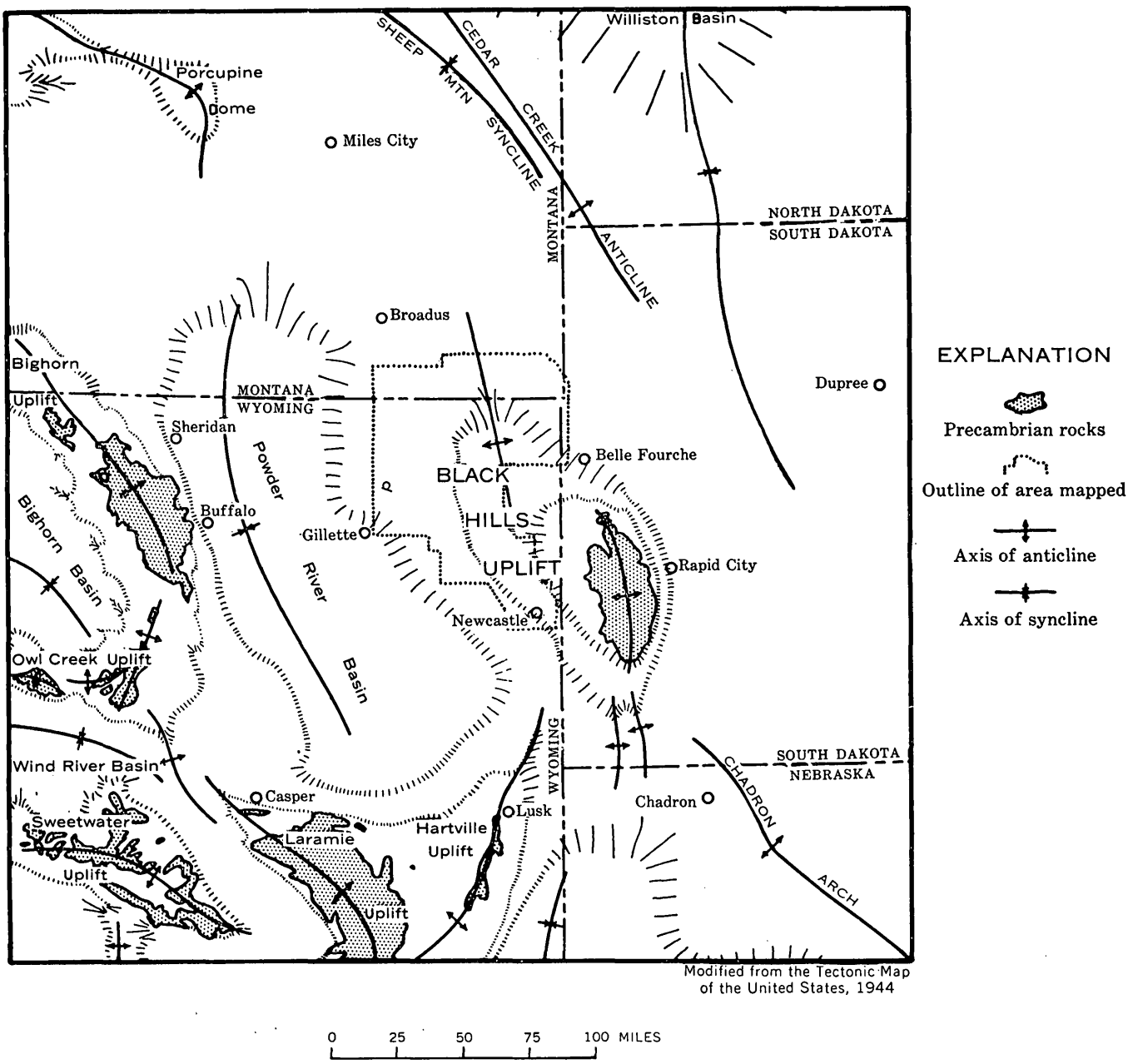

FIGURE 8.—Generalized map showing the Black Hills uplift in relation to nearby structural features.

FOLDS

BLACK HILLS MONOCLINE

The Black Hills monocline trends generally northwestward for about 90 miles across the central part of the mapped area from near Newcastle, Weston County, Wyo., almost to the Wyoming-Montana State line. It consists of a belt of steeply dipping rocks 1½ to 6 miles wide, across which the structural relief is about 4,000 feet. The belt is narrowest between Newcastle and Pedro in the southern part of the area and in the vicinity of Oshoto in the northern part. At these places the dips are almost vertical. Elsewhere along the monocline, the dips range from 20° to 35° to the west or southwest. At the surface, the belt of steep dips is at most places defined by the outcrop belt of the formations that lie between the Mowry shale and the Fox Hills sandstone. West of the monocline the dip flattens abruptly, and the Lance formation and younger rocks slope southwestward 2° to 5° toward the axis of the Powder River Basin. East of the monocline, except where the crest is folded into anticlines or domes, the

Newcastle sandstone and older formations dip 3° to 5° southwest, west, or northwest.

The monocline turns sharply southward about 5 miles southeast of Newcastle. A branching monocline splits from the main fold at this point and extends northward along the east side of Stockade Beaver Creek for several miles in the southeastern corner of the area. The monocline splits again at Pedro, a few miles northwest of Newcastle, with the branches rejoining west of Osage to form a structural terrace about 5 miles long and 3 miles wide in the intervening area. The terrace is shown at the surface by the comparatively broad outcrop width of the Niobrara and Carlile formations. At Thornton, the monocline changes strike from northwest to north, and the dips flatten to form an anticlinal nose that plunges about N. 60° W. in the Pierre and Fox Hills formations. East of Stroner in T. 55 N., R. 67 W., the monocline splits into two branches that form the sides of a broad northwestward-dipping structural terrace in the Pierre, Fox Hills, and Lance formations. Both branches die out at about the Wyoming-Montana State line.

PUMP CREEK ANTICLINE AND VICINITY

The Pump Creek anticline is a shallow fold with a sinuous axial trace that trends northward for about 6 miles in Tps. 47 and 48 N., R. 64 W., Weston County, Wyo. The anticline is asymmetrical with dips of as much as 14° on the east flank and 1° to 2° on the west flank. An elongated northward-trending dome at the north end of the fold has a closure of about 25 feet. The Fall River formation comes to the surface in an area of 2 to 3 square miles along the crest of the fold. A fairly sharp syncline parallels the anticline on the east.

A broad structural saddle southeast of the Pump Creek anticline separates it from a smaller anticline and parallel syncline north of Clay Spur in T. 47 N., Rs. 63 and 64 W. The axis of the anticline trends northward for about 2 miles. The Skull Creek shale is exposed at the crest of the anticline; dips in the Newcastle sandstone on the flanks are about 1°, and the fold has less than 50 feet of closure.

The Pump Creek anticline was previously described by Longwell and Rubey (1923).

OIL CREEK DOME

The Oil Creek dome is at the southern edge of T. 47 N., R. 62 W., in the valley of Oil Creek where the sedimentary rocks are bent upward into a low dome nearly bisected by the creek. The Stockade Beaver shale member of the Sundance formation comprises the oldest rocks exposed; younger members of the Sundance are successively exposed outward on the flanks of the dome. The fold is about a mile across and has a closure in the Sundance formation of 50 to 75 feet.

An estimated thickness of 100 to 150 feet of beds of Lakota formation has been removed beneath a slight angular unconformity at the base of the Fall River formation on the west side of the dome in the E½ sec. 32, T. 47 N., R. 62 W. (Izett, Pillmore, and Mapel, 1961). This relation indicates that some folding occurred at the site of the dome before deposition of the Fall River formation. Some folding also occurred after deposition of the Fall River at or near the site of the dome as shown by a shallow northwest-trending syncline and parallel anticline in the Fall River and older rocks adjacent to the dome on the northwest.

ARCH CREEK ANTICLINE

The Arch Creek anticline, in T. 49 N., R. 64 W., Crook County, Wyo., lies north of the Pump Creek anticline on the same structural trend. The fold is a broad domal feature, about 2½ miles long, having an indefinite axial trend. It exposes the Fall River formation at the surface. Closure of this fold in the Fall River formation is probably less than 25 feet. The anticline flattens southward and merges with a structural terrace that separates the Arch Creek anticline from the northern end of the Pump Creek anticline 3 to 4 miles to the south.

THORNTON DOME

Thornton dome is a sharp nearly symmetrical fold along the crest of the Black Hills monocline in the northwestern corner of T. 48 N., R. 65 W., Weston County, Wyo. The dome is about 3 miles long and 1½ miles wide and has about 400 feet of closure. The Skull Creek shale is exposed in the central part of the dome, and encircling ridges of the Newcastle sandstone and Mowry shale outline the fold. The axis of the fold trends about N. 45° W., which parallels the trend of the Black Hills monocline. Dips of about 12° may be observed on either flank in the Mowry shale.

A low, indefinite anticlinal fold or structural terrace in the Mowry shale, apparently en echelon to Thornton dome, extends from near the south end of the dome southward about 3 miles to the vicinity of Upton. This fold has little if any surface closure.

The geology and structure of a small area including Thornton dome have been described by Hancock (1920a).

OIL BUTTE-PINE RIDGE ANTICLINE

The Oil Butte-Pine Ridge anticline is a prominent structural and topographic feature along the crest of the Black Hills monocline. It extends about 10 to 12 miles from the northeastern corner of T. 52 N., R. 67

W., to the southeastern corner of T. 50 N., R. 66 W., Crook County, Wyo.

The fold consists of two elongated en echelon domes connected by an anticlinal ridge; the Fall River formation forms much of the surface. The west flank of anticline is a continuation of the Black Hills monocline, and the dips on this flank are 6° to 12° W., steepening westward. Maximum dips on the east flank are about 25° at the northern end of the fold and about 10° in the central and southern parts. Closure of the anticline including both domes, totals about 400 feet. The northern and structurally higher dome is about 4 miles long and has about 250 feet of closure. The Morrison formation crops out near the northern end of this dome in the valley of Cyclone Creek and in several deep canyons on the east limb. The southern dome is about 2½ miles long and has a closure of 150 to 200 feet. The Belle Fourche River breaches the southern dome exposing the Redwater shale member of the Sundance formation; gullies on the flanks of the fold locally expose the Morrison and Lakota formations.

The geology of parts of the Oil Butte-Pine Ridge anticline has been previously discussed by Barnett (1915), and by Bergendahl, Davis, and Izett (1961).

ROCKY POINT ANTICLINE

The Rocky Point anticline, in Tps. 56 and 56½N., Rs. 68 and 69 W., Crook and Campbell Counties, Wyo., locally makes the crest of the westernmost of the two branching monoclinal folds at the north end of the Black Hills monocline. The anticline has a northwesterly trend and is about 8 miles long. Dips along the southwestern flank are 10° to 25° SW. The northeastern limb is vaguely defined and in places merges with a broad structural terrace that extends from the monocline northward with dips of 2° to 5°NW. The anticline plunges gently northwestward in the same direction as the structural terrace bordering it to the north.

Surface formations in the vicinity of the Rocky Point anticline are the Pierre shale, Fox Hills sandstone, and Lance formation. The Monument Hill bentonitic member of the Pierre shale forms the crest of the fold near its southern end, and the younger formations form ridges on the flanks. The fold has little if any closure.

W. W. Rubey (1924) has described the structure and geology of the Rocky Point anticline in some detail.

ELKHORN DOME

The Elkhorn dome is a small fold on the northwest-plunging nose of the Black Hills in the east part of T. 56 N., R. 66 W. The fold, which is bisected by Elkhorn Creek, is about 1½ miles in diameter and has a little more than 100 feet of closure. The Lakota formation at the center of the dome, and the Fall River and Skull Creek formations on the flanks, are the surface rocks involved in the folding. Davis and Izett (1962, p. 45) give additional details about this structure.

TIE CREEK DOME

The Tie Creek dome lies in the southwest part of T. 56 N., R. 65 W., about 3 miles southeast of the Elkhorn dome. Like the Elkhorn dome, the Tie Creek dome is about a mile in diameter and has about 100 to 150 feet of closure. The Lakota formation is exposed at the surface at its crest. This dome is also included in the area described by Davis and Izett (1962, p. 45–46).

NORTH FORK DOME

The North Fork dome is a shallow fold in the Newcastle sandstone and Mowry shale near the North Fork of the Little Missouri River, T. 57 N., R. 65 W. The fold is about 1½ miles in diameter and probably has less than 50 feet of closure at the surface. Dips on the flanks of the dome average 2° to 3°.

MEDICINE CREEK DOME

The Medicine Creek dome is a low, broad fold on the crest of the high divide at the head of Medicine Creek, T. 56 N., R. 64 W. The fold is about 2½ miles across and has slightly more than 100 feet of closure at the surface. The Fall River formation comprises the surface formation at most places on the dome; the Lakota formation crops out in a few deep canyons that head near the crest of the dome and extend southeastward to Deer Creek.

GOVERNMENT CANYON ANTICLINE

The Government Canyon anticline is a slightly elongated dome with about 50 feet of closure in the southern half of T. 57 N., R. 64 W. The axis of the anticline trends northwestward and can be followed for about 2 miles. Rocks on the northwest flank dip as much as 8° and on the southeast flank 5°. The Fall River formation is arched upward to form the surface of the higher divides at the crest and on the flanks of the fold; the Lakota formation is exposed in the valleys of Government Canyon and its tributaries, which dissect the anticline.

CAMP CREEK MONOCLINE AND WOLF CREEK ANTICLINE

The Camp Creek monocline is a steep northwestward-trending monocline in southwestern Carter County, Mont. It borders on the west a low arch with a vaguely defined undulating crest known as the Wolf Creek anticline.

The Camp Creek monocline may be followed for about 15 miles from the center of T. 9 S., R. 57 E., northward to the northern edge of T. 7 S., R. 56 E., where it

leaves the mapped area. The steepest dips along the fold range from about 10° near the southern end to about 25° in T. 8 S., R. 56 E. As a result of this fold, the outcrops of the Carlile shale, Niobrara formation, and the lower part of the Pierre shale swing sharply northward in a narrow band for several miles at the northern end of the Black Hills uplift. The displacement of any particular bed across the fold is about 700 feet in T. 8 S., R. 56 E., and about 1,000 feet in the township to the north. A more gentle monocline joins the Camp Creek monocline from the southwest in T. 7 S., R. 56 E., and this second fold connects the Camp Creek and Black Hills monoclines across an intervening distance of about 15 miles.

The axis of the Wolf Creek anticline follows a sinuous northwestward-trending path 1 to 4 miles east of the Camp Creek monocline. The Camp Creek monocline forms the west flank of the anticline in T. 7 S., R. 56 E., the axis of the Wolf Creek anticline veers eastward in the township to the southeast and a narrow structural terrace separates the two folds. Dips on the east flank of the anticline are gentle, ranging from about 1° to 3° N. or NE. The Carlile shale, which crops out at the southern end of the anticline, is the oldest formation exposed.

COLONY-ALBION ANTICLINE

The Colony-Albion anticline, one of the most prominent folds on the eastern side of the Black Hills uplift, extends for at least 25 miles from T. 56 N., R. 60 W., Crook County, Wyo., to the edge of the mapped area in T. 7 S., R. 61 E., Carter County, Mont. The name Colony anticline is applied to the southern part of the fold, and the name Albion anticline to the northern part. The fold is asymmetrical with dips of as much as 12° on the steeper west flank and dips mostly less than 5° on the more gentle east flank. The south end of the fold is a dome about 6 miles long with about 150 feet of closure. The Skull Creek shale is exposed along its crest, and the dome is bordered by fairly prominent ridges of Mowry shale that rise from outlying low lands of Belle Fourche shale. The axial trend at the southern end of the anticline is about N. 45° W. The axis of the fold turns northward in the northwestern corner of T. 57 N., R. 61 W., and from this point it plunges northward in the Belle Fourche shale and younger rocks to the edge of the mapped area, a distance of about 15 miles.

SEVEN MILE ANTICLINE

The Seven Mile anticline branches from the Colony-Albion anticline in the southern part of T. 9 S., R. 61 E., and extends northwestward for about 10 miles as a low fold in the Carlile shale. Dips on the flanks of the anticline range from about 2° to 5°. A dome at the northern end of the fold in southeastern corner of T. 8 S., R. 60 E., may have a closure of about 100 feet. The Turner sandy member of the Carlile shale is the oldest rock exposed.

A sharp syncline with a closure of about 200 feet lies southwest of the Seven Mile anticline. A remnant of the Niobrara formation is exposed in the trough of this syncline.

SHEPARD ANTICLINE

The Shepard anticline, in the southwestern part of T. 57 N., R. 61 W., Crook County, Wyo., is an elongate, northwestward-trending structural feature about 2 miles long. The axis of the fold lies about 2 miles west of the axis of the Colony-Albion anticline, and the two folds are parallel. Beds on the flanks of the Shepard anticline dip about 3° to 5°. The closure is about 100 feet, and the Mowry shale is the oldest formation exposed on the crest.

CHICAGO CREEK ANTICLINE

The Chicago Creek anticline lies a short distance south and southeast of the Colony-Albion and Shepard anticlines in T. 56 N., Rs. 60 and 61 W., Crook County, Wyo. Its axis is about 7 miles long and trends northwest; beds on the flanks dip from about 3° to 6°. Closure is about 100 feet. The Skull Creek shale crops out in the center of the anticline and is circled in turn by the Newcastle sandstone and Mowry shale.

BULL CREEK ANTICLINE

The Bull Creek anticline trends northwestward for about 12 miles from T. 57 N., R. 62 W., Crook County, Wyo., to T. 9 S., R. 60 E., Carter County, Mont. The anticline is asymmetrical with dips of 3° to 10° on the southwest side and 2° to 5° on the northeast side. Closure is about 150 feet on a dome about 4 miles long at the southern end. The axis of the fold lies in a valley of Belle Fourche shale almost surrounded by low hills made by the Greenhorn formation.

A synclinal depression with slightly more than 100 feet of closure lies south of the anticline in T. 57 N., R. 62 W. A few remnants of the lower unnamed member of the Carlile shale crop out locally in the trough of the depression.

