Geology of the Winnett-Mosby Area, Petroleum, Garfield Rosebud, and Fergus Counties Montana

GEOLOGICAL SURVEY BULLETIN 1149

Prepared as part of the program of the Department of the Interior for the development of the Missouri River basin

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

Geology of the Winnett-Mosby Area, Petroleum, Garfield Rosebud, and Fergus Counties Montana

By WILLIAM D. JOHNSON, Jr., *and* HOWARD R. SMITH

GEOLOGICAL SURVEY BULLETIN 1149

Prepared as part of the program of the Department of the Interior for the development of the Missouri River basin

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1964

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library has cataloged this publication as follows:

Johnson, William David, 1923–

Geology of the Winnett-Mosby area, Petroleum, Garfield, Rosebud, and Fergus Counties, Montana, by William D. Johnson, Jr., and Howard R. Smith. Washington, U.S. Govt. Print. Off., 1963.

iv., 91 p. maps (1 col.) diagr., tables. 24 cm. (U.S. Geological Survey. Bulletin 1149.)

Part of illustrative matter fold. in pocket.

Bibliography: p. 86–88.

1. Geology—Montana—Winnett-Mosby area. I. Smith, Howard R. 1925– joint author. (Series)

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

CONTENTS

ILLUSTRATIONS

[Plates 1-3 are in pocket]

TABLES

GEOLOGY OF THE WINNETT-MOSBY AREA, PETROLEUM, GARFIELD, ROSEBUD, AND FERGUS COUNTIES, MONTANA

By William D. Johnson, Jr., and Howard R. Smith

ABSTRACT

The Winnett-Mosby area contains about 833 square miles in central Montana, mostly in Petroleum and Garfield Counties; it also includes about 14 square miles in northern Rosebud County and 5 square miles in eastern Fergus County. The area is 49 miles in length from east to west and ranges in width from 12 miles at the north and south ends to 24 miles near the middle in the vicinity of the Musselshell River.

The Musselshell River flows north across the eastern part of the area through a deep, rather narrow, steep-sided valley, which is bordered in part on the west by broad terraces. Across the eastern part of the area, a line of steep ridges makes a narrow, V-shaped band, the apex of which is to the east. North of the ridges, in the Musselshell Valley, the country is rough badlands, and east of the ridges it is an uneven sagebrush-covered plain. Prominent westward-facing cuestas cross the country west of the Musselshell River, and a broad rolling upland underlies the southern part of the area. Several small buttes rise 200 to 300 feet above the surrounding plains southwest of Winnett.

Sedimentary rocks exposed in the Winnett-Mosby area are Cretaceous in age and have a thickness of 4,800 feet. A deep well has penetrated about 3,700 feet of strata below the stratigraphically lowest outcropping beds. The unexposed strata range in age from Cambrian through Jurassic, excluding rocks of Silurian, Permian, and Triassic age which have not been identified in this part of Montana. The exposed sequence consists of eight formations, one of which, the Colorado shale, is divided into nine members. The Carlile member of the Colorado shale is further divided into four mappable lithologic units.

Outcropping Lower Cretaceous rocks are represented by four members of the Colorado shale. In ascending order, these are the lower sandstone, Skull Creek, unnamed sandy, and Mowry members. The lower sandstone member, about 70 feet thick, forms prominent dip slopes on the west side of the area. Overlying the lower sandstone member is 175 feet of dark shale and thin yellowish-brown sandstone of the Skull Creek member. The lower sandy part of the Skull Creek in the subsurface is informally called the Dakota silt. The unnamed sandy member is about 415 feet thick and consists principally of gray sandy shale and thin glauconitic and locally ferruginous sandstone. This member may be equivalent to the Newcastle sandstone of the Black Hills. Overlying the unnamed sandy member is 200 feet of the Mowry member, the uppermost unit of Early Cretaceous age. It consists of thin very siliceous sandstone interlaminated with shale and weathers to resistant bare silver-gray outcrops.

The remaining part of the Colorado shale includes five members of Late Cretaceous age, which are from oldest to youngest, the Belle Fourche, Mosby sandstone, calcareous shale, Carlile, and Niobrara members. The Belle Fourche member

conformably overlies the Mowry member, is 240 to 310 feet thick, and is made up of dark sandy and, locally, bentonitic shale, thin shaly sandstone, and, in the lower half, thin bentonite beds. Abundant ironstone concretions characterize the lower part of this member. The Mosby sandstone member and overlying calcareous shale member together are equivalent to the Greenhorn formation of the Black Hills. The Mosby is 29 feet thick and consists of noncalcareous sandstone and shale; the calcareous shale member is 23 feet thick and consists of calcareous shale that weathers very light gray. The Carlile member, which is 310 feet thick, is subdivided into four units: the first and oldest unit is dark bluish-gray shale, the second is dark-gray shale containing abundant ironstone concretions, the third is dark-gray sandy shale containing abundant limestone concretions that weather yellowish orange, and the fourth and youngest is olive-gray to dark-gray sandy shale containing large septarian limestone concretions that weather light gray. The Niobrara, the uppermost member of the Colorado shale, is a sequence, 380 feet thick, of noncalcareous and calcareous shale and bentonite beds; the Sage Hen limestone member of Lupton and Lee (1921), a thin persistent bed of concretions, is at the base of the Niobrara.

Conformably overlying the Colorado shale is 130 to 235 feet of sandy shale and soft sandstone of the Telegraph Creek formation of Late Cretaceous age; next in order is the Eagle sandstone, about 290 feet thick, which forms prominent hogbacks and cuestas. The two formations are undifferentiated over part of the area east of the Musselshell River. Brownish-gray marine shale containing large distinctive concretions and many bentonite beds characterizes the Claggett shale which overlies the Eagle sandstone. The thickness of the Claggett ranges from 345 to 430 feet. The Judith River formation overlies the Claggett and is mostly a nonmarine sequence of sandstone, shale, siltstone, and mudstone about 273 feet thick, which form conspicuous hogbacks in areas of steep dips. Conformably overlying the Judith River formation is 1,165 to 1,318 feet of marine shale of the Bearpaw shale. Many bentonite beds and abundant very fossiliferous limestone concretions are characteristic of this formation. The uppermost marine formation of Cretaceous age is the Fox Hills, which in the mapped area ranges in thickness from 63 to 141 feet. The youngest rocks of Cretaceous age are the nonmarine beds of the Hell Creek formation of which an estimated 300 feet crops out in the area.

Igneous rock of ultramafic composition has been intruded as dikes, sills, and plugs in the western part of the mapped area.

The mapped area is located on a part of the Big Snowy anticlinorium known as the Cat Creek-Devils Basin uplift. Differential vertical movement along faults that bound a compound horst in the basement rocks under the Cat Creek-Devils Basin uplift probably caused the uplift and the secondary structural features within it. En echelon faults cut the exposed sedimentary rocks in a belt along the crest of the Cat Creek anticline and in another belt in the southern part of the area.

Tectonic movements that formed the Big Snowy anticlinorium apparently occurred no earlier than Eocene time and possibly as late as middle Oligocene. Intrusion of igneous rocks in the Winnett-Mosby area probably occurred during a late stage of the tectonic activity, and therefore they are Eocene or slightly younger in age.

Terraces at eight levels extend along the Musselshell River, and a complex system of terraces also borders the major creeks. The gravel in all the deposits was derived principally from mountains to the west. Boulders ice rafted into the area during the Illinoian or early Wisconsin stage of glaciation rest on all but the two lowest terrace levels in the valley of the Musselshell River, but no glacial gravel is incorporated in the terrace deposits.

Oil is produced from West, Mosby, and East domes on the Cat Creek anticline; it also was formerly produced from a well in the Rattlesnake Butte area. Since the discovery of oil on Mosby dome in 1920, to January 1, 1959, the Cat Creek field has produced 19.2 million barrels of oil. Commercial production is from four zones: the lower sandstone member of the Colorado shale (First Cat Creek sand of Reeves) and the Second Cat Creek sand in the Kootenai formation, both of Cretaceous age; and sandstone beds in the Morrison and Swift formations of Jurassic age. The crude oil ranges in gravity from 47° to 51° API and has no associated gas. Rocks that also may contain oil include the Piper formation of Jurassic age, Mississippian and Pennsylvanian rocks formerly called the Amsden formation in central Montana, and the nonmarine part of the Heath formation of Late Mississippian age.

INTRODUCTION

LOCATION AND EXTENT OF AREA

The Winnett-Mosby area comprises about 833 square miles in central Montana (fig. 1) principally in Petroleum and Garfield Coun-

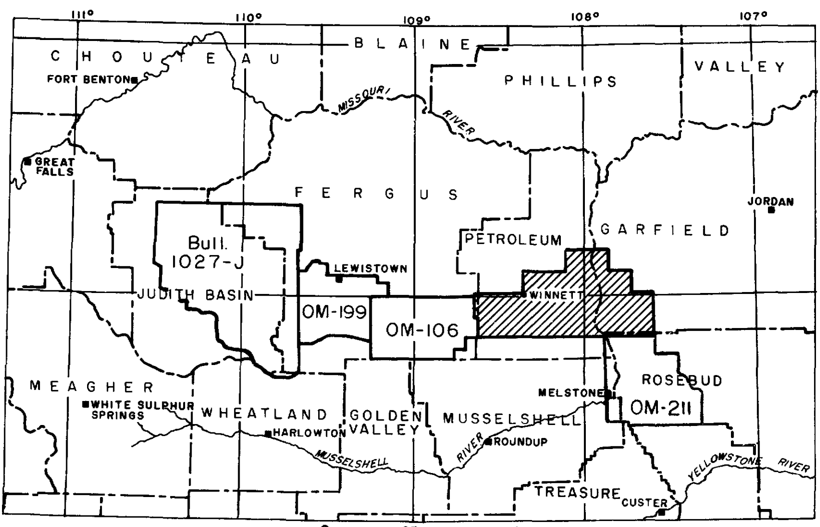

FIGURE 1—Index map of central Montana showing location of the Winnett-Mosby area and its relation to other areas covered by reports of the Geological Survey.

ties; it also includes about 14 square miles in northern Rosebud County and 5 square miles in eastern Fergus County. The area extends about 49 miles from east to west and ranges in width from 12 to 24 miles. The maximum width is in the vicinity of the Musselshell River, which forms the boundary between Petroleum and Garfield Counties.