LA FLAMME ANTICLINE

The La Flamme anticline plunges northwestward from T. 8 N., R. 1 E., Butte County, S. Dak., where it enters the mapped area, to T. 56 N., R. 61 W., Crook County, Wyo., a distance of about 14 miles. Beds on the west side of the anticline dip as much as 10° toward a syncline that is probably a continuation of the syn-

cline on the west side of the Bull Creek anticline to the north. Beds on the east side of the La Flamme anticline dip from 2° to 5° to the northeast. At the northern end of the anticline, the Fall River formation comes to the surface in a high broad ridge that is enclosed on three sides by the Skull Creek shale. Near the southern end in the mapped area, Hay Creek breaches the anticline and exposes rocks as old as the Stockade Beaver shale member of the Sundance formation.

FOLDS OF INTRUSIVE ORIGIN

Several sharp, nearly circular domes and structural basins, which have igneous rocks in their cores or along their flanks, occupy a belt about 10 miles wide that extends across the area for about 40 miles from Inyan Kara Mountain in T. 49 N., R. 62 W., northwestward to the Poison Creek dome in T. 54 N., R. 67 W. Characteristically, the folds are almost circular in plan and have steeply dipping flanks that flatten abruptly at their outer edges. These folds seem clearly to be the result of igneous intrusions. In a few additional folds no igneous rocks appear, but as Darton (1909, p. 73) stated, "the dome structure is precisely similar to that in uplifts in which erosion has exposed the igneous core, it is difficult to ascribe them to any other cause."

MISSOURI BUTTES-DEVILS TOWER AREA

The Missouri Buttes, in Tps. 53 and 54 N., R. 66 W., consist of four igneous plugs in a sharp depression. The Fall River formation caps a broad divide in the vicinity of the plugs and, in general, dips gently westward. Within a few hundred feet of the Buttes, the Fall River formation bends sharply downward to form a roughly circular structural basin with about 200 feet of closure. Dips on the west side of the depression are as much as 30° toward the center. The Skull Creek shale, Newcastle sandstone, and Mowry shale are locally exposed in the depression adjacent to the Buttes.

Two domes each with about 300 feet of closure are about a mile to the southwest and half a mile to the north of Missouri Buttes, respectively. Each is about a mile in diameter. They rise abruptly from nearly horizontal beds adjacent to them, with dips along their flanks of as much as 45°. The Redwater shale member of the Sundance formation is exposed at the crest of the dome to the north, and the Lakota formation is exposed at the crest of the dome to the southwest. Both domes are surrounded by highly silicified sandstone beds of the Lakota formation. A well drilled near the center of the dome southwest of the Buttes penetrated phonolite porphyry, probably in the Minnelusa sandstone, at a depth of about 1,500 feet.

Devils Tower, 3½ miles southeast of Missouri Buttes in T. 53 N., R. 65 W., is an igneous plug nearly surrounded at its base by the Redwater shale and the Lak and Hulett sandstone members of the Sundance formation. These rocks dip from 3° to 7° toward the Tower to form a structural depression about half a mile in diameter with about 100 feet of closure.

BARLOW CANYON DOME

The Barlow Canyon dome is a rather broad nearly circular fold on the north side of Barlow Canyon in T. 54 N., R. 66 W. The dome is about 1½ miles in diameter and has about 200 feet of closure on the Fall River formation and about 300 feet of closure on the Hulett sandstone member of the Sundance formation. The Spearfish formation is the oldest formation exposed in the fold. The Gypsum Spring and Morrison formations are absent on the crest of the dome, and the Redwater shale member of the Sundance formation has been thinned by pre-Lakota erosion to about 40 feet from an average thickness of nearly 170 feet in nearby areas. Beds on the flanks of the dome dip outward a maximum of about 10°. A phonolite porphyry sill crops out at the base of the Hulett sandstone member of the Sundance formation near the bottom of Barlow Canyon on the south flank of the dome. This sill is about 1,000 feet long and as much as 60 feet thick. The presence of igneous rock in the vicinity of the dome suggests that some folding resulted from igneous intrusion, presumably in early Tertiary time. Earlier episodes of folding at this locality are indicated by the absence of the Gypsum Spring formation, and by the angular unconformity at the base of the Lakota formation (Izett, Pillmore, and Mapel, 1961). Structural relations in the Barlow Canyon area are shown in more detail by Izett (1963).

POISON CREEK DOME

The Poison Creek dome, in the northeast part of T. 54 N., R. 67 W., is a sharp nearly circular fold about three-quarters of a mile in diameter. The Fall River formation forms the center of the dome and dips as much as 10° outward on the flanks, but the dips flatten abruptly within a few hundred feet on all sides. The dome has a closure of about 125 feet. In its general shape, the dome resembles others believed to have formed by igneous intrusion, and a well drilled near the center of the dome bottomed at a depth of about 2,000 feet in igneous rock probably intruded in the Minnelusa formation.

LYTLE CREEK DOME

A small dome, faulted on the north side, brings the Hulett sandstone member of the Sundance formation and older rocks to the surface in the southeastern corner

of T. 53 N., R. 64 W. This fold is here called the Lytle Creek dome from Lytle Creek, which crosses it. The dome has a surface closure of about 50 feet. A narrow anticlinal ridge connects it to westward-dipping rocks on the flank of the main part of the Bear Lodge Mountains to the east. On the south and west, the Hulett sandstone member of the Sundance formation and older rocks dip away from the crest at angles of as much as 12°. The Spearfish formation crops out in the core of the dome along the valley of Lytle Creek and is the oldest formation exposed by the fold. An igneous sill underlies the Hulett sandstone member in the center of the dome, and several sills were found in the Spearfish and Sundance formations in the vicinity.

MILLER CREEK DOME

A faulted dome with about 250 feet of closure lies mostly south of Miller Creek in the south-central part of T. 52 N., R. 64 W. The Stockade Beaver shale member of the Sundance formation is exposed in the center of the dome and is encircled, in turn, by the Hulett sandstone, Lak, and Redwater shale members of the Sundance formation. The beds have a maximum dip of 25° outward from the center. No igneous rock is exposed in this dome, but a large body of intrusive rock crops out about 1 mile northeast in sec. 27, T. 52 N., R. 64 W., and other igneous bodies were found about a mile to the east and a mile to the south in secs. 2, 9 and 10, T. 51 N., R. 64 W., respectively. The Murphy Corp. Snook 1 (well 72, pl. 1), drilled on the crest of the dome, reached 142 feet into the Pahasapa limestone without penetrating igneous rock; an intrusive, if present, is below this stratigraphic horizon. Pillmore and Mapel (1963, p. 39–41) described additional structural details at the Miller Creek dome.

HOUSTON CREEK DOME

The Houston Creek dome lies about 2 miles southeast of the Miller Creek in the valley of Houston Creek, T. 51 N., R. 64 W. The dome is almost circular in plan, is about 1 mile across, and has about 100 feet of closure at the surface. The deformed surface rocks belong mostly to the Sundance formation, and the oldest beds exposed are part of the Stockade Beaver shale member of the Sundance.

INYAN KARA MOUNTAIN

Sedimentary rocks at Inyan Kara Mountain are sharply upturned to form a dome a little more than a mile in diameter, mostly in T. 49 N., R. 62 W. The fold is intruded near the crest and on the southwestern side by a large laccolith (Darton, 1905a, p. 8) or igneous plug (Mapel and Pillmore, 1963a). Outcropping sedimentary rocks involved in the steepest folding include all formations from the Pahasapa limestone to the Sundance. Dips of 30° to vertical were measured in the Minnekahta limestone on the north side of the fold, and the Pahasapa limestone is vertical to overturned in a large outcrop on the southwest side.

STRAWBERRY MOUNTAIN

Strawberry Mountain, in the northeastern part of T. 48 N., R. 62 W., is a sharply folded dome outlined by tree-covered dip slopes mostly on the Minnekahta limestone. The fold is slightly elongated northeast and is about 1½ miles long. It has a closure of about 450 feet. The Minnelusa formation comes to the surface in the central and southwestern parts of the fold and is the oldest formation exposed. The steepest dips on the flanks of the fold are about 30°, increasing locally to nearly vertical on the southeast side. The nearest igneous rock is exposed at Inyan Kara Mountain about 4 miles northwest.

OTHER FOLDS

The rocks that form the northward-plunging nose of the Black Hills uplift in northern Crook County are warped into numerous small folds of diverse orientation. The folds are well displayed in the area between the Little Missouri and Belle Fourche Rivers where the Fall River formation forms extensive broadly undulating divides and plateaus whose surfaces closely reflect the structure. Likewise, minor folds in the central part of the area are strikingly shown by undulations in cliffs made by the Hulett sandstone member of the Sundance formation.

The control for structure contouring west of the Black Hills monocline was not adequate at most places to show minor flexures. There seems no reason to suppose, however, that the Fall River formation and older rocks are not locally as intricately folded on a small scale west of the monocline as they are east of it.

FAULTS

The sedimentary rocks in the northern part of the Black Hills are cut by faults at various places, but, with a few exceptions, the faults have displacements of less than 100 feet, and almost none of them could be traced for more than a mile. All the faults whose dips could be determined appear to be vertical, or nearly so. Faults that cut incompetent beds of shale such as make up much of the Cretaceous sequence may extend farther than shown on the geologic map (pl. 1) inasmuch as weathering of these rocks tends to obscure the fault traces.

Several faults occur along the Black Hills monocline transverse to its strike. Most of the others occur east

of the monocline in the vicinity of Hulett Creek and along the north and south sides of the Little Missouri River. Faults cut some domes formed by the intrusion of igneous rock.

FAULTS ALONG THE BLACK HILLS MONOCLINE

Faults ranging in length from 500 to about 1,500 feet cut across steeply dipping Cretaceous rocks and locally across Jurassic and Triassic rocks at four places along the Black Hills monocline east of Stockade Beaver Creek in T. 44 N., R. 60 W., Weston County, Wyo. Rocks cut by the northernmost fault, in sec. 5, are displaced horizontally a maximum of about 300 feet to the east on the north side of the fault. Rocks cut by the next two faults to the south are offset lesser amounts in the same direction, and rocks adjacent to the southernmost faults, in sec. 19, are offset horizontally about 300 feet west on the north side of the fault.

In secs. 5 and 6, T. 45 N., R. 62 W., Weston County, Wyo., a westward-trending fault about a mile long displaces the Belle Fourche shale, Greenhorn formation, and lower unnamed member of the Carlile shale downward on the north side relative to the same formations on the south side. The displacement appears to be about 25 to 50 feet.

Two parallel faults about a quarter of a mile apart trend northeastward across secs. 32 and 33, T. 49 N., R. 66 W. The southern fault is about 2 miles long and cuts the Greenhorn formation, Carlile shale, Niobrara formation, and Pierre shale. Rocks north of the fault are upthrown about 100 feet. The northern fault is about a mile long and offsets the Niobrara formation and Pierre shale; the vertical displacement is about 200 feet, upthrown on the south.

Six small faults, each less than a mile long, cut the Greenhorn, Carlile, or Niobrara formations in sec. 21, T. 52 N., R. 67 W., sec. 33, T. 53 N., R. 67 W., secs. 16 and 21, T. 54 N., R. 67 W., and secs. 29 and 30, T. 56 N., R. 67 W., respectively. The faults dip steeply and have maximum vertical displacements of less than 100 feet.

Two parallel north-trending faults on the nose of the Rocky Point anticline, mostly in T. 56½ N., R. 69 W., form a graben about a quarter of a mile long in which a block of Fox Hills sandstone has been dropped about 100 feet.

FAULTS OF THE HULETT CREEK-LITTLE MISSOURI RIVER AREA

A series of northeast-trending normal faults occur in an area that extends from the Black Hills monocline west of Hulett Creek along both sides of the Little Missouri River to Elkhorn Creek. The faults strike about parallel to the regional strike of the beds and dip steeply either northwest or southeast. All the faults are normal, and the displacement is vertical. The maximum displacement on any fault is about 100 feet, the average displacement being about 25 feet. Along most of the faults, the northwest side is downthrown. Faults in the Hulett Creek area and south of the Little Missouri River displace the Lakota, Fall River, Skull Creek, and Newcastle formations and those north of the Little Missouri River offset the Newcastle sandstone and the Mowry and Belle Fourche shales.

The spatial relation of the faults to the sharp bend and split in the nearby Black Hills monocline (pl. 1) suggest that the faulting resulted from tensions induced in the sedimentary rocks by folding of the monocline.

FAULTS RELATED TO INTRUSIVE DOMES

Lytle Creek and Miller Creek domes and Inyan Kara Mountain in the east-central part of the area, and a small dome adjacent to the Missouri Buttes in the central part, are cut by faults that are mostly restricted to the areas of steepest folding.

Inyan Kara Mountain is nearly surrounded by a curving fault with an inferred surface trace in the shape of a horseshoe open to the northeast. The fault brings igneous and sharply folded sedimentary rocks on the upthrown side in the area circumscribed by the fault against relatively undeformed sedimentary rocks on the downthrown side outside this area. The displacement along the fault appears to be about 600 feet in the SE¼ sec. 24, T. 49 N., R. 63 W., where the Spearfish formation on the upthrown side is brought against the upper part of the Sundance and Morrison formations. The displacement may be about the same for several hundred yards farther south where the Pahasapa limestone is brought to the surface on the upthrown side. The fault dies out at both ends in the lower part of the Sundance formation.

A northwestward-trending fault about 2½ miles long on the north side of the Lytle Creek dome in T. 53 N., R. 64 W., drops the Lakota formation on the north against the Hulett sandstone member of the Sundance formation on the south. The maximum displacement is about 200 feet. A short branching fault near the northwest end of the main fault cuts the Hulett member and overlying parts of the Sundance formation. Another fault with perhaps 200 feet of displacement, also downthrown on the north, extends from the eastern edge of the dome northeastward for at least a mile and brings the Spearfish formation on the south against the Redwater shale member of the Sundance formation on the north.

The north side of Miller Creek dome is cut by several short, westward-trending faults that displace various members of the Sundance formation downward in steps going northward. The maximum displacement along any of these faults is less than 50 feet.

A curving westward-trending fault cuts across the crest of a small dome north of the Missouri Buttes, mostly in secs. 33 and 34, T. 54 N., R. 66 W. This fault is downthrown on the south and has about 50 feet displacement.

OTHER FAULTS

Short faults having only a few feet displacement are shown by the geologic map (pl. 1) in secs. 13, 14, 25, and 36, T. 45 N., R. 61 W.; secs. 14 and 15, T. 46 N., R. 61 W.; secs. 30 and 31, T. 47 N., R. 63 W.; secs. 5, 7, and 8, T. 53 N., R. 64 W.; and at a few other places in the mapped area.

PERIODS OF DEFORMATION

The sedimentary rocks exposed in the Black Hills are nearly everywhere virtually concordant in dip from the Deadwood formation of Cambrian age to the Wasatch formation of Eocene age. Unconformities are present in the sequence, and some of them represent considerable intervals of erosion, or at least of nondeposition. At most places, however, pre-Tertiary folding was probably very gentle.

In the rocks younger than Triassic, a slight upwarping of the central and southern parts of the Black Hills relative to the nothern part in Middle or Late Jurassic time is shown by pre-Sundance truncation of the Gypsum Spring formation. Possible minor folding in Late Jurassic or Early Cretaceous time is suggested by a local unconformity at the base of the Lakota formation at Barlow Canyon (Izett, Pillmore, and Mapel, 1961) where, at places, the Morrison formation and much of the Redwater shale member of the Sundance formation were removed by pre-Lakota erosion, and at the head of Oil Creek (T. 47 N., R. 62 W.) where only about 50 feet of the Lakota formation is present between the overlying Fall River and underlying Morrison formation. On the basis of spectrographic analyses of detrital gold from the Newcastle sandstone and the presence of detrital cassiterite in the Newcastle and Fall River formations, Crowley (1950) suggested possible uplifting and deep erosion of the Black Hills during Fall River and Newcastle time. The present authors, and some others (Waagé, 1959, p. 49; MacKenzie and Poole, 1962, p. 70; and Mapel, Chisholm, and Bergenback, 1964), find no supporting evidence.

As pointed out by Darton (1909, p. 76) and subsequent writers, the major structural deformation and uplift of the Black Hills began in early Tertiary time—or possibly latest Cretaceous time—and ended before deposition of the Oligocene White River formation. Igneous rocks making up the Missouri Buttes, Devils Tower, and other plugs, sills, or dikes in the area were intruded before deposition of the White River formation, presumably at the time of uplift.

Chamberlin (1945) proposed that Laramide deformation in the Rocky Mountain region, including the Black Hills, was the result of dominantly horizontal forces acting northeast-southwest, and that the north- and northwest-trending fractures prevalent in much of the northern Rocky Mountains and Great Plains are shears produced by the compression. An opposing view for the Black Hills was stated by Noble, Harder, and Slaughter (1949) and by Noble (1952). These writers explained the main structural features of the Black Hills by dominantly vertical forces. Noble (1952, p. 35–36) pointed to the punched up igneous plugs and domes in the northern part of the Black Hills, the terrace-shaped folds with strata passing from nearly horizontal to nearly vertical within short distances, and the pattern of long plunging folds radiating in some areas from the center of the uplift as features reflecting simple vertical movement. Intrusion of magma of batholithic proportions at depth was postulated by Noble (1952, p. 36) as an explanation for the vertical forces.

ECONOMIC GEOLOGY

Mineral deposits of economic importance in the mapped area include oil and gas, uranium, bentonite, and coal, and, for local use, road metal and riprap. Oil has been produced for many years mostly from areas near Newcastle in Weston County, and more recently from areas near Moorcroft in Crook County, Wyo. In 1953 uranium became an important product of northern Crook County, Wyo. Bentonite pits in Weston and Crook Counties, Wyo. furnish much of the bentonite used in the United States. Large coal reserves are present in the western part of the area, and coal mining was once an important industry, although when the area was examined in 1954 and 1955 production came from only one mine, near Gillette.

Of possible future economic importance are the limestone beds in the Minnekahta limestone, which are quarried on the eastern side of the Black Hills for cement and road metal, and gypsum from the Gypsum Spring and lower part of the Spearfish formations.

OIL AND GAS

Oil was first produced on the northwestern side of the Black Hills in the 1880's from seeps in the Newcastle sandstone near Newcastle (Darton, 1904) and from seeps in the Newcastle sandstone and Fall River forma-

tion along the west flank of the Oil Butte-Pine Ridge anticline, T. 51 N., R. 67 W. (Barnett, 1915). By the end of 1959, 22 oil fields had been discovered northwest of Newcastle in Weston, Crook, and Campbell Counties, Wyo. Production of oil from these fields to the end of 1959, including production from the Fiddler Creek and Mush Creek fields, which lie mostly outside the mapped area, total more than 37.6 million barrels. The following table gives the production and other data on the oil fields, which are shown on plate 1.