PURPOSE AND SCOPE OF INVESTIGATION

The present investigation was undertaken as part of the Department of the Interior program for the development of the Missouri River basin. The purpose was detailed geologic mapping so that the possibilities for new oil production along the Cat Creek anticline might be evaluated, and the structural features in previously unmapped areas might be delineated. The Cat Creek oil field, near the southeast end of the Cat Creek anticline, has produced about 19.2 million barrels of oil as of January 1, 1959, but production has gradually diminished in recent years.

The southeastern part of the area east of the Musselshell River was mapped from July to October of 1952 by William D. Johnson, Jr., and John P. Trexler. The rest of the area was mapped by Johnson and Howard R. Smith during the field seasons of 1953 and 1954.

Geologic data were recorded on aerial photographs at the scale of 1:20,000. The land subdivisions on the base map were compiled from township plats of the Bureau of Land Management. However, the subdivisions in Tps. 13 and 14 N., Rs. 26 and 27 E., as indicated by roads, fences, and a few section corner markers, differ markedly from those shown on the township plats, and therefore section lines in those townships are shown by dashed lines on the map. Elevations for structure contouring were calculated from elevations given by U.S. Coast and Geodetic Survey bench marks along State Route 18, along the Chicago, Milwaukee, St. Paul & Pacific RR., and along the road from Winnett to Musselshell, Mont.

ACKNOWLEDGMENTS

Conferences in the field with W. A. Cobban, of the U.S. Geological Survey, who previously had measured and described the Colorado shale and overlying formations on the Cat Creek anticline, were very helpful. The Continental Oil Co. kindly provided housing for the Survey party at its camp in the Cat Creek field during the 1952 and 1953 field seasons.

PREVIOUS WORK

Hatcher (Stanton and Hatcher, 1905, p. 56) in 1888 noted outcrops of the Eagle sandstone along the south side of Flat Willow Creek. Bowen (1914) included part of the Winnett-Mosby area in a reconnaissance coal survey between Musselshell and Judith, Mont., and Bowen (1915, 1919) later discussed conditions of deposition in central Montana during the Eagle and Judith River epochs. Lupton and Lee (1921) described in some detail the southeast end of the Cat Creek anticline. Reeves (1927), in a fairly comprehensive report, described the areal geology and structure of a large part of the Winnett-Mosby area, particularly along the Cat Creek anticline. Thom and Dobbin (1922) discussed oil and gas prospects of Garfield County, the western part of which is in the Winnett-Mosby area, and Thom (1923) discussed the principal structural features of central Montana. Cobban (1951a, 1953a) made a detailed study of Cretaceous rocks along part of the Cat Creek anticline and as a result subdivided the Colorado shale into 13 lithologic units. Wingerter and Mercer (1951) described, in general, the stratigraphic section of Cretaceous rocks along part of State Route 18. Hadley (1956) published a short report on the Cat Creek oil field.

The mapped area is included in Reeside's (1944) general study of Cretaceous deposits in the western interior of the United States. Alden (1932), in his work on the physiography and glacial geology of eastern Montana, discussed briefly the terraces and glacial boulders in the Musselshell Valley near the Mosby Post Office. Ground-water studies by Perry (1931, 1932) included parts of the Winnett-Mosby area. The area of this report is bounded on the west by the Button Butte-Forestgrove area (Gardner, 1950, fig. 1) and on the southeast by the Melstone-Sumatra area mapped in 1955–56 by Smith (1962).

GEOGRAPHY

SURFACE FEATURES AND RELIEF

The Winnett-Mosby area is in the Missouri Plateau section of the Northern Great Plains province (Fenneman, 1931, p. 61). The Musselshell River flows north across the eastern part of the area through a deep narrow steep-sided valley, which is bordered at places on the west by broad nearly level terraces; the valleys of the major streams west of the river are also bordered by terraces. Along the Musselshell Valley, particularly in the northern part of the area, the country is eroded to rough badlands. Across the eastern part of the mapped area a line of steep ridges makes a narrow, V-shaped band, the apex of which is to the east. Much of the country east of these ridges is an uneven sagebrush-covered plain. Prominent westward-facing cuestas interrupt the general eastward slope of the country west of the Musselshell. About 8 miles southwest of Winnett several small buttes rise 200 to 300 feet above the surrounding plains. In the southern part of the area a broad rolling upland stands 500 to 600 feet above Flat Willow Creek. The total relief in the Winnett-Mosby area from the Musselshell River at the north border to a high ridge in the southwest corner is about 1,400 feet.

CLIMATE AND VEGETATION

The climate of the Winnett-Mosby area is characterized by long winters with short periods of severe cold and by short warm summers. Just south of this area, at the U.S. Weather Bureau station 4 miles east-northeast of the former post office of Flat Willow, the normal annual temperature for the period 1944–54 was 44.9°F. The normal annual precipitation for the period 1944–54 was 12.6 inches, ranging from a low of 7 inches in 1952 to a high of 15.9 inches in 1944. About 83.5 percent of the precipitation falls from April through October; June is the wettest month. The prevailing wind in this part of Montana is from the northwest.

Grass and sagebrush make up the vegetation characteristic of this part of Montana. The soils formed on the sandy formations and on the gravel terraces support sparse growths of various grasses. On the shale formations the predominant vegetation is sagebrush. Stands of ponderosa pine and scrub cedar are found locally, particularly in the breaks on the north-facing slopes along the Musselshell River and its tributaries. Cottonwoods are widely scattered along the river and the large creeks.

DRAINAGE

The Musselshell River, the master stream in the Winnett-Mosby area, rises in the Castle Mountains in west-central Montana and flows east and northeast through a broad valley south of the Little Belt and Big Snowy Mountains; much of its load is contributed by streams draining those mountains and by streams draining the Crazy Mountains, which lie south of the river near its upper reaches. At Melstone, Mont., 16 miles south of the mapped area, the river makes an abrupt turn to the north and flows through a more youthful valley to a junction with the Missouri River about 19 miles north of the Winnett-Mosby area. This abrupt change in direction from a course subparallel to the east-west structural trend of central Montana to one that is nearly perpendicular suggests that the Musselshell formerly flowed eastward from Melstone to the Yellowstone River and was captured by an ancient tributary of the preglacial Missouri River. The topographic relief is fairly low east of Melstone; however, if a former channel existed in that area, no evidence remains.

The Musselshall River flows to the north through a valley that is about 100 feet deep at the south edge of the mapped area and more than 200 feet deep at the north edge. Where the river crosses resistant sandstone, the valley is narrow, the valley sides steep, and the meanders tight, but where the river is eroding soft shale, the valley is wider, the sides more gentle, and the meanders open. The meander pattern probably was developed at a higher level, but subsequently became incised by a change in base level during the Pleistocene. The history of drainage changes in eastern and central Montana is discussed in detail by Alden (1932).

East of the river the main streams are Calf and Sage Hen Creeks and tributaries of Rattlesnake Creek. West of the river the main streams are Cottonwood, Cat, Flat Willow, Box Elder, and Willow Creeks. Rejuvenation also is evident along these streams, for they are progressively more incised toward their mouths. All the secondary streams in the area are intermittent, and gaging records show that even the Musselshell River has failed to flow during prolonged periods of drought.

Two examples of stream piracy are evident in the Winnett-Mosby area. The most notable is the capture of Flat Willow Creek by a tributary of the Musselshell River in sec. 6, T. 13 N., R. 30 E. Before its capture, which occurred when Flat Willow Creek was flowing at a higher level, the creek drained to the southeast from sec. 6 and emptied into the river on the west edge of sec. 9 about 2 miles upstream from its present mouth. The lower 2 miles of the present valley is narrower and trends slightly northeast rather than to the southeast as does the valley above the point of capture. A small stream now occupies part of the old creek valley; in the NE¼ sec. 7, T. 13 N., R. 30 E., this stream reverses its direction of flow from southeast to northwest and joins Flat Willow Creek near the elbow of capture. A southeast-flowing stream draining the NE¼ T. 15 N., R. 29 E., has been captured in the NW¼NW¼ sec. 17, T. 15 N., R. 30 E., by a north-flowing tributary of the Musselshell River.

SETTLEMENT AND ACCESSIBILITY

Winnett, the county seat of Petroleum County and the only town in the area, had a population of 407 in 1950. About 21 miles by road northeast of Winnett are the Cat Creek Post Office and a small settlement in the Cat Creek oil field. On State Route 18 just east of the Musselshell River is the post office of Mosby.

State Route 18, which crosses the area from east to west, connects Winnett with Grass Range and Lewistown, 24 and 54 miles, respectively, to the west, and with Jordan, 78 miles to the northeast. A secondary highway extends from Winnett south and southwest to a junction with U.S. Highway 87 about 21 miles north of Roundup, Mont. A graded road leads up the west side of the Musselshell River valley from State Route 18 near Mosby to Melstone, Mont., and another extends from the secondary highway south of Winnett to Musselshell, Mont. The only bridge across the Musselshell River in the mapped area is on State Route 18, but during low water the river can be forded by car at many places. A branch line of the Chicago, Milwaukee, St. Paul & Pacific RR. extends from Lewistown eastward to its terminus at Winnett.