Data on oil fields

Name of field	Year discovered [1]	Structural feature	Producing formation		Well status Dec. 31, 1959 [1]			API gravity (degrees)	Deepest test to Dec. 31, 1959		Cumulative production of oil to Dec. 31, 1959 (barrels) [2]
			Name	Average depth or range in depth (feet)	Producing	Shut in	Abandoned		Formation	Total depth (feet)	
Campbell County, Wyo.											
Adon	1948	Anticline	Minnelusa	9,345	0	1	3	31	Pahasapa	9,945	32,500
Mitchell Creek	1953		do	7,650	0	1	1	22	do	8,639	1,600
Bertha	1955		Newcastle	5,442	1	0	1	38	Skull Creek	5,583	16,500
Rozet	1959		do	6,900–6,950	5	0	0		do	7,004	23,600
Crook County, Wyo.											
Miller Creek	1959	Monocline	Fall River	5,950	7	0	3		Morrison	6,204	
West Moorcroft	1956	do	Newcastle	3,800	3	2	4	33	do	3,980	117,400
Moorcroft	1887	do	do	725	0	1	15	22	Fall River	1,791	800
Donkey Creek	1953	Anticline	do	6,280	3	0	0	41	Deadwood	9,781	4,159,200
			Fall River	6,200–6,400	28	0	4	39			
			Minnelusa	7,500–7,850	15	0	4	28			
South Donkey Creek	1957	Anticline	Fall River	6,380	8	0	4	39	Morrison	6,711	
Robinson Ranch	1958	Terrace	Minnelusa	6,000–6,125	10	0	3		Minnelusa	6,281	848,500
Grasshopper Butte	1953	do	Newcastle	1,600	2	0	5	38	Fall River	2,203	
Barton	1956	do	Fall River, Lakota	50–250	3	9	18	21	Minnelusa	1,490	
Kara	1955	do	Carlile	2,800	6	0	3	37	Fall River	3,256	
Wakeman Flats	1919	do	do	500	1	0	21	39	do	2,365	3,500
Wind Creek	1958	do	Fall River, Lakota	750	9	0	10	24	Morrison	822	
Crook and Weston Counties, Wyo.											
Coyote Creek	1956	Monocline	Newcastle, Fall River	6,000–6,125	46	0	10		Minnelusa	8,220	510,700
Thornton	1915	do	Carlile	600	8	5	33	41	Lakota	1,957	500
Fiddler Creek	1932	Terrace	Newcastle	4,500	42	151	50	43	Spearfish	5,926	[3] 11,928,300
Osage	1919	do	Belle Fourche, Newcastle	50–3,500	300	94	826	37	Minnelusa	4,653	7,014,000
Pedro	1922	Monocline	do	100–400	8	15	23	30	Fall River	2,740	800
Skull Creek-Mush Creek [3]	1943	Terrace	Newcastle	2,900–5,200	236	41	382	34–42	Minnelusa	5,850	[3] 12,984,100
Newcastle	1957	Monocline	do	600	3	1	13		Fall River	1,368	

[1] Based on records of the Conservation Div., U.S. Geol. Survey.
[2] From Petroleum Information, 1960, Thirtieth annual résumé, Rocky Mountain oil and gas operations for 1959.
[3] Producing areas mostly outside area of map, pl. 1.

The Osage, Mush Creek, Skull Creek, and Fiddler Creek fields in northern Weston County account for all but about 15 percent of the total production. Oil in these fields occurs in discontinuous sandstone lenses in the Newcastle sandstone. Dips in most of the producing areas are 1° to 3° SW., except in the Osage field where the dip steepens locally. Oil is found in similar traps in the Newcastle sandstone in the Grasshopper Butte and Moorcroft fields in southern Crook County.

Other rock units that yield oil include the Turner sandy member of the Carlile shale in the closely grouped Thornton, Wakeman Flats, and Kara fields in northern Weston and southern Crook Counties; the Belle Fourche shale in the Pedro and Osage fields in Weston County, the Fall River formation in the Donkey Creek, Coyote Creek, and Miller Creek fields in southwestern Crook and northwestern Weston Counties; and the Minnelusa formation in the Adon and Mitchell Creek fields in Campbell County, and Donkey Creek and Robinson Ranch fields in southwestern Crook County. The Donkey Creek, Adon, and Mitchell Creek fields, which produce from older rocks, were located by seismic data. Dips of the surface formations in the vicinity of these fields are 1° to 2° SW.

Several anticlines and domes on the flanks and crest of the Black Hills uplift in Wyoming and Montana have closure on the surface and thus offer potential traps for the accumulations of oil and gas. Most of the more prominent of these folds have been tested, at least to the Minnelusa formation, as shown by the following table, but none of the tests have been successful.

Wenger and Reid (1958, p. 148) grouped crude oils from the Powder River Basin into two types: oils

from formations younger than Jurassic that are green, paraffinic, and waxy, have high pour points, and are low in sulfur (0.5 percent or less); oils from formations older than Jurassic that are black and asphaltic, have low pour points, and are high in carbon residue and sulfur. Wenger and Reid (1958) and Biggs and Espach (1960) give crude oil analyses for several of the fields in the mapped area. Development and production of the fields was described by Biggs and Espach (1960) and by the Wyoming Geological Association (1957, 1961).

Table 1 gives data on 250 wells drilled in the mapped area. The locations of the wells are shown on plate 1.

Anticlines and domes tested unsuccessfully for oil and gas

Name of anticline or dome	Oldest formation exposed at the surface	Oldest formation tested		
		Name	Depth (feet)	Year tested
Arch Creek	Fall River	Minnelusa	1,675	1927
Barlow Canyon	Spearfish	do	1,099	1957
Bull Creek	Belle Fourche	Deadwood	4,243	1940
Chicago Creek	Skull Creek	do	3,793	1955
Colony	do	Minnelusa	2,290	1920
Government Canyon	Lakota	Pahasapa	2,476	1941
La Flamme	Sundance	Deadwood	2,859	1956
Miller Creek	do	Pahasapa	1,954	1959
Oil Butte-Pine Ridge	do	Deadwood	3,499	1943
Poison Creek	Fall River	Minnelusa	2,025	1945
Pump Creek	do	Pahasapa	2,462	1939
Rocky Point	Pierre (upper part)	do	6,105	1941
Seven Mile	Carlile	Precambrian	5,160	1957
Thornton	Skull Creek	Minnelusa	2,505	1924
Wolf Creek	Pierre	Precambrian	7,097	1956

TABLE 1.—*Information on selected wells drilled for oil and gas; well status brought up to Nov. 1, 1959*

No. on pl. 1	Location			Company and farm	Date completed or abandoned	Total depth (feet)	Oldest rocks reached	Production or shows of oil or gas [1]
	T.	R.	Sec. and quarters					
				South Dakota				
1	8N	1E	NWSW 19	R. R. Harman, Fishel No. 1	1954	1,475	Minnelusa	
				Montana				
2	7S	54E	NENE 21	Southern Calif. Aircraft Govt. 1	1958	5,654	Morrison	
3	7S	56E	NWNE 14	Skelly Oil Co. Bergen 1	1956	7,097	Precambrian	
4	8S	52E	NWSE 4	Gulf Oil Corp. Boyle 1	1952	9,062	Deadwood	
5	8S	56E	NESW 1	Union Oil Co. Govt. Lowe 1	1955	6,339	Precambrian	
6	8S	56E	SWSW 22	Delhi Oil Corp. Wheatley 2	1950	3,160	Fall River	
7	8S	57E	SENE 7	Poss Petrol. Co. 1	1926	2,505	Sundance(?)	GS.
8	8S	57E	NENE 20	Hunt Oil Co. Norton 1	1948	1,640	Fall River	
9	8S	57E	SESE 27	Hunt Oil Co. Hunt 1	1948	1,036	Skull Creek(?)	
10	8S	57E	NWNE 30	Hunt Oil Co. Norton 2	1948	1,849	Fall River	
11	8S	58E	NWSW 18	Mobile Producing Co. F-13-18-G Govt.	1958	4,656	Pahasapa	
12	9S	52E	SWNW 10	Davis Oil Federal-Evans 1	1958	5,506	Morrison	
13	9S	55E	SWNW 34	Northern Ordnance, Inc., McGhee 1	1949	3,545	Fall River	
14	9S	56E	SESW 10	Delhi Oil Corp. Wheatley 1	1950	2,681	Lakota	GS, Newcastle.
15	9S	58E	NWSE 29	Union Oil Co. Govt.-Catron 1	1956	4,852	Precambrian	
16	9S	59E	NWSW 23	Union Oil Co. Govt.-Newton 1	1956	4,878	do	
17	9S	61E	NENE 7	L. W. Roche Morgan 1	1949	1,495		
18	9S	61E	SESW 8	Frantz Corp. 1	1920	1,785	Lakota	OS.
19	9S	61E	NWSE 17	Continental Oil Co. Govt. 1	1957	5,160	Deadwood	
				Wyoming				
20	58N	68W	SWSE 27	Amerada Petrol. Corp. Starr 2	1949	3,995	Lakota	
21	58N	68W	NESW 32	Amerada Petrol. Corp. Starr 1	1948	4,461	Morrison	
22	58N	68W	SENW 35	Amerada Petrol. Corp. Ormesher 2	1950	3,670	Fall River	OS, Newcastle.
23	58N	70W	SESE 29	R. G. Steele Pethybridge 1	1955	5,532	Morrison	
24	58N	71W	SESW 28	Davis Oil Co. Rogers 1	1959	7,707	Minnelusa	
25	57N	61W	SENE 17	Properties Inc. Newland 1	1959	800	Sundance	
26	57N	61W	SWSW 27	Roxana Petrol. Corp. Shepard 1	1920	2,290	Minnelusa(?)	
27	57N	62W	NWNW 3	Union Oil Co. Casey-Govt. 1	1940	4,243	Deadwood	
28	57N	62W	SENE 3	Marine Oil Co. Early 1	1925	968	Newcastle(?)	
29	57N	64W	NWSW 28	Vickers Petrol. Corp. Duncan-Lobban 1	1941	2,476	Pahasapa	
30	57N	65W	NWNW 15	Karda Oil and Gas Co. Montah-Wyco 1	1950	2,760	do	
31	57N	66W	SWSE 6	Amerada Petrol. Corp. Hale 2	1950	1,678	Morrison	
32	57N	67W	SWSW 23	Amerada Petrol. Corp. Dundas 1	1950	1,511	do	
33	57N	68W	NENE 1	Amerada Petrol. Corp. Blackbank Hill Unit 1	1950	2,902	do	
34	57N	70W	NENE 22	D. E. L. Byers Govt. 1	1956	5,500	do	
35	56½N	69W	SWSW 34	Pure Oil Co. Wexal 1	1948	6,382	Pahasapa	
36	56N	61W	NENW 14	Hunt Oil Co. Miller-Govt. 1	1955	3,793	Deadwood	
37	56N	68W	SENW 4	R. R. Murray Roberts-Govt. 1	1948	3,304	Skull Creek	
38	56N	68W	SESE 25	Indian Exploration Co. Govt. 1	1955	4,016	Minnelusa	OS, Minnelusa.
39	56N	68W	SWSW 28	Superior-Phillips-Hunt Smith 1	1948	3,667	Morrison	
40	56N	69W	SWSE 4	Continental Oil Co. Knapp 1	1941	6,105	Pahasapa	OS, Minnelusa.
41	56N	69W	SESW 13	Superior-Phillips-Hunt Wexal 1	1948	4,000	Lakota	
42	55N	66W	NESE 23	Perl Smith Fowlkes 1	1957	1,816	Minnelusa	
43	55N	67W	NENW 6	Anschutz Drilling Co. Govt. 1	1957	3,862	do	Do.
44	55N	67W	SWSW 8	Clayton Oil Co. Dennis 1	1958	5,197	do	Do.
45	55N	67W	NWSW 15	Williams Bros. Corp. Continental Oil Co. 1	1945	3,380	Deadwood	
46	55N	68W	NWSW 21	Trigood Oil Co. Stroner-Wood 1	1949	5,490	Sundance	
47	55N	68W	SWSW 24	Texas Co. State of Wyoming 1	1949	4,610	Morrison	
48	55N	69W	NWNW 21	Progressive Drilling Co. Hamm-Govt. 1	1956	5,666	do	
49	55N	70W	SESE 2	Great Basin Petrol. Co. Govt.-Cosmo 44-2	1954	7,242	Minnelusa	
50	55N	70W	SWSW 24	Pan Am. Oil Co. Fallwell 1	1959	7,478	do	
51	54N	60W	NENW 6	Northwestern Oil and Gas 1	1931	1,585	Opeche	
52	54N	60W	NWSW 21	Mobil Producing Co. F-13-21 P. Helmer	1956	2,859	Deadwood	
53	54N	63W	NESE 2	Sinclair Oil Co. Federal Wallace 1	1959	2,461	Pahasapa	
54	54N	66W	SESW 13	Petroleum Inc. E. Holmes	1957	1,099	Minnelusa	Do.

See footnote at end of table.

TABLE 1.—*Information on selected wells drilled for oil and gas; well status brought up to Nov. 1, 1959*—Continued

No. on pl. 1	Location T.	Location R.	Location Sec. and quarters	Company and farm	Date completed or abandoned	Total depth (feet)	Oldest rocks reached	Production or shows of oil or gas [1]
55	54N	67W	SENE 12	Williams Bros. Corp. Christiansen 1	1945	2,025	Igneous rock in Minnelusa(?).	
56	54N	68W	SESE 12	Texas Co. Brislawn 1	1951	4,900	Morrison	
57	54N	68W	SWNE 14	D. C. Morton, Morton 1	1957	5,190	do	
58	54N	69W	NWNW 15	Texota Oil Co. Govt. 1-A	1956	5,901	Fall River	
59	54N	69W	NESE 25	Voss Oil Co. Govt.-Miller 1	1955	5,576	do	
60	54N	69W	SESE 27	Voss Oil Co. Govt.-Crawford 1-B	1955	5,583	Skull Creek	OP, Newcastle.
61	54N	69W	NWNW 29	Voss Oil Co. Govt.-Davis 1-C	1955	5,629	do	
62	54N	71W	NWNW 25	National Coop. Ref. Govt. 1	1959	7,968	Minnelusa	
63	53N	65W	NWSW 4	H. D. Curtis 1	1928		Opeche(?)	
64	53N	66W	SESE 5	Starr Oil Co. Anderson 1	1949	1,533	Igneous rock in Minnelusa(?).	
65	53N	67W	NWNE 17	O. Burns Evans 1	1942?			
66	53N	68W	NWNE 28	Buffalo Drlg. Co. Stevens 1	1949	5,715	Fall River	
67	53N	69W	CSWSW 23	Amerada Petrol. Corp. Bertha Unit 1	1949	6,513	Sundance	
68	53N	70W	NWSW 28	Trigood Oil Co. Govt. 1	1951	7,852	Minnelusa	OS, Minnekahta, Minnelusa.
69	53N	70W	SWNE 33	Trigood Oil Co. Hamm et al. 2	1953	8,639	Pahasapa	OP Minnelusa.
70	53N	72W	SESW 14	Texas Co. Adon Unit 4	1951	9,714	do	
71	53N	72W	SESE 35	Texas Co. Dye 3	1948	8,865	Minnelusa	OS, Minnekahta, Minnelusa.
72	52N	64W	NESW 33	Murphy Corp. Snook 1	1959	1,954	do	OS, Minnelusa.
73	52N	67W	NWNW 11	M. W. Willan Zimmerchide 1	1956	740	Lakota	
74	52N	67W	SWSW 23	Buffalo Drlg. Co. Jones 1	1948	2,195	Pahasapa	
75	52N	67W	NWNW 25	Northern Ordnance, Inc., Somers 1	1950	2,351	Pahasapa(?)	
76	52N	67W	SESE 31	Owanah Oil Co. Federal 31-1	1956	3,982	Lakota	OP, Newcastle.
77	52N	67W	SENE 33	Quality Oil Co. Govt. 1	1956	1,791	do	Do.
78	52N	68W	NWNE 8	True Oil Co. Harris-Simpson 1	1959	7,312	Minnelusa	
79	52N	68W	SWSW 25	Texas Co. Mellott 1	1957	4,850	Fall River	
80	52N	68W	SESW 28	Trigood Oil Co. Govt-Dunning 1	1959	5,934	Morrison	OS, Newcastle.
81	52N	68W	SWSE 32	Skelly Oil Co. Govt.-Munoz 1	1959	6,085	Lakota	OS, Newcastle, Fall River.
82	52N	69W	NWSW 4	Amerada Petrol. Corp. East Adon Unit 1	1949	6,512	Sundance	
83	52N	72W	NWNE 2	Texas Co. Gormley 1	1948	9,945	Pahasapa	OP, Minnelusa.
84	52N	72W	NWNW 2	Texas Co. Gormley 2	1948	9,684	do	
85	51N	66W	SENW 18	Continental Oil Co. Coltharp 1	1943	3,499	Deadwood	
86	51N	67W	NWSW 15	Coronado Petroleum Co., Inc., Govt.-Betts 1	1955	4,519	Pahasapa	
87	51N	67W	NESW 25	Central States Drlg. Co. McKean 1	1949	2,827	do	
88	51N	67W	CNWSE 32	C. B. Chittin State 1	1959	6,095	Minnelusa	
89	51N	68W	NENE 1	Skelly Oil Co. Goetzinger 1	1957	4,200	Skull Creek	OP, Newcastle.
90	51N	68W	SWNE 7	Petroleum Inc. Harris-Simpson 1	1959	6,445	Morrison	
91	51N	68W	NWNE 8	Skelly Oil Co. Sundem 2	1959	6,035	Fall River	OP, Fall River.
92	51N	68W	NWNW 11	Trigood Oil Co. Wood-McKean 1	1955	5,578	do	
93	51N	68W	SENE 13	Trigood Oil Co. Wood-McKean 2	1957	4,934	do	
94	51N	68W	SWSW 16	Trigood Oil Co. Arcol State 1	1958	7,586	Minnelusa	OS, GS, Fall River.
95	51N	68W	SWSE 22	J. D. Specher Munoz 1	1955	5,577	Newcastle	
96	51N	68W	SWSW 30	Samuel Gary 1-A	1959	6,425	Minnelusa	
97	51N	68W	SENW 36	Champlin Oil Co. State 1	1959	6,745	do	OP, Minnelusa.
98	51N	69W	SESE 16	Davis Oil Co. TP State 1	1957	6,570	Morrison	
99	51N	70W	NENE 36	True Oil Co. State 1	1959	8,372	Minnelusa	
100	50N	65W	NENW 26	E. F. Carnell Barton 2	1958	1,870	do	OS, Minnelusa.
101	50N	65W	SWSE 27	Glenwood Oil Co. Barton 2	1956	82	Fall River	OP, Fall River.
102	50N	65W	SESE 34	Fleming & Willis Barton-State 1	1956	190	Lakota	OS, Lakota.
103	50N	66W	NWSW 19	R. G. Parrent McKean 1	1953	1,717	do	
104	50N	66W	NENW 21	J. J. Reasor Thompson 1	1959	2,275	Minnelusa	
105	50N	66W	NWNW 31	Petrol. Exploration Co. Barton 2	1953	1,671	Skull Creek	OP, Newcastle.
106	50N	67W	NESE 12	M. D. Miller Waymire 3	1949	840	Fall River	OS, Newcastle(?).
107	50N	67W	SWNW 18	Amerada Petrol. Corp. Robinson 1	1948	5,090	Morrison	
108	50N	67W	NWSW 25	R. H. Phillips Roberts 1	1953	2,296	Skull Creek	
109	50N	67W	NWNE 28	P. M. Petroleum Buckmiller 1	1959	6,380	Minnelusa	
110	50N	67W	NWNE 29	P. M. Petroleum E. Garlepy	1957	6,179	do	OS, Fall River, Lakota, Minnelusa.
111	50N	67W	NWNE 32	Pan Am. Oil Co. Robinson 1	1958	6,582	do	OP, Minnelusa.
112	50N	68W	NESE 3	Wm. Hamm, Jr., Cox-Govt. 1	1950	5,492	Skull Creek	
113	50N	68W	SESE 20	Texas Co., John-Jessen 1	1957	6,447	Morrison	OP, Fall River.
114	50N	68W	NWSE 29	Brinkerhoff Drilling Brinkerhoff-Lester 1	1957	7,795	Minnelusa	
115	50N	68W	NESE 31	OWanah Oil Co. Cranston 2	1958	7,789	do	OS, Fall River.
116	50N	68W	SESE 32	Trigood Oil Co. Marshall "E" 2	1958	7,799	do	OP, Minnelusa.
117	50N	69W	NWSW 12	Davis Oil Co. Federal-Kummerfield 1	1958	6,665	Morrison	
118	50N	69W	SWSW 18	Davis Oil Co. Isaac 1	1957	7,188	do	
119	50N	69W	SENE 24	Davis Oil Co. Federal-Thompson 1	1959	6,480	do	
120	50N	69W	NWNE 30	Davis Oil Co. Brennal 1	1959	7,087	do	
121	50N	70W	SWNE 16	Farmers Union State 1	1959	7,615	do	
122	50N	70W	NWSW 23	Sinclair Oil Co. P. Svalina	1959	8,740	Minnelusa	OP, Newcastle.
123	50N	71W	SESE 19	Arrowhead Exp. Co. Potter 1	1957	9,811	do	OS, Minnelusa.
124	49N	63W	NESE 5	Ralph Gardner Edwards 1	1952	1,450	do	
125	49N	63W	SENW 17	Ralph Gardner Krieger, Pierson, and McClintook 1	1948	1,232	do	
126	49N	64W	SWSW 20	Glenwood Oil Co. Wallace and May 1	1957	1,735	do	Do.
127	49N	64W	NWNW 33	Glenwood Oil Co. May 1	1958	250	Morrison	
128	49N	65W	SENW 5	True Oil Co. Thompson 2	1959	482	do	OP, Lakota.
129	49N	65W	NWNW 10	Glenwood Oil Co. Foster 1	1957	401	do	Do.
130	49N	65W	SWSE 22	Teton Exploration Co. Govt. 1	1957	390	do	
131	49N	65W	SENW 36	Emnett Pearey 1 Pearey-State 2	1957	375	do	
132	49N	66W	NWNW 6	C. B. Chittim Barton 2	1959	3,908	Minnelusa	
133	49N	66W	NENW 10	L. R. Thatcher 1	1941	1,045	Newcastle	
134	49N	66W	SWSE 12	Syl-Del Mines, Inc., Marquiss 5	1958	728	Lakota	OS, Lakota.
135	49N	66W	NENE 18	C. E. Brehm, Nicolen 1	1959	4,151	Minnelusa	
136	49N	66W	SESE 19	M. D. Miller Commercial Oil and Gas Co. 1	1945	2,365	Skull Creek	OS, Carlile.
137	49N	66W	SENW 23	Wyoming Oil Co. Degner 1-A	1958	798	Lakota	OP, Lakota.
138	49N	66W	SESW 25	H. &M. Construction Co. Wagner 1	1958	744	Morrison	
139	49N	66W	SWSE 33	E. M. Thomasson Govt. 6	1957	615	Carlile	OP, Carlile.
140	49N	67W	NWSW 4	Pan Am. Oil Co. C-1	1959	6,660	Minnelusa	
141	49N	67W	NWSW 5	Lester Ferley Butts 1	1959	5,211	Fall River	OS, Fall River.
142	49N	67W	NESW 15	W. & M. Oil Co. Robinson 1	1955	3,018	Carlile	
143	49N	67W	SWSW 18	Amerada Petrol. Co. Cortes 1	1949	5,832	Lakota	
144	49N	67W	SWNW 20	Petroleum Inc. Macy 1	1959	7,295	Minnelusa	Do.
145	49N	67W	SWSW 25	Moore Development Moore 1	1953	3,225	Fall River	

See footnote at end of table.

TABLE 1.—*Information on selected wells drilled for oil and gas; well status brought up to Nov. 1, 1959*—Continued

No. on pl. 1	Location T.	Location R.	Location Sec. and quarters	Company and farm	Date completed or abandoned	Total depth (feet)	Oldest rocks reached	Production or shows of oil or gas [1]
146	49N	67W	SESE 29	Embar Oil Co. Macy 1	1959	7,258	Minnelusa	
147	49N	67W	SENW 35	Lester Ferley Govt. 1	1959	5,313	Minnelusa	
148	49N	68W	SESW 1	Wyoming Oil Co. Hickenbottom 1	1956	5,802	Lakota	
149	49N	68W	SWSE 5	True Oil Co. B-13	1958	7,849	Minnelusa	OP, Minnelusa.
150	49N	68W	SESE 6	Texas Co. Harris 1	1956	6,498	Fall River	OP, Fall River.
151	49N	68W	NWNW 14	Petroleum Inc. Butler 1	1958	6,080	do	GS, Fall River.
152	49N	68W	NENW 17	Texaco Co. Stevenson 1	1958	6,580	do	OP, Newcastle, OP, Fall River.
153	49N	68W	SWNW 20	True Oil Co. Koch 5	1958	6,619	do	OP, Fall River.
154	49N	68W	NWSE 22	Petroleum Inc. Butler 1	1958	6,345	Morrison	OP, Newcastle.
155	49N	68W	SESW 27	True Oil Co. Watt A-11	1959	6,485	Lakota	
156	49N	68W	CSESE 28	True Oil Co. Watt 9	1959	6,470	Fall River	OP, Fall River.
157	49N	68W	NWNW 29	True Oil Co. Koch-Krause 1	1957	6,690	Morrison	
158	49N	68W	SESE 34	True Oil Co. Watt A-13	1959	6,615	Fall River	Do.
159	49N	68W	SENW 36	True Oil Co. State BC 36-1	1959	6,370	do	OS, Fall River.
160	48N	63W	SENE 30	Moffatts-Meyers Dev. Co. Douglas 1-w	1951	475	Sundance	
161	48N	64W	SENE 7	Ben Fleming Pfeiffer 1	1956	476	Morrison	
162	48N	64W	SESE 15	Birdsall and Fischer Govt. 1	1954	2,504	Pahasapa	
163	48N	64W	SENW 26	John Brorby et al. George 1	1939	4,570	do	
164	48N	65W	NWNE 6	Boulder Pet. Co. Barton 1	1958	754	Lakota	
165	48N	65W	SWSW 8	Prod. and Ref. Corp. Bush 1	1924	2,505	Minnelusa	
166	48N	65W	NENW 21	Tamarack Dev. Co. Govt. 1	1958	2,115	do	
167	48N	65W	NESW 25	City of Upton 1	1946	680	Lakota	
168	48N	66W	NENW 3	Noel Bros. O'Conner 1	1952	1,112	Fall River	
169	48N	66W	NENW 5	Black Hills Drlg. Barton-Horton 1	1955	1,050	do	
170	48N	66W	SWNW 18	National Assoc. Pet. Co. Federal Farm Mortgage Corp. 1	1950	5,270	do	
171	48N	67W	NWNE 10	R. P. Johnson Kimsey 1	1957	5,519	Morrison	
172	48N	67W	SENW 18	Miracle-Fifer Govt. 1	1956	6,450	Fall River	
173	48N	67W	SESE 35	Texas Co. Oekers 1	1951	5,950	Lakota(?)	
174	48N	68W	SESW 3	Kewanee Oil Co. Buttram 4	1959	6,556	Fall River	OP, Fall River.
175	48N	68W	SWNW 6	Mobile Producing Co. F-12-6-G	1959	8,220	Minnelusa	OS, Carlile, Fall River; GS Minnelusa.
176	48N	68W	SENW 8	Kewanee Oil Co. Govt. 1	1959	7,075	do	
177	48N	68W	SESE 9	Midwest-Kewanee Oil Co. Bukor 1	1958	8,235	do	OS, Fall River.
178	48N	68W	SWSW 15	Kewanee Oil Co. Raven 1	1959	6,985	Morrison	
179	48N	68W	SWSE 26	Petroleum Inc. Lowe-Govt. 1	1959	7,036	do	
180	48N	68W	NENE 36	S. Gary-Huber Corp. State 1	1959	6,947	do	
181	47N	63W	SWSE 3	Farley and Freeman Thomas 1	1954	2,500	Pahasapa	
182	47N	63W	NENW 19	Wyalta Holdings Ltd. Darvson-Bethpage-Mission 1	1957	385	Fall River	OS, Newcastle.
183	47N	63W	SESE 30	B. C. Hewett National Lead 3	1956	306	Newcastle	OP, Newcastle.
184	47N	63W	NESW 31	Northern Development Co. 1	1939	501	Fall River	
185	47N	63W	NESW 36	Webster Oil Co. Bock 1	1921	1,687	Minnelusa	
186	47N	64W	SESE 11	Omaha Oil Syndicate 1	1930	437	Fall River	
187	47N	64W	NENW 19	B. C. Hewett Foltz 1	1955	595	Lakota	
188	47N	64W	NESE 21	Petroleum Exploration Co Gilmer 1	1947	532	Morrison	
189	47N	64W	SENW 28	Union Oil Co. Calif. Alverson 1	1921	2,235	Sundance	
190	47N	65W	SWNE 28	Gose Syndicate Gose 1	1940	5,060	Morrison	
191	47N	66W	SWSE 6	Texaco Dow and McHugh 1	1959	5,798	Fall River	
192	47N	66W	NWNW 18	Davis Oil Davis 1	1959	5,924	do	
193	47N	66W	NWNW 23	Lion Oil Co. Nolan 1	1959	5,385	Morrison	
194	47N	66W	SENW 33	L. S. Chism Byran 1	1950	5,764	Lakota	
195	47N	67W	SESE 5	Brinkerhoff Drilling Co. Oeikers 1	1957	8,535	Minnelusa	
196	47N	67W	SENW 26	Texas Pacific Coal and Oil Co. Govt. 1	1951	8,780	do	
197	47N	67W	NENE 11	Petroleum Inc. Govt. 1	1959	7,056	Morrison	
198	47N	67W	SWSW 23	Davis Oil Co. Brost 1	1959	7,555	do	
199	46N	62W	SENW 18	S. K. Wadley System-Terminal 1	1957	2,738	Pahasapa	
200	46N	63W	SWSW 3	Moffatt-Myers Development Co. Draper 2	1951	329	Fall River	
201	46N	63W	NENE 7	Deadwood-Osage Oil Co. 1	1920	1,230	Lakota	
202	46N	63W	NWSE 9	Black Hills Power and Light Co. 1-w	1941	2,592	Pahasapa	
203	46N	63W	SWNW 16	Black Hills Power and Light Co. 2-w	1951	2,991	do	
204	46N	63W	NWNE 19	Wyoming Gas and Oil Co	1920	1,645	Fall River	OS, Newcastle.
205	46N	63W	SWNE 21	Osage Trust Co. 5	1938	1,500	Spearfish	
206	46N	63W	SESE 29	Davis Oil Co. Federal Benhart 1	1959	2,903	Minnelusa	
207	46N	63W	NESW 30	J. D. Sprecher Band 1	1959	1,477	Skull Creek	OP, Newcastle.
208	46N	63W	NESE 33	Melton and O'Dell Govt. 2	1957	1,138	Newcastle	
209	46N	64W	SESW 9	Emnett Pearey, Pearey Martin 1	1957	3,630	Fall River	
210	46N	64W	SESW 11	Paul Abrecht State 1-11	1957	1,800	Newcastle	Do.
211	46N	64W	SWSW 15	P. M. Oil Enterprises Govt. 11	1957	3,367	do	
212	46N	64W	NESW 18	Texaco Inc. Gilmore 3	1959	4,549	do	Do.
213	46N	64W	SENE 20	P. M. Oil Enterprises Ray 1	1957	4,375	Fall River	OS, Newcastle.
214	46N	64W	NWNW 26	U.S. Dept. of Interior, G. E. Kiesling	1932	2,560	Lakota	
215	46N	64W	SWNW 28	Nicolai Spath Watt 1	1956	4,580	Fall River	
216	46N	64W	NESW 34	True Oil Co. Utter-Martens 1	1957	4,660	do	
217	46N	65W	NESE 2	Trigood Oil Co. Jessie D-1	1945	4,513	Skull Creek	
218	46N	65W	NWSE 12	Perl Smith Govt. 2	1958	4,505	Newcastle	
219	45N	61W	SESE 10	Leuthart and Briggs 1	1926	850	Minnelusa	
220	45N	61W	SWSE 20	City of Newcastle	1949	2,638	Pahasapa	
221	45N	62W	SWNW 16	R. B. Mitler Trustee 1	1922	2,975	Sundance	
222	45N	62W	NWSW 21	J. G. Dyer Horten 1	1958	3,125	Skull Creek	
223	45N	62W	SWSE 25	L. W. Edwards Engle 1	1955	2,158	do	
224	45N	62W	SENW 26	Coronado Petroleum Co. Engle 1	1956	3,880	do	OP, Newcastle.
225	45N	62W	NESW 28	Brinkerhoff Drilling Co. Horton 1	1948	3,358	Fall River	
226	45N	62W	NWSW 32	R. M. Olds Govt. H-1	1957	3,400	Skull Creek	Do.
227	45N	63W	NENE 1	H. T. Thorson 5	1957	200	Belle Fourche	OP, Belle Fourche.
228	45N	63W	NWSE 5	Lysite Ventures, Inc., 5-1	1957	1,585	Newcastle	OP, Newcastle.
229	45N	63W	SWNWSE 11	Yorman Oil, Inc., Override Oil 1	1955	2,300	Lakota	OS, Newcastle; OS, Fall River.
230	45N	63W	SENE 14	Yorman Oil, Inc., Maxwell 1	1954	3,104	Skull Creek	OS, Carlile; OS, Newcastle.
231	45N	63W	NWSE 18	Black Hills Drilling Co. Smith 1	1948	4,138	Fall River	
232	45N	63W	NESW 29	Olds Oil Co. Norton 1	1948	4,030	Lakota	
233	45N	63W	SWSE 32	Superior Oil Co. Christiana 1	1947	4,170	do	
234	45N	64W	NENE 2	Johnson, Wold, and Ryder Govt. 1	1959	4,653	Minnelusa	

See footnote at end of table.

TABLE 1.—*Information on selected wells drilled for oil and gas; well status brought up to Nov. 1, 1959*—Continued

No. on pl. 1	Location			Company and farm	Date completed or abandoned	Total depth (feet)	Oldest rocks reached	Production or shows of oil or gas [1]
	T.	R.	Sec. and quarters					
235	45N	64W	SENE 5	Husky Refining Co. Middleton 1	1949	5,005	Morrison	
236	45N	64W	SENE 14	Rex Shenton et al. King 1	1951	4,485	Lakota	
237	44N	61W	NWSW 1	Texas Calgary Co. Govt. 2	1959	200	Newcastle	OP, Newcastle.
238	44N	61W	SESE 6	Williams Oil Co. Martin 1	1920	2,055	Fall River	
239	44N	61W	SWSW 12	Coronado Petroleum Co. Lak 1	1955	4,629	Minnelusa	OS, Fall River.
240	44N	61W	NENW 31	Mon-O-Co Oil Corp. Aimonette Estate 1	1940	3,760	Sundance	
241	44N	62W	SWSE 1	Black Hills Drilling Co. Graham 1	1955	6,227	Deadwood	
242	44N	62W	NWNE 8	Sam Day Govt. 7	1957	3,426	Newcastle	
243	44N	62W	NESE 11	John Brorby Hanson 1	1942(?)	3,568	Morrison(?)	GS, Carlile.
244	44N	62W	NWNW 23	Brinkerhoff Drilling Co. Livingston 1	1948	3,305	Fall River	
245	44N	62W	NWNW 31	Calloway and Smith Govt. 1	1948	3,934	do	
246	44N	63W	NWSE 8	Morton Drilling Co. Sedgwick and McKean 1 (Farm 2)	1949	4,442	Lakota	
247	44N	63W	NWNE 15	Mon-O-Co. Oil Corp. Clark 1	1947	4,315	do	OP, Newcastle.
248	44N	63W	NENW 21	Texas Co. 6	1952	4,676	Morrison	
249	44N	63W	SWNW 24	Mush Creek Producing Co. Smith 1	1945	4,912	Spearfish	OS, Newcastle.
250	44N	63W	NWNW 32	Yellowstone Drilling Co. Barton 1	1949	5,008	Lakota	

[1] OS, oil show; GS, gas show; OP, oil produced; name of formation in which oil or gas occurs, if known, follows the symbol.