Most of the Winnett-Mosby area provides grazing land for beef cattle. Dry farming is confined principally to the sandy soils on the Eagle sandstone and the Telegraph Creek formation and to the high terrace surfaces between Flat Willow and McDonald Creeks. Irrigated crops are grown on low terraces on the north side of Flat Willow Creek below Petrolia Reservoir and along the lower reaches of Box Elder and McDonald Creeks. Small areas also are irrigated on the flood plain of the Musselshell River and along the larger creeks. Wheat is the principal crop on both dry and irrigated lands; other important crops are alfalfa seed, barley, and hay.

STRATIGRAPHY

Sedimentary rocks exposed in the Winnett-Mosby area are Cretaceous in age, and have a thickness of 4,800 feet. The sequence is divided into eight formations, one of which, the Colorado shale, is subdivided into nine members. The Carlile member of the Colorado shale contains four mappable lithologic units (pl. 1).

A deep well in the northern part of the area, the California Co. Peterson 1 in sec. 13, T. 15 N., R. 30 E., penetrated about 3,700 feet of rocks below the stratigraphically lowest beds cropping out in the area. This well began in Upper Cretaceous rocks and penetrated rocks of Jurassic, Mississippian, Devonian, Ordovician, and Cambrian ages. Pennsylvanian and uppermost Mississippian rocks are present under most of the area, but they are missing in the north-central part below a major pre-Middle Jurassic unconformity (Nieschmidt, 1953). The general character and the range in thickness of the exposed and unexposed sedimentary rocks in the mapped area are summarized in table 1, and the correlation of some Lower Cretaceous and Upper Jurassic rocks in drill holes is shown on plate 2.

TABLE 1.—*Generalized section of sedimentary rocks in the Winnett-Mosby area, Montana*

[Lithology of unexposed formations from drillers' logs, sample service company logs, and U.S. Geol. Survey Oil and Gas Inv. Chart OC-50]

System	Series	Group	Formation and member	Thickness (feet)	Character
			Exposed rocks		
Cretaceous	Upper		Hell Creek formation	300±	Light-gray nonmarine sandstone and yellowish-gray to brownish-black siltstone.
Cretaceous	Upper	Montana	Fox Hills formation	63–141	Yellowish-gray to olive-gray sandstone.
Cretaceous	Upper	Montana	Bearpaw shale	1, 165–1, 318	Medium-gray to brownish-gray marine shale; contains abundant fossiliferous limestone concretions and beds of bentonite.
Cretaceous	Upper	Montana	Judith River formation	273	Yellowish-gray sandstone, siltstone, and mudstone at the top; gray to greenish-gray nonmarine sandstone, siltstone, and mudstone in the middle; yellowish-gray marine sandstone and sandy shale at the base.
Cretaceous	Upper	Montana	Claggett shale	345–430	Brownish-gray marine shale; abundant limestone concretions in upper part; many layers of bentonite in lower part.
Cretaceous	Upper	Montana	Eagle sandstone	200±–288	Yellowish-gray sandstone and sandy shale at the top; olive-gray sandy shale in the middle; grayish-yellow cliff-forming sandstone at the base; grades laterally to sandy shale in the eastern part of the area.
Cretaceous	Upper	Montana	Telegraph Creek formation	130–234	Light-olive-gray to yellowish-gray sandy shale and sandstone; abundant ironstone concretions in the lower part.
Cretaceous	Upper		Colorado shale: Niobrara member	379	Light-olive-gray noncalcareous to calcareous shale; contains thin beds of bentonite and many limestone and sandstone concretions.
Cretaceous	Upper		Colorado shale: Carlile member	310	Dark-gray sandy shale; upper two-thirds contains abundant limestone concretions that weather light gray and yellowish orange; zone of abundant ironstone concretions in the lower part.
Cretaceous	Upper		Colorado shale: Calcareous shale member	23	Medium-gray calcareous shale.
Cretaceous	Upper		Colorado shale: Mosby sandstone member	29	Two yellowish-gray ledge-forming sandstone units separated by medium-gray sandy shale.
Cretaceous	Upper		Colorado shale: Belle Fourche member	240–307	Medium-dark-gray sandy shale; many beds of bentonite and ironstone concretions in the lower part.
Cretaceous	Lower		Colorado shale: Mowry member	197–210	Light-olive-gray siliceous sandstone interlaminated with dark-gray shale; many thin beds of bentonite.
Cretaceous	Lower		Colorado shale: Unnamed sandy member	417–430	Medium-gray sandy shale interbedded with yellowish-gray sandstone.
Cretaceous	Lower		Colorado shale: Skull Creek member	175–250	Olive-gray to medium-gray shale with yellowish-gray sandstone in the lower half.
Cretaceous	Lower		Colorado shale: Lower sandstone member	20–70	Light-gray to yellowish-brown sandstone.
			Unconformity		

TABLE 1.—*Generalized section of sedimentary rocks in the Winnett-Mosby area, Montana*—Continued

System		Series	Group	Formation and member		Thickness (feet)	Character
Unexposed rocks							
Cretaceous—Continued		Lower—Continued		Kootenai formation	Second Cat Creek sand of local usage; Third Cat Creek sand of local usage	300–430	Red, purple, and gray sandstone, siltstone, and shale; thick gray to white sandstone beds near the middle and at the base.
				Unconformity			
Jurassic		Upper		Morrison formation		165–245	Green, red, gray, and black shale and siltstone and light-gray and greenish-gray sandstone; locally a coal bed at or near the top.
			Ellis	Swift formation		95–185	Light-gray to greenish-gray calcareous glauconitic sandstone in the upper part; dark-gray to greenish-gray shale and some red shale in the lower part.
				Rierdon formation		20±–200	Dark-gray to greenish-gray calcareous shale and some gray to light-greenish-gray argillaceous limestone.
		Middle		Piper formation		0–200	Red, maroon, dark-gray, and grayish-green shale; contains a bed as much as 50 ft thick of gray to grayish-tan argillaceous limestone; probably absent near west border of the area.
				Unconformity			
Carboniferous	Pennsylvanian or Mississippian		Big Snowy	Alaska Bench limestone		0–178	Gray, red, and white dolomite in the upper part and gray locally cherty limestone in the lower part; absent in the north-central part of the area.

TABLE 1.—*Generalized section of sedimentary rocks in the Winnett-Mosby area' Montana*—Continued

System		Series	Group	Formation and member	Thickness (feet)	Character
Unexposed rocks—Continued						
Carboniferous—Continued			Big Snowy—Continued	Cameron Creek formation	0–54	Black, brown, gray, and red shale; absent in the north-central part of the area.
	Missis-sippian	Upper		Heath formation	0–570	Black and gray shale, locally contains thin streaks of coal; thin beds of gray and black argillaceous limestone and dolomite; absent in the north-central part of the area.
				Otter formation	240–340	Green, gray, and black dolomitic shale, gray to brown dolomite; white to gray limestone; and white anhydrite.
				Kibbey sandstone	220–230	White and red sandstone, siltstone, and shale; some cream and tan dolomite; and some anhydrite.
		Lower	Madison	Charles formation	600	Cream to grayish-tan anhydritic dolomitic limestone; white, gray, and tan anhydrite; and grayish-tan anhydritic dolomite.
				Mission Canyon limestone	460	Tan and brown anhydritic dolomite and oolitic limestone.
				Lodgepole limestone	585	White, tan, and grayish-brown argillaceous limestone containing spicular chert in the lower part; a basal zone of grayish-tan glauconitic cherty dolomite.
				—Unconformity—		
Devonian		Upper	Jefferson	Duperow formation	145	Tan and brown anhydritic shaly dolomite.
				—Unconformity—		
Ordovician		Upper		Red River formation (of Canada)	230	Cream and tan argillaceous dolomite mottled red.
				—Unconformity—		
Cambrian				Uncorrelated rocks; base not penetrated	80+	Cream, tan, and pink glauconitic dolomitic shaly limestone.

LOWER AND UPPER CRETACEOUS

COLORADO SHALE

The Colorado shale consists of about 1,900 feet of medium- to dark-gray locally sandy marine shale interbedded with lesser amounts of light-gray to yellowish-brown very fine grained to fine-grained sandstone, some of which is highly silicified. Abundant distinctive limestone concretions and beds of ironstone concretions characterize parts of the formation. Thin beds of bentonite are common throughout the shale.

The Colorado shale is divided into the following nine members, from oldest to youngest: the lower sandstone, Skull Creek, unnamed sandy, and Mowry members, all of Early Cretaceous age; and the Belle Fourche, Mosby sandstone, calcareous shale, Carlile, and Niobrara members of Late Cretaceous age. The correlation of these units with their equivalents in the northern Black Hills of South Dakota has been discussed by Cobban (1951a).

LOWER SANDSTONE MEMBER

The lower sandstone member of the Colorado shale was named the First Cat Creek sand by Reeves (1925, p. 91) for its occurrence in the subsurface at the Cat Creek anticline in the northern part of the Winnett-Mosby area. The upper part of the member makes for small outcrops in secs. 7, 18, 19, and 30, T. 13 N., R. 25 E., along the west boundary of the area. It is exposed at the base of long grass-covered dip slopes which locally extend several hundred feet into the Winnett-Mosby area from the adjoining Button Butte-Forestgrove area. The dip slope generally is covered with small platy sandstone fragments.

The member is light-gray, yellowish-gray, and yellowish-brown fine-grained laminated to thin-bedded sandstone that weathers brownish gray. The sandstone is composed of quartz grains that contain abundant black and light-brown specks. Some layers are finely crossbedded and ripple marked and contain scattered small ferruginous concretions that weather yellowish brown. Burrows and trails of small organisms are preserved on the bottom of some beds.