URANIUM

Uranium in commercial amounts was discovered in 1952 near the town of Carlile, T. 52 N., R. 66 W., Crook County, Wyo. (Harder, 1955). From 1952 to 1963, uranium has been mined near Carlile; in Barlow Canyon, T. 54 N., R. 66 W.; at Hulett Creek, T. 55 N., R. 67 W.; on the west side of Elkhorn Creek, T. 56 N., R. 66 W.; and on the west side of the La Flamme anticline, T. 54 N., R. 60 W. The deposits are in beds of sandstone in the Lakota and Fall River formations. The ore minerals are carnotite and tyuyamunite where the deposits are above the local ground-water table, and uraninite and coffinite where the deposits are below. These minerals coat sand grains and fill the interstices between the grains, or are disseminated in fragments or seams of carbonaceous material in the sandstone. In general, the ore deposits are less than 4 feet thick and irregular in plan, and the horizontal dimensions are several times greater than the vertical dimension. They have an erratic distribution, and most of the known deposits show no apparent trend or preferred alinement, except that they roughly parallel the stratification or cross lamination. The contact of the ore with the country rock is sharp in some deposits, and gradational through 2 or 3 feet in others.

The ore deposits at Carlile are on a broad structural terrace, in contrast with the other deposits that are on the flanks of minor anticlines or domes. Faults cut the ore-bearing formation at Hulett Creek; elsewhere no faults, or only minor postore faults, have been found near the ore bodies.

In addition to the uranium deposits so far discovered, areas of abnormally high radioactivity are reported in the Fall River formation at the Oil Butte–Pine Ridge anticline, Thorne divide, Poison Creek dome, along Dinky, Tie, and Bronco John Creeks, and at Government Canyon, all in the northern part of Crook County, and in the Lakota or Fall River formations at several places in the general vicinity of Missouri Buttes, and along the divides east and west of Inyan Kara Creek, in Tps. 51–52 N., Rs. 65–66 W.

All the known deposits and the greatest number of radioactivity anomalies so far reported are in the Lakota and Fall River formations, although one or more radioactivity anomalies have been reported from most of the other formations exposed, and visible uranium minerals have been found in the Newcastle sandstone at Strawberry Hill, in sec. 3, T. 55 N., R. 65 W.

The ore minerals mentioned in the following discussion were identified by E. J. Young or J. W. Adams, and all analyses were made in the laboratories of the U.S. Geological Survey.

DEPOSITS IN THE LAKOTA FORMATION

CARLILE AREA

Uranium ore occurs near Carlile in the NW¼ sec. 26, T. 52 N., R. 66 W., in a bed of fine- to medium-grained friable sandstone 21 feet thick about 30 feet below the top of the Lakota formation (Bergendahl, Davis, and Izett, 1961, p. 668–694). The total thickness of the Lakota formation in this vicinity is 125 to 140 feet, and the formation is about horizontal. Deposits that had been mined by the end of 1958 consisted of three ore bodies on the edge of a high bluff overlooking the Belle Fourche River, and a fourth ore body, apparently once continuous with one of the others, in a landslide block at the base of the bluff. In general, the ore bodies are tabular and parallel to the bedding, rarely more than 3 feet thick, and irregular in outline. The largest is 275 feet long and as much as 100 feet wide. The ore occurs as carnotite and

tyuyamunite in fine-grained aggregates that coat sand grains and fragments of carbonized wood and fill the interstices between grains. Thin seams and lenses of carbonized wood and clayey siltstone alined along planes of stratification are abundant in the ore-bearing sandstone, and the ore is richest where several of these seams coalesce. Mining was done mostly by stripping, but some underground mining was done from two short adits. C. A. Razor (written communication, 1959) reported the production as 10,000 tons of ore averaging 0.31 percent U_3O_8 from these deposits to the end of 1958.

Another ore deposit, or series of deposits, in the Carlile area adjacent to the ones described above is in a conglomeratic sandstone at or near the base of the Lakota formation. The deposit had not been completely drilled out when the area was last examined (1958) and geologic details were lacking. The ore minerals are uraninite and probably coffinite. Geologic mapping (Bergendahl, Davis, and Izett, 1961, p. 694–697) indicated that the deposit is in a structural basin about half a mile in diameter with about 40 feet of closure.

HULETT CREEK AREA

In 1958 the Homestake Mining Co. started development of an ore body in the Lakota formation in the Hulett Creek area, Crook County, Wyo. The ore was being developed by a 400-foot vertical shaft in the SW¼ sec. 3, T. 55 N., R. 67 W.

Drilling by the Homestake Mining Co. indicated that the ore is in the basal part of the Lakota formation, at or a few feet above the contact with the Morrison formation. The basal unit of the Lakota formation is a fine- to medium-grained sandstone with lenses of conglomeratic sandstone. The sandstone is locally cemented with carbonates and locally contains fragments of carbonized wood along the bedding.

The ore minerals, which were not yet identified at the time this report was prepared (1958), are black and very fine grained and are mixed with very fine grained pyrite. They occur, with the pyrite, as cement interstitial to the sand and conglomerate grains and in veins, generally less than 5 mm wide, that crosscut the grains and, if present, the carbonate cement. Some additional information is given by Robinson and Rosholt (1961).

The ore deposit occurs on either side, and apparently parallel to, a northeast-trending fault that extends from about the center of sec. 3, T. 55 N., R. 67 W., to the eastern boundary of the township. The fault is normal with the northwest side downthrown a maximum of about 30 feet. The Homestake Mining Co. in their annual report for 1957 reported that 295,000 tons of ore with an average grade of 0.32 percent U_3O_8 had been blocked out by drilling.

WEST FLANK OF THE LA FLAMME ANTICLINE

Uranium minerals, probably carnotite and tyuyamunite, occur in the upper part of the Lakota formation on the west flank of the La Flamme anticline in the NE¼ sec. 18 and the SE¼ sec. 7, T. 54 N., R. 60 W. These minerals are disseminated in small discontinuous pods in a grayish-white medium-grained sandstone that contains feathery seams of carbonized wood. The sandstone above the ore is stained purplish red through a thickness of 3 to 4 feet. The deposits were worked in 1954 from two small open pits.

DEPOSITS IN THE FALL RIVER FORMATION

BARLOW CANYON

The lower part of the Fall River formation contains uranium ore on the north side of Barlow Canyon in the SE¼ sec. 15, T. 54 N., R. 66 W. The ore body is about 3 feet thick, about 200 feet long, and lies in a sequence of fine-grained sandstone and silty sandstone that contains partings and thin beds of silty shale and seams of carbonaceous material. Dips in the Fall River formation are 1° to 2° northward. In this deposit, radioactive seams of carbonaceous material and sandstone impregnated with iron oxides contain a yellow uranium mineral that coats sand grains and forms cement. The uranium mineral contains calcium in addition to uranium and gives negative vanadium and potassium tests, is not fluorescent, and has a refractive index of less than 1.86.

HULETT CREEK AREA

Uranium ore occurs in the Fall River formation near Hulett Creek in secs. 3, 4, and 10, T. 55 N., R. 67 W., Crook County, Wyo. The deposits are in a sandstone lens at the top of the formation, which has been folded into a broad, gently northwest-plunging anticline and which is cut by several northeast-trending normal faults. The sandstone lens trends northwest and is about 8,000 feet long, 2,000 feet wide, and from 10 to 45 feet thick (Robinson and Goode, 1957a, 1957b; Robinson and Rosholt, 1961).

Eight ore deposits have been mined from the Fall River formation in the Hulett Creek area to the end of 1958. In general, the deposits are 5 to 200 feet long, 2 to 80 feet wide, and a few inches to 10 feet thick. They are elongate, in general, parallel to the sandstone lens, and occur at the margins or base of the lens. Five of the deposits consisted of carnotite or tyuyamunite, and three, which were below the local water table, of uraninite and coffinite. The ore minerals coat the sand grains, fill the interstices between sand grains, and impregnate carbonaceous material. Commonly they occur at the base of a sandstone bed just above an impervious clay seam. Associated with some of the ore deposits are

carbonate-cemented sandstone concretions and concretionary beds; fragments of carbonized wood are abundant in the ore-bearing sandstone. Total production from the Hulett Creek area to January 1, 1958, was about 15,000 tons of ore containing 0.24 percent U_3O_8.

ELKHORN CREEK

In 1958, three mines had been developed near the top of the Fall River formation in the Elkhorn Creek area in the SW¼ and NW¼ sec. 26 and the SE¼ of sec. 34, T. 56 N., R. 66 W., Crook County, Wyo. (Davis and Izett, 1962). Two of the deposits occur near the west end of a large east-trending sandstone lens about 2 miles long, 1,500 feet wide, and 30 to 60 feet thick; and the third deposit is in a northwest-trending sandstone lens about 2,000 feet long, less than 1,000 feet wide, and a maximum of 35 feet thick. Where thick, the lenses are the top bed of the Fall River formation.

The deposits are in the more carbonaceous part of the sandstone lenses, which is near the base above an impervious siltsone or claystone layer. The uranium mineral is mostly coffinite or uraninite, and it is both finely disseminated in the sandstone and concentrated in and around carbonized wood fragments and pyrite concretions. Part of the top of one deposit was oxidized, and the uranium minerals carnotite and tyuyamunite occur in small lenses or pods along carbonaceous layers and coat the surfaces of joints in the oxidized zone.

The two larger deposits are on the south and west flanks of a northeast-trending anticline and the third on the northeast flank of a northwest-trending anticlinal nose. Controls for emplacement of the ore were probably mainly stratigraphic and lithologic, although the folds may have played some part in channeling or impounding the mineralizing solutions.

Production from the Elkhorn Creek area had amounted to about 17,000 tons of ore containing 0.2 percent U_3O_8 to January 1, 1958.

BENTONITE

The bentonite deposits of the Black Hills region of Wyoming and South Dakota are the major source of bentonite in the United States. Gunsallus and Russ (1955) reported that in 1952 the Wyoming-South Dakota district produced 898,787 short tons of bentonite valued at $11,722,491, or a total of 63 percent of the bentonite sold or used by producers during that year. Most of this production is from the Black Hills region. Recent reports on the geology and technology of the bentonite deposits of the Black Hills include reports by Knechtel and Patterson (1955; 1962) on the northern Black Hills bentonite district, Wing (1940) on the Belle Fourche district, South Dakota, and Heatham (1939) on bentonite in Wyoming.

Bentonite, both in relatively pure beds and as an ingredient of the shales, is found in all the marine Cretaceous rocks throughout the mapped area except for the Fox Hills sandstone, the youngest of the marine Cretaceous formations. Most of the commercial deposits, however, occur in beds near the base of the Belle Fourche shale, at the top of the Mowry shale and in the Newcastle standstone. The following table gives a summary description of the principal beds:

Description of the principal bentonite beds in the northern part of the Black Hills, Wyoming, Montana, and South Dakota

[Modified, in part, after Knechtel and Patterson (1955)]

Stratigraphic position	Bed	Thickness (feet)	Character of bed	Distribution
Pierre shale:				
Base of Mitten black shale member	I, Pedro, or Ardmore.	1–30	Nonswelling bentonite at most places; swelling at Pedro and vicinity.	Northern Butte County, S. Dak., and northwestern Crook County, Wyo.; central Weston County, Wyo.
About 75 ft below top of Gammon ferruginous member.	H	1– 2	Impure bentonite containing 50 to 75 percent nonclay constituents.	Northwestern Crook County, Wyo., and southern Carter County, Mont.
Greenhorn formation or Belle Fourche shale.	G	3– 6	Nonswelling bentonite with as much as 30 percent nonclay constituents.	In South Dakota, 50 to 60 ft above top of Belle Fourche shale; in Wyoming 40 to 50 ft below top of Belle Fourche shale. Exposed locally in northern half of mapped area and in vicinity of Upton in southern part.
Belle Fourche shale:				
350 to 500 ft above base	Gray-red or F	1– 7	Iron-stained gray bentonite. Locally of good quality.	Throughout mapped area.
20 to 30 ft above base	E	1– 5	Impure bentonite containing more than 20 percent nonclay constituents.	Do.
1 to 4 ft above base	D	¼– 1	Highly dilatant bentonite of good quality	Do.
Mowry shale:				
At top	Clay-Spur	1– 7	Chief source of high-quality bentonite in United States.	Do.
30 to 35 ft below top	B	½– 1½	Low dilatant bentonite; too thin for mining	Do.
Newcastle sandstone, upper part	A	1– 8	Highly dilatant bentonite of good quality	Stratigraphic position seems to vary, but a bentonite is present near top of Newcastle sandstone at most outcrops; 30 ft thick in auger hole in sec. 6, T. 52 N., R. 62 W. (Knechtel and Patterson, 1955).

Bentonite pits, or mines, are not shown on the geologic map (pl. 1) because at most places they are too numerous to be plotted at the map scale. The principal mining areas are along the Belle Fourche-Mowry contact from Alzada, Mont., southeastward to the eastern margin of the map; around the Colony, Shepard, and Chicago Creek anticlines; along the north side of the Little Missouri River from Alzada, Mont. to the southeast corner of T. 56 N., R. 67 W.; in T. 54 N., R. 67 W.; and from near Thornton in T. 49 N., R. 65 W. to the vicinity of Osage in T. 47 N., R. 63 W.

The two following sections show the unusually thick bentonite bed in the basal part of the Mitten black shale member of the Pierre shale near Pedro and southeast of Upton, Weston County, Wyo.

Bentonite beds at about the base of the Mitten black shale member of the Pierre shale in a stream bank in the SW¼SW¼ sec. 32, T. 47 N., R. 64 W., Weston County, Wyo.

Mitten black shale member (part):	Feet
9. Shale, brownish-gray, hard, platy; much organic material on bedding surfaces	18
8. Shale, brown, much yellow stain, soft and powdery	10
7. Shale, dark-gray, bentonitic	2.3
6. Bentonite, light grayish-brown, silty	2.8
5. Bentonite, greenish-gray to light yellowish-gray	1.3
4. Shale, grayish-green, sandy, bentonitic; many flakes of biotite	.8
3. Bentonite, light-gray to light yellowish-gray, slightly swelling; a seam 0.5 ft thick of a colorless granular mineral 2.3 ft above base	5.8
2. Shale, black, hard	.01
1. Bentonite, light-gray to light yellowish-gray, slightly swelling; base not exposed	3.4
Partial thickness (rounded) of Mitten black shale member	44
Aggregate thickness of bentonite	13.3

Base of the exposure.

Bentonite beds at the base of the Mitten black shale member 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, 1958]

Pierre shale (part):	Feet
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

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

Pierre shale (part)—Continued	Feet
Mitten black shale member (part)—Continued	
39. Bentonite and shale, interlaminated: laminae are about 2 mm thick	2.0
38. Bentonite, cream; a few thin partings of black shale	3.6
37. Shale, gray, silicified	.4
36. Bentonite, light-yellow, clayey, nonswelling	.2
35. Shale, dark gray-brown, organic-rich, hard	1.6
34. Bentonite, light-yellow, nonswelling	.3
33. Shale, dark-gray, organic-rich, hard	5.0
32. Bentonite, light-yellow, nonswelling	.2
31. Shale, dark gray-brown, organic-rich, hard	.2
30. Bentonite, orange, nonswelling	.1
29. Shale, dark-gray, hard	2.6
28. Bentonite, cream to orange; rests sharply on underlying unit; grades upward into overlying unit	.8
27. Shale, dark-gray, soft; partings of bentonite; jarosite on bedding planes; silicified in upper 3 ft	3.4
26. Bentonite, tan, clayey; 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, cream to light-yellow, nonswelling	2.8
19. Shale, dark gray-brown, organic-rich, hard; silicified in bottom 0.3 ft	.5
18. Bentonite, orange, nonswelling	.1
17. Shale, dark gray-brown, organic-rich; many thin partings of bentonite	2.5
16. Bentonite, cream to light-yellow, nonswelling	.3
15. Shale, dark gray-brown, organic-rich, 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, organic-rich, hard	1.4

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

	Feet	
Pierre shale (part)—Continued		
Mitten black shale member (part)—Con.		
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; relic outlines of shards plainly visible in thin sections; X-ray analysis shows a mixture of nonswelling clays and clinoptilolite (L. G. Schultz, analyst)	5.9	
Bentonite, pale greenish-gray, swelling; fairly abundant flakes of biotite; hard clay concretions in upper part 0.2 to 0.8 ft in diameter	1.4	
Shale, dark reddish-brown, hard; seams of clinoptilolite at top and base (L. G. Schultz, analyst)	.5	
Bentonite, pale greenish-gray, swelling; fairly abundant flakes of biotite; about 12 ft above base a very hard light-gray bed of bentonite 1.3 ft thick	19.5	
Thickness of Pedro bentonite bed		30.3
Partial thickness (rounded) of 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

COAL

Commercially important beds of low-rank subbituminous coal or lignite occur in the western part of the area in the Wasatch formation and the underlying Tongue River member of the Fort Union formation, and beds of bituminous coal occur at several places in the eastern part of the area near the base of the Lakota formation. The Wyodak Coal Co. mine near Gillette, where coal is produced from a bed at the base of the Wasatch formation, was the only mine active in 1954 and 1955. Fairly large amounts of coal were once produced from other mines near Gillette and from mines near Cambria and Aladdin; all of these mines have been abandoned since about 1930.

Several earlier publications of the U.S. Geological Survey give information on the coal resources of various parts of the mapped area, including reports by Stone and Lupton (1910) on the Powder River coal field, by Davis (1912) on the Little Powder River coal field, by Dobbin and Barnett (1927) on the Gillette coal field (including a chapter by Thom on the Minturn district), by Darton (1905b) and Stone (1912) on areas near Aladdin, Sundance, Skull Creek, and Cambria, and by Berryhill and others (1950) on the coal resources of Wyoming. Chemical analyses of the coal at various places in the area and in nearby areas can be found in the reports cited above. Berryhill and others (1950, p. 60–61) estimated the original reserves of subbituminous coal in the Fort Union and Wasatch formations in Tps. 50 to 58 N., Rs. 70 and 71 W., Campbell County, Wyo., at about 8,700 million short tons, and they estimated (1950, p. 57, 59) the original reserves of bituminous coal in the Lakota formation at various places in Weston and Crook Counties, Wyo., at about 41 million short tons.