In a section measured just west of the mapped area in sec. 1, T. 13 N., R. 24 E., the lower sandstone member is about 70 feet thick; however, the upper 21 feet is partly covered and the contact with the overlying Skull Creek member could not be determined exactly. Drillers' logs of wells in the north-central part of the area show that the lower sandstone member ranges in thickness from about 20 to 70 feet and has an average thickness of about 50 feet.

The lower sandstone member lies on the Kootenai formation of Early Cretaceous age without angular discordance, but the contact may represent a hiatus (Cobban and Reeside, 1952, chart 10b; Bauer and Robinson, 1923, p. 171). The contact is marked by a sharp contrast between brownish-gray sandstone of the lower sandstone member and red, purple, and gray beds of the Kootenai formation.

In some earlier reports this sandstone of Reeves (1925) was considered the upper unit of the Kootenai formation, but most later reports generally consider it part of the Colorado shale (Cobban and Reeside, 1952, chart 10b). The lower sandstone member is considered Early Cretaceous in age, but no fossils except burrows and trails have been found. It is equivalent to the Fall River sandstone of the Black Hills (Cobban, 1951a, p. 2175).

The lithologic character of the lower sandstone member is shown in the following measured section.

Section of the lower sandstone member of the Colorado shale in the NW¼SE¼ sec. 1, T. 13 N., R. 24 E., Fergus County, Mont.

	Thickness (feet)
Colorado shale:	
Skull Creek member:	
Partly covered interval; black slightly sandy shale and fragments of light-olive-gray fine-grained sandstone that weather dark brown	15. 5
Lower sandstone member:	
Covered interval; fragments of yellowish-gray to yellowish-brown fine-grained sandstone on a long moderately steep slope	21. 1
Sandstone, yellowish-gray, fine-grained, slightly crossbedded; weathers yellowish brown to brownish gray; forms low ledge	3. 0
Partly covered interval; some dark-gray and brownish-gray slightly silty shale and brownish-gray fine-grained sandstone	1. 0
Sandstone, yellowish-gray to light-brownish-gray, fine-grained, crossbedded; predominantly thin bedded, but a few beds as much as 1.1 ft thick; thin partings of very light greenish-gray shaly sandstone; few thin lenses of iron-stained conglomeratic sandstone less than 0.5 ft thick; unit weathers brownish gray to dark gray	8. 5
Covered interval; probably thin-bedded shaly sandstone	8. 5
Sandstone, yellowish-gray to light-gray, mostly fine-grained, finely laminated, finely crossbedded; some layers of medium-grained sandstone; matrix of light-colored quartz with abundant black and brown specks; some ripple-marked layers; forms prominent ledge	8. 5
Partly covered interval; probably yellowish-gray thin-bedded shaly sandstone	5. 5
Sandstone, light-gray to pinkish-gray, fine-grained, hard, massive, crossbedded; composed mainly of quartz; weathers mottled yellowish gray, yellowish brown, and dark gray; scattered ferruginous concretions that weather yellowish brown	1. 6
Partly covered interval; mottled medium-gray to moderate yellowish-brown sandstone and shaly sandstone	2. 6
Sandstone, light-gray to pinkish-gray and yellowish-gray, fine-grained, thin-bedded, hard, finely crossbedded; intercalated with shaly sandstone; beds as much as 1 ft thick in upper part; matrix of light-colored quartz with light-brown specks; scattered ferruginous concretions that weather yellowish brown; bedding in sandstone seems to go through the concretions; fucoidal markings on bedding; weathers yellowish gray to light brownish gray; caps prominent ledge at base of the member	7. 5
Sandstone, dark-gray, fine-grained, shaly; interbedded with thin hard layers of moderate-yellowish-brown sandstone	. 8
Sandstone, moderate-yellowish-brown; some streaks of medium-gray fine-grained thin-bedded hard sandstone	1. 1
Total thickness of lower sandstone member	69. 7
Kootenai formation:	
Sandstone, mottled medium-dark-gray, dark-gray, and yellowish-gray, fine-grained, shaly	3. 0+

689-268 O—63——2

SKULL CREEK MEMBER

The Skull Creek member of the Colorado shale crops out locally along the west edge of the Winnett-Mosby area near Elk and Pike Creeks. In areas of moderately steep dips, sandstone beds in the Skull Creek member form long dip slopes. A bed of sandstone, 9 feet thick, about 50 feet above the base of the member forms persistent low flatirons along the west edge of the area and in the adjacent Button Butte-Forestgrove area. Where the dips are gentle, the Skull Creek member generally is poorly exposed with only a few outcrops of sandstone and dark glistening shale.

The Skull Creek member is composed mostly of olive-gray to medium-gray shale which is slightly sandy in the upper and lower parts of the member. Scattered throughout the shale, but more common in the lower 100 feet, are thin beds of yellowish-gray to olive-gray and locally yellowish-brown very fine grained to fine-grained noncalcareous sandstone, some of which is ferruginous and weathers to light-yellowish-brown to dark-brown platy fragments. Hard ironstone concretions or irregular concretionary lenses that weather to blackish-brown flakes are scattered through the shale. Several thin rusty-weathering bentonite beds are in the upper part of this member. In the subsurface throughout this part of central Montana, the lower sandy part of the Skull Creek member is persistent and fairly uniform in thickness. The top of the sandy interval, which is informally called the Dakota silt by many geologists, gives a sharply increased deflection of the resistivity curve on electric logs and is used widely as a horizon for electric-log correlations (pl. 2).