The following summary is based largely on the earlier reports.

COAL IN THE WASATCH FORMATION

The basal bed of the Wasatch formation, as mapped during the present investigation, is a coal bed ranging in thickness from about 30 to 90 feet. This coal was called the D bed by Dobbin and Barnett (1927, p. 14) in the Gillette coal field, and the C bed by Davis (1912, p. 428) in the Little Powder River coal field. It was correlated by these writers and by Thom (1927) with the Roland coal bed of the Sheridan coal field (Taff, 1909, p. 142). The coal is extensively burned along its outcrop, and the resulting heat has produced conspicuous masses of red clinker 50 or more feet thick that cap divides and buttes along the western edge of the mapped area in Campbell County, Wyo., and Powder River County, Mont.

The so-called Roland bed is exposed in the Gillette coal field at the Wyodak Coal Co. mine east of Gillette in the NE¼ sec. 28, T. 50 N., R. 71 W., in an open pit about 120 feet deep and several hundred feet long. Here the coal is slightly more than 90 feet thick. Dobbin and Barnett (1927, p. 16) and Thom (1927, p. 58) suggested that the great thickness of coal at this locality resulted from merging of the Roland with the Smith bed, a coal that elsewhere lies 30 to about 90 feet stratigraphically below the Roland bed. According to Thom (1927, p. 60–61), drill holes show the Roland bed to be about 60 feet thick at Gillette.

About 15 miles north of Gillette, in the NE¼ sec. 10, T. 51 N., R. 72 W., four drill holes reportedly found from 85 to 95 feet of coal at the horizon of the Roland bed.[3] A pit dug in the Roland bed in the SW¼NE¼ sec. 3, T. 52 N., R. 72 W., shows the coal to be at least 30 feet thick, without partings, and a seismograph shothole drilled within a few feet of the pit reportedly penetrated coal through an additional 8 to 10 feet.

[3] Control of coal crop fire at Moyer Gulch, Gillette, Campbell County, Wyo., 1951, unpub. rep. of the U.S. Bur. Mines on file at the U.S. Bur. Mines office, Billings, Mont.

COAL IN THE TONGUE RIVER MEMBER OF THE FORT UNION FORMATION

Low-rank subbituminous coal crops out at several horizons in the Tongue River member of the Fort Union formation. Six beds with maximum observed thicknesses ranging from 4 to 16 feet have been described by Davis (1912) in various parts of Tps. 53 to 58 N., Rs. 71 and 72 W., Campbell County, Wyo., as shown by the following table:

Maximum observed thicknesses of some coal beds in the eastern part of the Little Powder River coal field and the average distances between them

[Adopted from Davis, 1912, p. 428–429]

	Thickness of bed, feet	*Interval, feet*
Bed C (base of the Wasatch formation of this report).		
Interval	----	110
Bed D (may not be present in eastern part of the Little Powder River coal field)	----	---
Interval	----	55
Bed E	16	---
Interval	----	20
Bed F	15	---
Interval	----	55
Bed G	4	---
Interval	----	110
Bed H	14	---
Interval	----	20
Bed I	4	---
Interval	----	100
Bed J	13	---
Interval to base Tongue River member Fort Union formation	----	300+

Some of the coal beds have burned locally, and their outcrops are marked by discontinuous bands of clinker.

A coal bed correlated by Thom (1927, p. 57) with the Smith coal bed of the Sheridan coal field is reported by Thom (1927, p. 61) to be from 22 to 35 feet thick in two water wells drilled at Gillette in the SW¼ sec. 22, T. 50 N., R. 72 W. The top of this bed is as much as 90 feet below the base of the Wasatch formation as mapped during the present investigation.

The coal in the Tongue River member of the Fort Union formation has not been mined except for small amounts dug out by local ranchers for their private use.

COAL IN THE LAKOTA FORMATION

A coal bed as much as 10 feet thick occurs in the lower part of the Lakota formation at Cambria in Weston County, Wyo., and thinner coal beds crop out in the lower part of the formation at a few places north of Cambria in northern Weston and southern Crook Counties, and near Aladdin in northern Crook County, Wyo. The coal is interbedded with carbonaceous siltstone and shale in relatively persistent carbonaceous zones that extend over large areas. The coal beds themselves, however, are lenticular, and no individual bed has been traced for any great distance. Stone (1912, p. 18) stated that the coal locally is a bituminous coking grade but that it varies from place to place and in different levels in the same bed. Noncoking bituminous, cannel, splint, and "pine needle" coal are found in addition to coking coal.

According to Stone (1912, p. 33), the thickest and most extensive deposits are at Cambria in T. 46 N., Rs. 61 and 62, W., where a coal bed under the divide between Cambria and Camp Canyon ranged mostly from 3 to 10 feet in thickness. Connolly and O'Harra (1929, p. 383) stated that in a late period in the history of the mines, an area of about 200 acres was found in which the thickness of coal ranged from 8 to 18 feet. The main coal horizon is 40 to 60 feet above the base of the Lakota formation at Cambria. The mines supplied coal for the Chicago, Burlington and Quincy Railroad and some coke was produced for smelters in the northern Black Hills. Berryhill and others (1950, p. 11) estimated the original coal reserves at Cambria at about 36 million short tons of which about 10.5 tons had been mined to 1950, and perhaps an equal amount lost in mining. The mines were abandoned in 1928.

A lenticular coal bed as much as 6½ feet thick crops out near the head of Skull Creek in sec. 31, T. 48 N., R. 62 W., at the same horizon as the coal bed at Cambria. Stone (1912, p. 22, 24, 30) reported other outcrops of coal in the lower part of the Lakota in Berry Canyon, sec. 12, T. 47 N., R. 63 W.; north of Mason Creek, sec. 29, T. 49 N., R. 63 W.; and on Coal Divide, sec. 10, T. 50 N., R. 64 W. The maximum thickness of coal at any of these outcrops is about 4 feet.

At Aladdin and along the valley of Hay Creek in secs. 27 and 28, T. 54 N., R. 61 W., soft bituminous coal is found in two beds about 10 to 20 feet apart. The lower bed is 3 to 5 feet thick, and the upper bed about 2 feet thick (Stone, 1912, p. 18). A total original reserve of about 0.6 million short tons of coal was estimated by Berryhill and others (1950, p. 57) for the area near Aladdin.

ROAD METAL AND RIPRAP

Sand and gravel from terrace and alluvial deposits, clinker, and shale from the Mowry shale are used for surfacing roads in the mapped area. Small terrace deposits border most of the major streams and furnish most of the road metal. They are small in areal extent, however, and rarely more than 5 to 10 feet thick, so that at most places large amounts of gravel cannot be obtained from any single deposit.

Clinker, the fused sandstone and shale that results from the burning of a coal bed under shallow cover, is widely used as road metal throughout Campbell County, Wyo. The so-called Roland coal bed at the base of the Wasatch formation is burned along its outcrop for distances of several miles leaving deposits of clinker as much as 50 feet thick. Some clinker is also available as the result of the burning of coal beds in the Tongue River member of the Fort Union formation.

The Mowry shale is widely used throughout Crook and Weston Counties, Wyo., for surfacing County roads. This shale, being siliceous and hard, makes an excellent all-weather surface.

Riprap for facing the dam at Keyhole Reservoir on the Belle Fourche River in southern Crook County was obtained from the talus apron around Missouri Buttes in sec. 4, T. 53 N., R. 66 W. Locally, concretionary limestone beds in the Pierre shale are used for riprap on small stock reservoirs.

REFERENCES CITED

Am. Assoc. of Petroleum Geologists, 1944, Tectonic map of the United States: Am. Assoc. Petroleum Geologists, Tulsa, Okla.

Andrichuk, J. M., 1955, Mississippian Madison group stratigraphy and sedimentation in Wyoming and southern Montana: Am. Assoc. Petroleum Geologists Bull., v. 39, no. 11, p. 2170–2210.

Baker, D. R., 1962, The Newcastle Formation in Weston County, Wyoming: a nonmarine (alluvial plain) deposit, *in* Wyoming Geol. Assoc. Guidebook, 17th Ann. Field Conf., Symposium on Early Cretaceous rocks, Wyoming and adjacent areas: p. 148–162.

Barnett, V. H., 1915, The Moorcroft oil field, Crook County, Wyoming: U.S. Geol. Survey Bull. 581–C, p. 83–104.

Bergendahl, M. H., Davis, R. E., and Izett, G. A., 1961, Geology and mineral deposits of the Carlile quadrangle, Crook County, Wyoming: U.S. Geol. Survey Bull. 1082–J, p. 613–706.

Berryhill, H. L., Jr., Brown, D. M., Brown, Andrew, and Taylor, D. A., 1950, Coal resources of Wyoming: U.S. Geol. Survey Circ. 81, 28 p.

Biggs, Paul, and Espach, R. H., 1960, Petroleum and natural gas fields in Wyoming: U.S. Bur. Mines Bull. 582, 538 p.

Bowles, C. G., and Wolcott, D. E., 1958, Solution and brecciation of the Minnelusa formation, *in* Geologic investigations of radioactive deposits-Semiannual progress report, June 1 to Nov. 30, 1958: U.S. Geol. Survey TEI–750, p. 37–72, issued by U.S. Atomic Energy Comm. Tech. Inf. Service, Oak Ridge, Tenn.

Brady, F. H., 1931, Minnelusa formation of Beulah district, northwestern Black Hills, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 15, no. 2, p. 183–188.

——— 1958, Evaporite deposits in the Minnelusa formation in the Sundance-Beulah area, Crook County, Wyoming, *in* Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin: p. 45–47.

Brobst, D. A., and Epstein, J. B., 1963, Geology of the Fanny Peak quadrangle, Wyoming and South Dakota: U.S. Geol. Survey Bull. 1063–I.

Brown, R. W., 1948, Correlation of Sentinel Butte shale in western North Dakota: Am. Assoc. Petroleum Geologists Bull., v. 32, no. 7, p. 1265–1274.

——— 1952, Tertiary strata in eastern Montana and western North and South Dakota, *in* Billings Geol. Soc. Guidebook 3d Ann. Field Conf., Black Hills-Williston Basin; p. 89–92.

Burk, C. A., and Thomas, H. D., 1956, The Goose Egg formation (Permo-Triassic) of eastern Wyoming: Wyoming Geol. Survey Rept. Inv. 6, 11 p.

Carey, B. D., Jr., 1954, A brief sketch of the geology of the Rattlesnake Hills, *in* Wyoming Geol. Assoc. Guidebook 9th Ann. Field Conf., Casper area; p. 32–34.

Carlson, C. G., 1958, The stratigraphy of the Deadwood-Winnipeg interval in North Dakota and northwestern South Dakota, *in* Saskatchewan Geol. Soc.–N. Dak. Geol. Soc. 2d Williston Basin Symposium; p. 20–26.

Chamberlin, R. T., 1945, Basement control in Rocky Mountain deformation: Am. Jour. Sci., v. 243–A, p. 98–116.

Cobban, W. A., 1951, Colorado shale of central and northwestern Montana and equivalent rocks of the Black Hills: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 10, p. 2170–2198.

——— 1952, Cretaceous rocks on the north flank of the Black Hills uplift, *in* Billings Geol. Soc. Guidebook 3d Ann. Field Conf., Black Hills-Williston Basin; p. 86–88.

——— 1958, Late Cretaceous fossil zones of the Powder River Basin, Wyoming and Montana, *in* Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin, Wyoming; p. 114–119.

Cobban, W. A., and Reeside, J. B., Jr., 1952, Correlation of the Cretaceous formations of the western interior of the United States: Geol. Soc. America Bull., v. 63, no. 10, p. 1011–1044.

Collier, A. J., 1922, The Osage oil field, Weston County, Wyoming: U.S. Geol. Survey Bull. 736–D, p. 71–110.

Connolly, J. P., and O'Harra, C. C., 1929, The mineral wealth of the Black Hills: South Dakota School Mines Bull. 16, 418 p.

Crowley, A. J., 1951, Possible Lower Cretaceous uplifting of Black Hills, Wyoming and South Dakota: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 1, p. 83–90.

Darton, N. H., 1901, Preliminary description of the geology and water resources of the southern half of the Black Hills and adjoining regions in South Dakota and Wyoming: U.S. Geol. Survey 21st Ann. Rept., pt. 4, p. 489–599.

——— 1904, Description of the Newcastle quadrangle, Wyoming and South Dakota: U.S. Geol. Survey Geol. Atlas, Folio 107, 9 p.

——— 1905a, Description of the Sundance quadrangle, Wyoming and South Dakota: U.S. Geol. Survey Geol. Atlas, Folio 127, 12 p.

———1905b, The coal of the Black Hills, Wyoming: U.S. Geol. Survey Bull. 260, p. 429–433.

——— 1909, Geology and water resources of the northern portion of the Black Hills and adjoining regions in South Dakota and Wyoming: U.S. Geol. Survey Prof. Paper 65, 105 p.

Darton, N. H., and O'Harra, C. C., 1905, Description of the Aladdin quadrangle, Wyoming, South Dakota, and Montana: U.S. Geol. Survey Geol. Atlas, Folio 128, 8 p.

——— 1907, Description of the Devils Tower quadrangle, Wyoming: U.S. Geol. Survey Geol. Atlas, Folio 150, 9 p.

Darton, N. H., and O'Harra, C. C., 1909, Description of the Belle Fourche quadrangle, South Dakota: U.S. Geol. Survey Geol. Atlas, Folio 164, 9 p.

Darton, N. H., and Paige, Sidney, 1925, Description of the central Black Hills, South Dakota: U.S. Geol. Survey Geol. Atlas, Folio 219, 34 p.

Darton, N. H., and Smith, W. S. T., 1904, Description of the Edgemont quadrangle, South Dakota and Nebraska: U.S. Geol. Survey Geol. Atlas, Folio 108, 10 p.

Davis, J. A., 1912, The Little Powder River coal field, Campbell County, Wyoming: U.S. Geol. Survey Bull. 471–F, p. 423–440.

Davis, R. E., and Izett, G. A., 1958, Keyhole sandstone member of Fall River formation, northern Black Hills, Wyoming and South Dakota: Am. Assoc. Petroleum Geologists Bull., v. 42, no. 11, p. 2745–2750.

——— 1962, Geology and uranium deposits of the Strawberry Hill quadrangle, Wyoming: U.S. Geol. Survey Bull. 1127, 87 p.

Denson, N. M., and Botinelly, Theodore, 1949, Geology of the Hartville uplift, eastern Wyoming: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 102.

Dobbin, C. E., and Barnett, V. H., 1927, The Gillette coal field, northeastern Wyoming: U.S. Geol. Survey Bull. 796–A, p. 1–50.

Dobbin, C. E., and Horn, G. H., 1949, Geology of the Mush Creek and Osage oil fields and vicinity, Wyoming: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 103.

Dobbin, C. E., Kramer, W. B., and Horn, G. H., 1957, Geologic and structure map of the southeastern part of the Powder River Basin: U.S. Geol. Survey Oil and Gas Inv. Map OM–185.

Dobbin, C. E., and Larsen, R. M., 1935, Geologic and structure-contour map of the southern half of the Cedar Creek anticline, Fallon County, Montana, and Bowman County, North Dakota: U.S. Geol. Survey Press Release 94227.

Dobbin, C. E., Miller, J. C., and Walter, K. L., 1935, Geologic and structure contour map of the Osage oil field, Weston County, Wyoming: U.S. Geol. Survey Press Release 109045.

Dobbin, C. E., and Reeside, J. B., Jr., 1929, The contact of the Fox Hills and Lance formations: U.S. Geol. Survey Prof. Paper 158–B, p. 9–25.

Eicher, D. L., 1958, The Thermopolis shale in eastern Wyoming, *in* Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin; p. 79–83.

Eldridge, G. H., 1896, Mesozoic geology, *in* Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver Basin in Colorado: U. S. Geol. Survey Mon. 27, p. 51–150.

Erdmann, C. E., and Larsen, R. M., 1935, Geologic and structure map of the northern half of the Cedar Creek anticline, Dawson, Prairie, Wibaux, and Fallon Counties, Montana: U.S. Geol. Survey Press Release 94227.

Foster, D. I., 1958, Summary of the stratigraphy of the Minnelusa formation, Powder River Basin, Wyoming, *in* Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin: p. 39–44.

Furnish, W. M., Barragy, E. J., and Miller, A. K., 1936, Ordovician fossils from upper part of type section of Deadwood formation, South Dakota: Am. Assoc. Petroleum Geologists Bull., v. 20, no. 10, p. 1329–1341.

Gill, J. R., and Cobban, W. A., 1961, Stratigraphy of lower and middle parts of the Pierre Shale, northern Great Plains, *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 424–D, p. D185–D191.

Gill, J. R., and Cobban, W. A., 1962, Red Bird Silty Member of the Pierre Shale, a new stratigraphic unit, *in* Short papers in geology, hydrology, and topography: U.S. Geol. Survey Prof. Paper 450–B, p. B21–B24.

Goodman, A. J., 1951, White specks in Colorado shale: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 11, p. 2427–2429.

Grace, R. M., 1952, Stratigraphy of the Newcastle formation, Black Hills region, Wyoming and South Dakota: Wyoming Geol. Survey Bull. 44, 44 p.

Gries, J. P., 1952, Paleozoic stratigraphy of western South Dakota, *in* Billings Geol. Soc. Guidebook 3d Ann. Field Conf., Black Hills-Williston Basin: p. 70–72.

Gunsallus, B. L., and Russ, B. V., 1955, Clays, *in* Minerals Yearbook 1952: U.S. Bur. Mines, v. 1, p. 295–314.

Hancock, E. T., 1920a, The Upton-Thornton oil field, Wyoming: U.S. Geol. Survey Bull. 716–B, p. 17–34.

——— 1920b, The Mule Creek oil field, Wyoming: U.S. Geol. Survey Bull. 716–C, p. 35–53.

Harder, J. O., 1955, Black Hills uranium deposits: Nuclear Eng. and Sci. Cong., Am. Inst. Chem. Engineers, Preprint 282, p. 1–9.

Hares, C. J., and others, 1946, Geologic map of the southeastern part of the Wind River Basin and adjacent areas in central Wyoming: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 51.

Haun, J. D., 1958, Early Cretaceous stratigraphy, Powder River Basin, Wyoming, *in* Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin: p. 84–89.

Heathman, J. H., 1939, Bentonite in Wyoming: Wyoming Geol. Survey Bull. 28, 20 p.

Hose, R. K., 1954, Geology of the Crazy Woman Creek area, Johnson County, Wyoming: U.S. Geol. Survey Oil and Gas Inv. Map OM–142.

Imlay, R. W., 1947, Marine Jurassic of Black Hills area, South Dakota and Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 31, no. 2, p. 227–273.

——— 1952, Marine origin of Preuss sandstone, Idaho, Wyoming, and Utah: Am. Assoc. Petroleum Geologists Bull., v. 36, no. 9, p. 1735–1753.

——— 1957, Paleoecology of Jurassic seas in the western interior of the United States, *in* Treatise on marine ecology and paleoecology, v. 2, Paleoecology: Geol. Soc. America Mem. 67, p. 469–504.

Izett, G. A., 1963, Geology of the Storm Hill quadrangle, Crook County, Wyoming: U.S. Geol. Survey Misc. Inv. Map I–372.

Izett, G. A., Pillmore, C. L., and Mapel, W. J., 1961, Evidence for Early Cretaceous folding in the Black Hills, Wyoming, *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 424–B, p. B156–B158.

Jenney, W. P., 1899, Field observations in the Hay Creek coal field, *in* Ward, L. F., The Cretaceous formation of the Black Hills as indicated by the fossil plants: U.S. Geol. Survey 19th Ann. Rept., pt. 2-e, p. 568–593.

Kepferle, R. C., 1959, Uranium in Sharon Springs member of Pierre shale, South Dakota and northeastern Nebraska: U.S. Geol. Survey Bull. 1046–R, p. 577–604.

Knechtel, M. M., and Patterson, S. H., 1955, Bentonite deposits of the northern Black Hills district, Montana, Wyoming, and South Dakota: U.S. Geol. Survey Mineral Inv. Map MF–36.

——— 1962, Bentonite deposits of the northern Black Hills district, Wyoming, Montana, and South Dakota: U.S. Geol. Survey Bull. 1082–M, p. 893–1030.

Longwell, C. R., and Rubey, W.W., 1923, Possibilities of finding oil in deep sands near the Osage field, Wyoming: U.S. Geol. Survey Press Releases 15869 and 120950.

Love, J. D., Tourtelot, H. A., Johnson, C. O., Sharkey, H. H. R., Thompson, R. M., Zapp, A. D., and Nace, H. L., 1945, Stratigraphic sections and thickness maps of Jurassic rocks in central Wyoming: U.S. Geol. Survey Oil and Gas Inv. Prelim. Chart 14.

MacKenzie, D. B., and Poole, D. M., 1962, Provenance of Dakota group sandstones of the Western Interior, *in* Wyoming Geol. Assoc. Guidebook, 17th Ann. Field Conf., Symposium on Early Cretaceous rocks, Wyoming and adjacent areas: p. 62–71.

Mapel, W. J., and Bergendahl, M. H., 1956, Gypsum Spring formation, northwestern Black Hills, Wyoming and South Dakota: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 1, p. 84–93.

Mapel, W. J., Chisholm, W. A., and Bergenback, R. E., 1964, Nonopaque heavy minerals in sandstone of Jurassic and Cretaceous age in the Black Hills, Wyoming and South Dakota: U.S. Geol. Survey Bull. 1161–C, p. C1–C59.

Mapel, W. J., and Gott, G. B., 1959, Diagrammatic restored section of the Inyan Kara group, Morrison formation, and Unkpapa sandstone on the western side of the Black Hills, Wyoming and South Dakota: U.S. Geol. Survey Mineral Inv. Map MF–128.

Mapel, W. J., and Pillmore, C. L., 1962, Stream directions in the Lakota formation (Cretaceous) in the northern Black Hills, Wyoming and South Dakota, *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 450–B, p. B35–B37.

——— 1963a, Geology of the Inyan Kara Mountain quadrangle, Crook and Weston Counties, Wyoming: U.S. Geol. Survey Bull. 1121–M, p. M1–M56.

——— 1963b, Stratigraphic sections and correlation of beds in the Inyan Kara Group and Morrison Formation, north end of the Black Hills, Crook County, Wyoming, and Butte County, South Dakota: U.S. Geol. Survey Open File Rept., 95 p.

——— 1963c, Geology of the Newcastle area, Weston County, Wyoming: U.S. Geol. Survey Bull. 1141–N, p. N1–N85.

Mapel, W. J., Robinson, C. S., and Theobald, P. K., 1959, Geologic and structure contour map of the northern and western flanks of the Black Hills, Wyoming, Montana, and South Dakota: U.S. Geol. Survey Oil and Gas Inv. Map OM–191.

Moore, R. C., 1949, Meaning of facies, *in* Longwell, C. R., Sedimentary facies in geologic history: Geol. Soc. America Mem. 39, p. 1–39.

Noble, J. A., 1952, Structural features of the Black Hills and adjacent area developed since Precambrian time, *in* Billings Geol. Soc. Guidebook, 3d Ann. Field Conf., Black Hills-Williston Basin; p. 31–37.

Noble, J. A., Harder, J. O., and Slaughter, A. L., 1949, Structure of a part of the northern Black Hills and the Homestake mine, Lead, South Dakota; Geol. Soc. America Bull., v. 60, p. 321–352.

Olive, W. W., 1957, The Spotted Horse coal field, Sheridan and Campbell Counties, Wyoming: U.S. Geol. Survey Bull. 1050, 83 p.

Peck, R. E., 1957, North American Mesozoic Charophyta: U.S. Geol. Survey Prof. Paper 294–A, p. 1–44.

Peterson, J. A., 1954, Marine Upper Jurassic, eastern Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 38,, no. 4, p. 463–507.

——— 1957, Marine Jurassic of northern Rocky Mountains and Williston Basin: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 3, p. 399–440.

——— 1958, Paleotectonic control of marine Jurassic sedimentation in the Powder River Basin, *in* Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin, 1958: p. 56–63.

Petroleum Information, 1960, Thirtieth annual résumé, Rocky Mountain oil and gas operations for 1959; Petroleum Information, Denver, Colorado.

Petsch, B. C., 1949, North part of the Whitewood anticline, South Dakota: South Dakota Geol. Survey Rept. Inv. 65, 30 p.

Pillmore, C. L., and Mapel, W. J., 1963, Geology of the Nefsy Divide quadrangle, Crook County, Wyoming: U.S. Geol. Survey Bull. 1121–E, p. E1–E52.

Post, E. V., and Bell, Henry, III, 1961, Chilson member of the Lakota formation in the Black Hills, South Dakota and Wyoming; *in* Short papers in the geologic and hydrologic sciences: U.S. Geol. Survey Prof. Paper 424–D, p. D173–D178.

Privrasky, N. C., Strecker, J. R., Grieshaber, C. E., and Byrne, Frank, 1958, Preliminary report on the Goose Egg and Chugwater formations in the Powder River Basin, Wyoming, *in* Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin: p. 48–55.

Reeside, J. B., Jr., 1952, Summary of the stratigraphy of the Morrison formation, *in* Yen, T. C., Molluscan fauna of the Morrison formation: U.S. Geol. Survey Prof. Paper 233–B, p. 22–26.

Reeside, J. B., Jr., and Cobban, W. A., 1960, Studies of the Mowry shale (Cretaceous) and contemporary formations in the United States and Canada: U.S. Geol. Survey Prof. Paper 355, 126 p.

Richards, P. W., and Rogers, C. P., Jr., 1951, Geology of the Hardin area, Big Horn and Yellowstone Counties, Montana: U.S. Geol. Survey Oil and Gas Inv. Map OM–111.

Robinson, C. S., 1956, Geology of the Devils Tower National Monument, Wyoming: U.S. Geol. Survey Bull. 1021–I, p. 289–302.

——— 1960, Origin of Devils Tower, Wyoming [abs.]: Geol. Soc. America Bull., v. 71, no. 12, pt. 2, p. 2040.

Robinson, C. S., and Goode, H. D., 1957a, Geology of the uranium deposits of the northern Black Hills, Wyoming: Trans. 60th Natl. Western Mining Conf., v. 1, p. 91–96.

——— 1957b, Preliminary geologic map of the Hulett Creek uranium mining area, Crook County, Wyoming: U.S. Geol. Survey Mineral Inv. Map MF–121.

Robinson, C. S., Mapel, W. J., and Cobban, W. A., 1959, Pierre shale along western and northern flanks of Black Hills, Wyoming and Montana: Am. Assoc. Petroleum Geologists Bull., v. 43, no. 1, p. 101–123.

Robinson, C. S., and Rosholt, J. N., Jr., 1961, Uranium migration and geochemistry of uranium deposits in sandstone above, at, and below the water table; Part II, Relationship of uranium migration dates, geology, and chemistry of the uranium deposits: Econ. Geology, v. 56, no. 8, p. 1404–1420.

Rubey, W. W., 1924, The Rocky Point plunging anticline, Wyoming, U.S. Geol. Survey Press Release 24421.

Rubey, W. W., 1927, Stream piracy in northeastern Wyoming [abs.]: Washington Acad. Sci. Jour., v. 17, p. 120.

——— 1929, Origin of the siliceous Mowry shale of the Black Hills region: U.S. Geol. Survey Prof. Paper 154–D, p. 153–170.

——— 1931, Lithologic studies of fine-grained Upper Cretaceous sedimentary rocks of the Black Hills region: U.S. Geol. Survey Prof. Paper 165–A, p. 1–54.

Russell, W. L., 1928, The origin of artesian pressure: Econ. Geology, v. 23, no. 2, p. 132–157.

Schmitt, G. T., 1953,, Regional stratigraphic analysis of middle and upper marine Jurassic in northern Rocky Mountains-Great Plains: Am. Assoc. Petroleum Geologists Bull., v. 37, no. 2, p. 355–393.

Searight, W. V., 1937, Lithologic stratigraphy of the Pierre formation of the Missouri Valley in South Dakota: South Dakota Geol. Survey Rept. Inv. 27, 63 p.

Skolnick, Herbert, 1958a, Lower Cretaceous Foraminifera of the Black Hills area: Jour. Paleontology, v. 32, no. 2, p. 275–285.

——— 1958b, Stratigraphy of some Lower Cretaceous rocks of the Black Hills area: Am. Assoc. Petroleum Geologists Bull., v. 42, no. 4, p. 787–815.

Sohn, I. G., 1957, Upper Jurassic-Lower Cretaceous Cyprideinae (Ostrocoda) in the Black Hills (abs.): Geol. Soc. America Bull., v. 68, no. 12, pt. 2, p. 1798.

——— 1958, Middle Mesozoic non-marine ostracodes of the Black Hills, *in* Wyoming Geol. Assoc. Guidebook 13th Ann. Field Conf., Powder River Basin: p. 120–126.

Sohn, I. G., and Peck, R. E., 1963, *Theriosyoecum wyomingense* (Branson, 1935), a possible guide ostracode to the Salt Wash member of the Morrison formation: U.S. Geol. Survey Bull. 1161–A, p. A1–A10.

Spivey, R. C., 1940, Bentonite in southwestern South Dakota: South Dakota Geol. Survey Rept. Inv., no. 36, 56 p.

Stevenson, R. E., 1952, Structures and stratigraphy of southwestern Butte County [South Dakota]: South Dakota Geol. Survey Rept. Inv. 69, 32 p.

Stone, R. W., 1912, Coal near the Black Hills, Wyoming-South Dakota: U.S. Geol. Survey Bull. 499, 66 p.

Stone, R. W., and Lupton, C. T., 1910, The Powder River coalfield, Wyoming, adjacent to the Burlington Railroad: U.S. Geol. Survey Bull. 381–B, p. 115–136.

Summerford, H. E., Schieck, E. E., and Hiestand, T. C., 1950, Oil and gas accumulation controlled by sedimentary facies in Upper Cretaceous Newcastle sandstone, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 34, no. 9, p. 1850–1865.

Taff, J. A., 1909, The Sheridan coal field, Wyoming: U.S. Geol. Survey Bull. 341–B, p. 123–150.

Tank, R. W., 1956, Clay mineralogy of Morrison formation, Black Hills area, Wyoming, and South Dakota: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 5, p. 871–878.

Thom, W. T., Jr., 1927, The Minturn district and the northwestern part of the Gillette field, *in* Dobbin and Barnett, The Gillette coal field, northeastern Wyoming: U.S. Geol. Survey Bull. 796–A, p. 50–64.

Thom, W. T., Jr., and Dobbin, C. E., 1924, Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. America Bull., v. 35, no. 3, p. 481–505.

Thom, W. T., Jr., and Spieker, E. M., 1931, The significance of geologic conditions in Naval Petroleum Reserve No. 3, Wyoming: U. S. Geol. Survey Prof. Paper 163, 64 p.

Waagé, K. M., 1959, Stratigraphy of the Inyan Kara group in the Black Hills: U.S. Geol. Survey Bull. 1081–B, p. 11–90.

Ward, L. F., 1894, The Cretaceous rim of the Black Hills: Jour. Geology, v. 2, p. 250–266.

——— 1899, The Cretaceous formation of the Black Hills as indicated by the fossil plants: U.S. Geol. Survey 19th Ann. Rept., pt. 2, p. 521–946.

Wells, R. C., 1937, Analyses of rocks and minerals from the laboratory of the United States Geological Survey 1914–1936: U.S. Geol. Survey Bull. 878, 134 p.

Wenger, W. J., and Reid, B. W., 1958, Characteristics of petroleum in the Powder River Basin, *in* Wyoming Geol. Assoc. Guidebook, 13th Ann. Field Conf., Powder River Basin: p. 148–156.

Wing, M. E., 1940, Bentonites of the Belle Fourche district: South Dakota Geol. Survey Rept. Inv. 35, 29 p.

Wyoming Geological Association Nomenclature Committee, 1956, Wyoming Stratigraphy, part 1, subsurface stratigraphy of the pre-Niobrara formations in Wyoming: Wyoming Geol. Assoc., Casper, Wyo.

Wyoming Geological Association Symposium Committee, 1957, Wyoming oil and gas fields symposium: Wyoming Geol. Assoc., Casper, Wyo., 484 p.

——— 1961, Wyoming oil and gas fields symposium, supplement 1: Wyoming Geol. Assoc., Casper, Wyo., p. 489–579.

Yen, Teng-Chien, 1952, Molluscan fauna of the Morrison formation: U. S. Geol. Survey Prof. Paper 233–B, p. 21–51.

Zapp, A. D., and Cobban, W. A., 1962, Some Late Cretaceous strand lines in southern Wyoming, *in* Short papers in geology, hydrology, and topography: U.S. Geol. Survey Prof. Paper 450–D, p. D52–D55.

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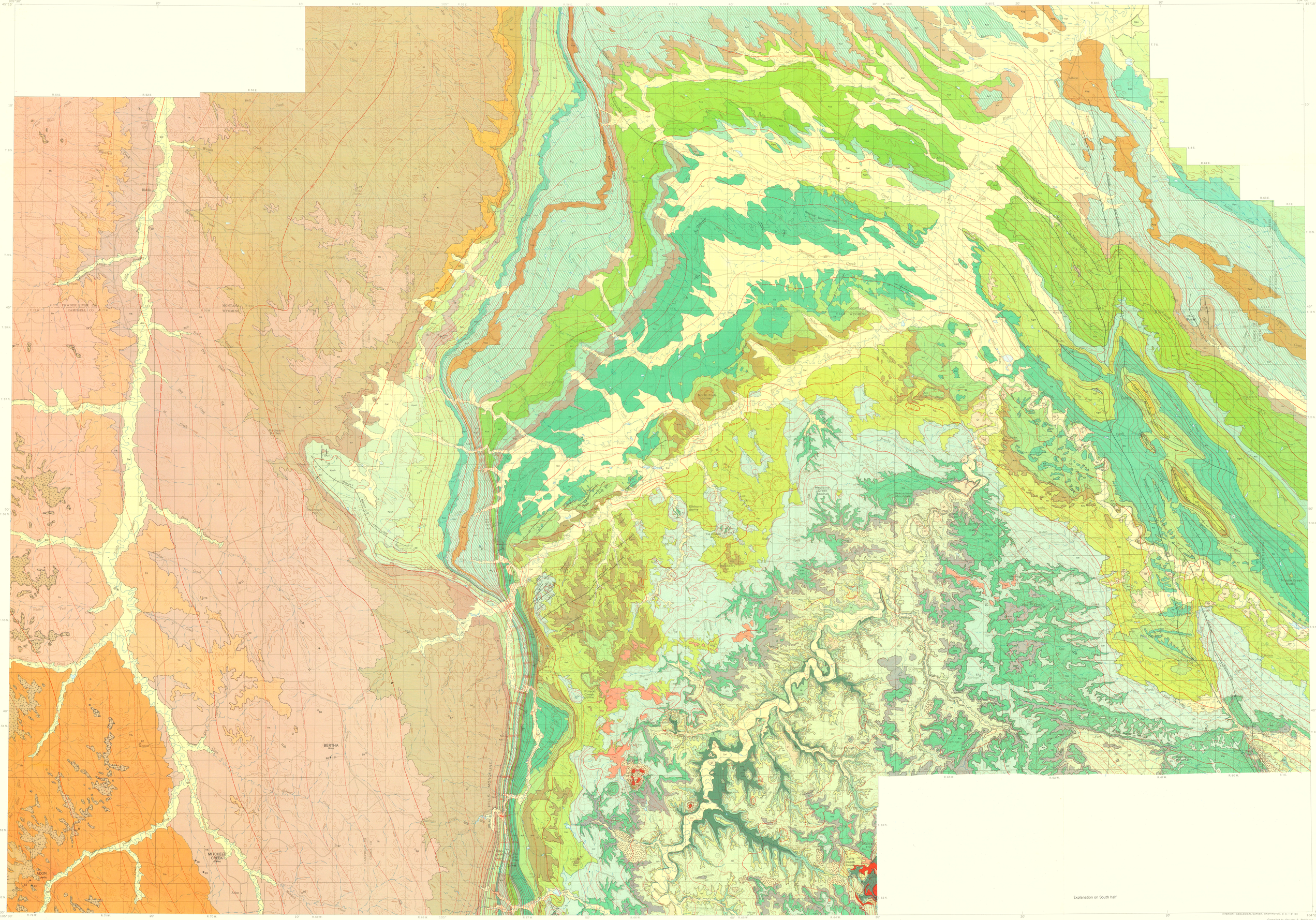

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GEOLOGIC AND STRUCTURE-CONTOUR MAP OF THE NORTHERN AND WESTERN FLANKS OF THE BLACK HILLS UPLIFT, WYOMING, MONTANA, AND SOUTH DAKOTA

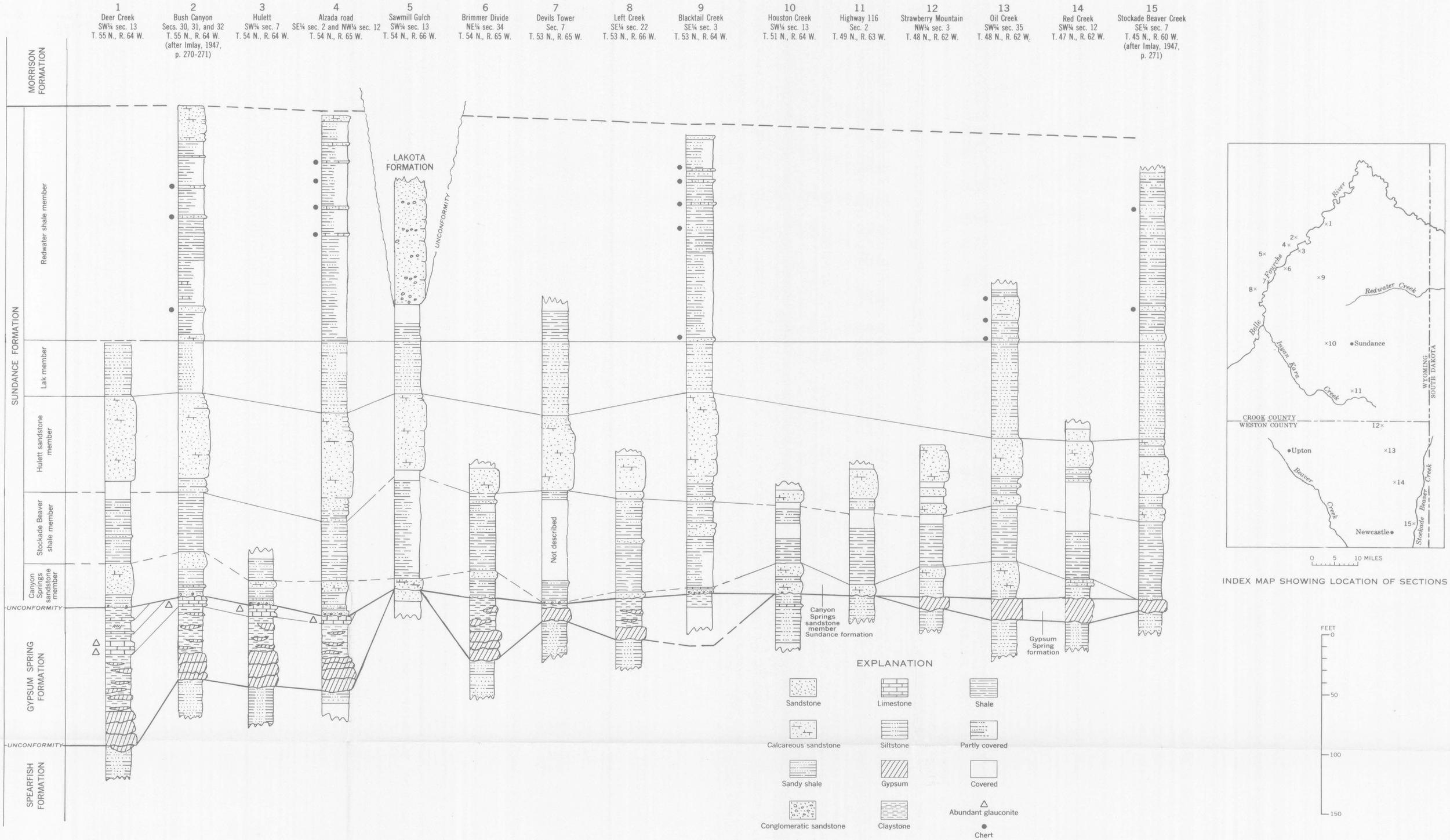
SCALE 1:96000

0 1 2 3 4 5 6 7 8 9 MILES

CONTOUR INTERVAL 100 FEET
DATUM IS MEAN SEA LEVEL

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—81108

Compiled by Charles S. Robinson
and William J. Mapel



INDEX MAP SHOWING LOCATION OF SECTIONS

STRATIGRAPHIC SECTIONS OF THE SUNDANCE AND GYPSUM SPRING FORMATIONS NORTHWESTERN BLACK HILLS WYOMING

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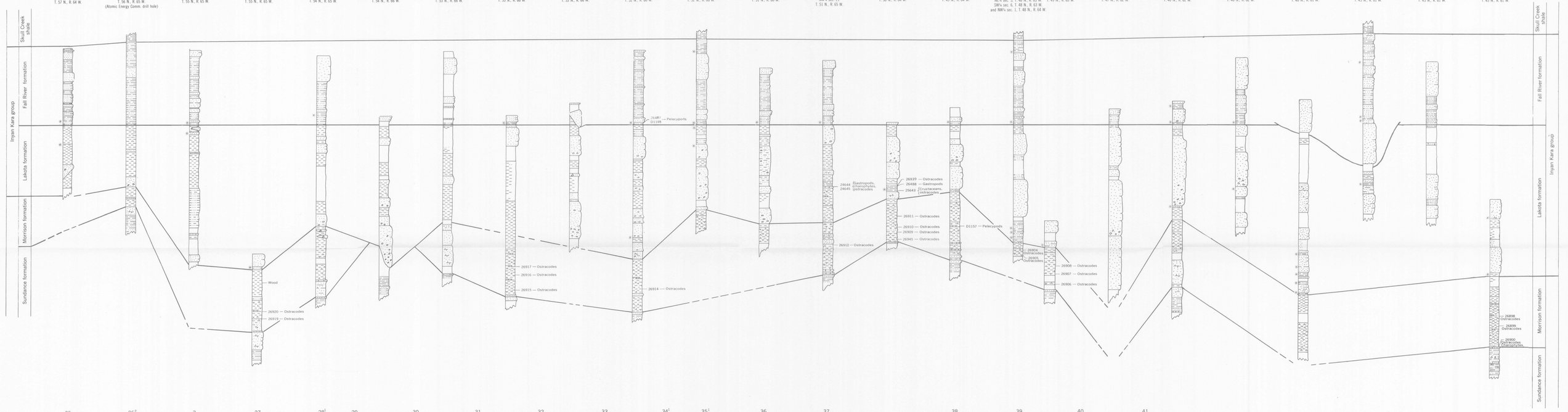

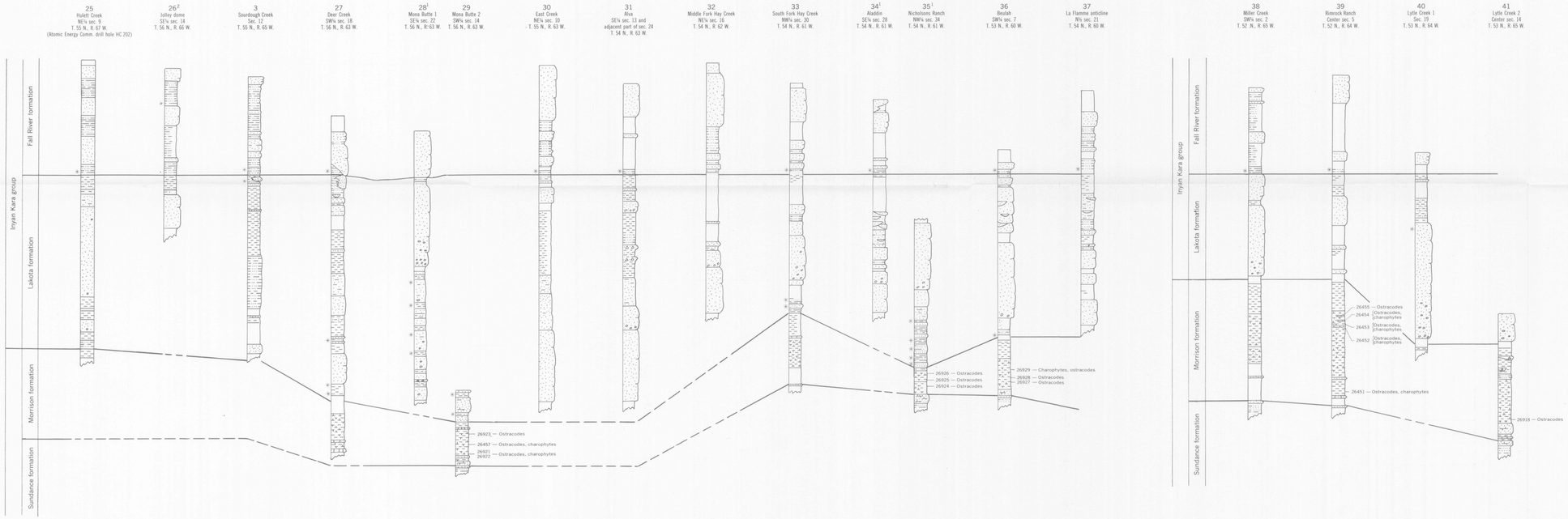

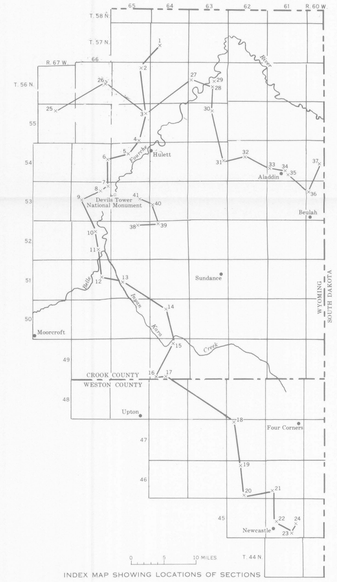

INDEX MAP SHOWING LOCATIONS OF SECTIONS

EXPLANATION

- Sandstone
- Conglomeratic sandstone
- Calcareous sandstone
- Siltstone
- Claystone
- Sandy claystone
- Calcareous claystone and marl
- Shale
- Sandy shale
- Limestone
- Gypsum
- Chert
- Partly covered
- Covered
- Carbonaceous material
- 26939 — Ostracodes U. S. Geol. Survey fossil locality
- 5 Locality number

[1]Section measured by K. M. Waagé and Copeland MacClintock.

[2]Section measured by G. A. Izett and R. E. Davis.

FEET
100
200
300

STRATIGRAPHIC SECTIONS OF THE FALL RIVER, LAKOTA, AND MORRISON FORMATIONS, NORTHWESTERN BLACK HILLS, WYOMING

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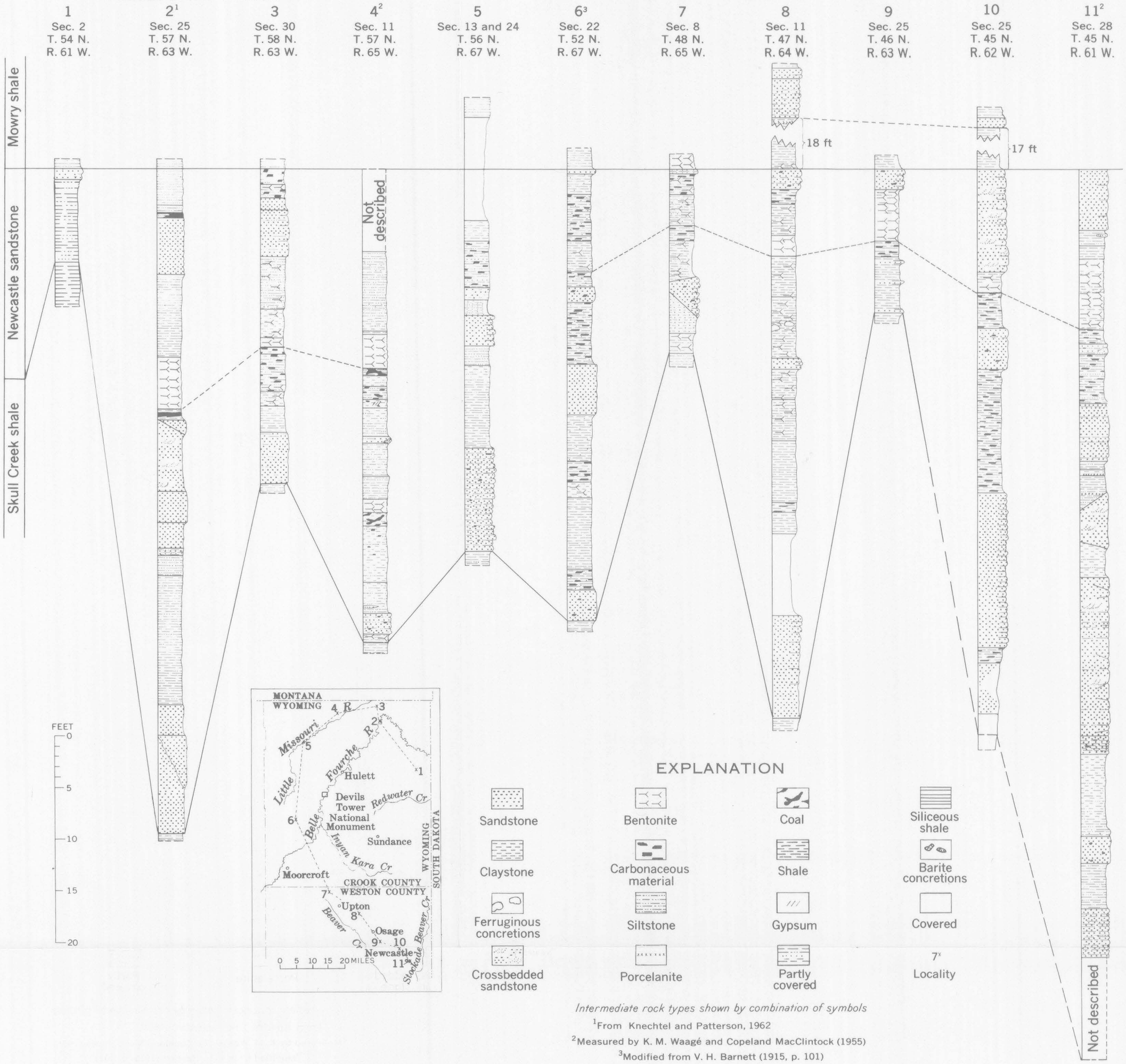

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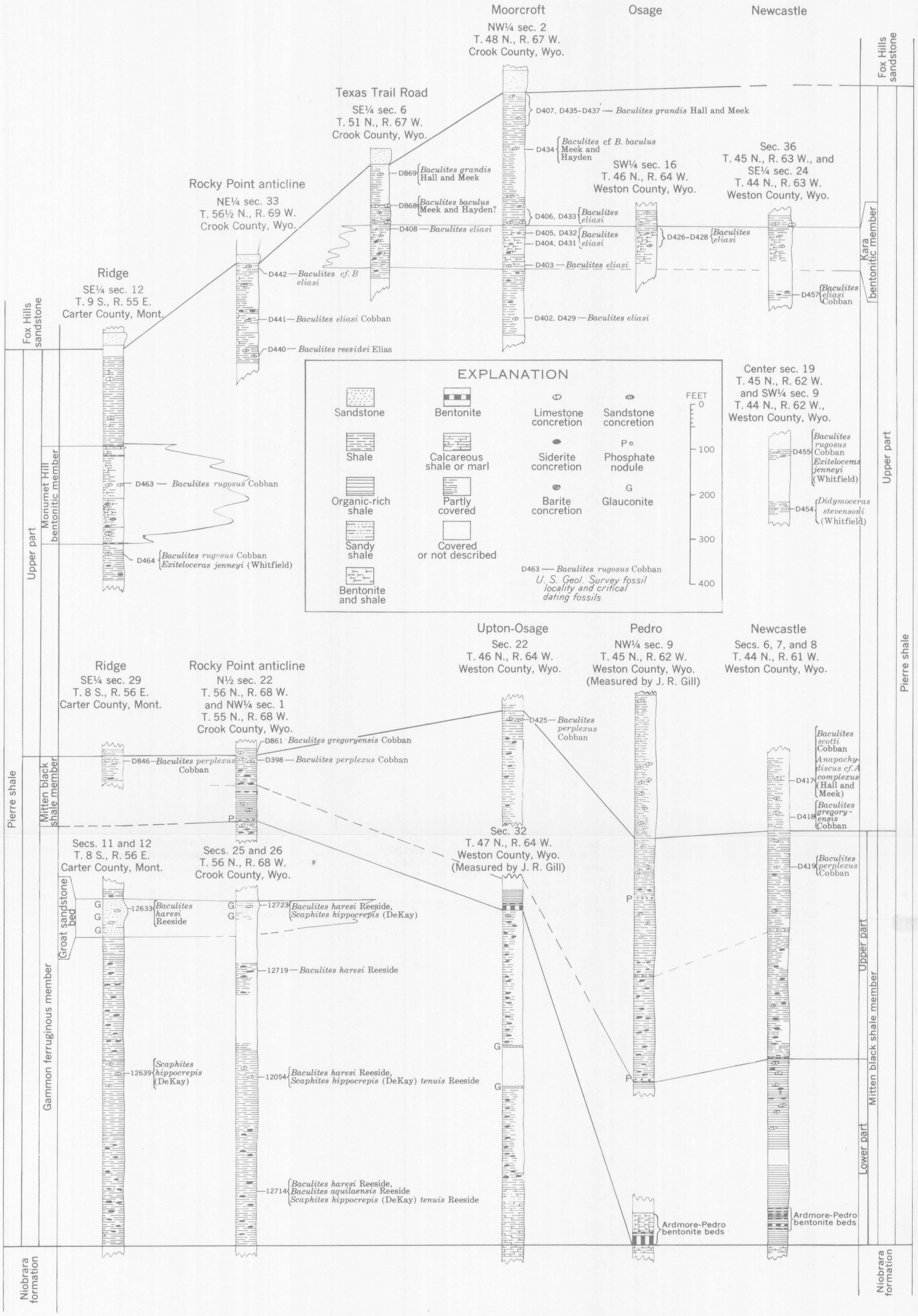

CORRELATION OF THE PIERRE SHALE BETWEEN RIDGE, MONTANA, AND NEWCASTLE, WYOMING

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