The Skull Creek member is about 175 feet thick near Pike Creek in sec. 19, T. 13 N., R. 25 E. The member is 250 feet thick (Cobban, 1951a, p. 2175) in The Texas Co. Northern Pacific 1 well east of the Musselshell River in sec. 35, T. 15 N., R. 30 E.

The Skull Creek member lies conformably above the lower sandstone member, and in most places the contact can be accurately located by an abrupt change in lithology and by a change in topography from dark sagebrush-covered flats or low hills on the Skull Creek to light grass-covered dip slopes on the lower sandstone member.

Fossils are scarce in the Skull Creek member, although Cobban (1951a, p. 2176) reported arenaceous Foraminifera and several species of pelecypods from the member near Grass Range, about 10 miles west of the area.

A detailed description of the Skull Creek member is given in the following measured section.

Section of the Skull Creek member of the Colorado shale in the S½NW¼, the NE¼NW¼, and the NE¼SW¼ sec. 19, T. 13 N., R. 25 E., Petroleum County, Mont.

	Thickness (feet)
Colorado shale:	
Unnamed sandy member:	
Shale, mottled medium-gray to moderate-yellowish-brown, slightly sandy, bentonitic; some thin lenses of shaly sandstone that weather orange brown; forms bare yellowish-gray popcornlike outcrop	19. 2
Skull Creek member:	
Shale, very dark gray, slightly sandy, highly fissile; forms very dark bare popcornlike outcrop at base of steep slope	3. 6
Shale, medium-gray, slightly sandy; contains thin lenses of hard platy light-gray very fine grained sandstone; sandstone weathers to hard fragments mottled and streaked by iron stains; forms bare outcrop	5. 4
Partly covered interval; dark-olive-gray sandy shale grading upward into soft yellowish-gray sandstone that weathers to hard iron-stained fragments; sandstone forms a light-colored band; elsewhere this unit contains several beds less than 0.2 ft thick of rusty-weathering bentonite	12. 8
Partly covered interval; olive-gray shale containing some rusty-weathering beds of bentonite; ferruginous sandstone fragments on outcrop	7. 0
Partly covered interval; mostly yellowish-gray to light-olive-gray very fine grained noncalcareous sandstone; weathers to soft yellowish-gray band and forms minor break in slope	2. 0
Shale, medium-gray to olive-gray; contains scattered ferruginous sandstone concretions; forms dark popcornlike outcrop	9. 5
Covered interval; probably shale	8. 0
Shale, medium-gray to olive-gray; contains some small sandstone concretions that weather light olive gray to yellowish brown and have veins of light-colored calcite; scattered ironstones in upper part; shale weathers to dark glistening outcrops	25. 5
Sandstone, olive-gray, very fine grained, noncalcareous; weathers to iron-stained fragments	. 1
Shale, medium-gray to olive-gray; contains lenses of ironstone concretions	8. 7
Sandstone, yellowish-gray, very fine grained, noncalcareous, shaly to thin-bedded; capped by layer of dark ferruginous sandstone; forms minor dip slope	1. 5
Shale, medium-gray to olive-gray, sandy in upper part; scattered ironstones, 0.7 to 1.3 ft long, in lower part; weathers to nearly bare gray slope	7. 9
Sandstone, light-yellowish-gray to light-yellowish-brown, fine-grained; weathers to fragments that are light reddish brown to dark brown	. 1
Shale, medium-gray to olive-gray; contains some thin beds of light-yellowish-gray to light-yellowish-brown fine-grained noncalcareous sandstone	7. 8

Section of the Skull Creek member of the Colorado shale in the S½NW¼, the NE¼NW¼, and the NE¼SW¼ sec. 19, T. 13 N., R. 25 E., Petroleum County, Mont.—Continued

	Thickness (feet)
Colorado shale—Continued	
Skull Creek member—Continued	
Sandstone, light-olive-gray, yellowish-gray, and moderate yellowish-brown, very fine grained, noncalcareous; ferruginous in upper part; in beds generally 1.2 to 3.3 ft thick; some interbedded layers of light-olive-gray sandy shale; scattered sandstone nodules that weather brownish orange; fucoidal markings on bedding surfaces; forms prominent dip slope	9. 0
Shale, medium-gray to olive-gray, sandy; grades into overlying sandstone	13. 1
Sandstone, mottled yellowish-gray and olive-gray, fine-grained, noncalcareous; weathered fragments are pale brown to light yellowish brown; forms minor ledge	1. 3
Shale, medium-gray to olive-gray, sandy; contains beds, 0.05 to 0.1 ft thick, of yellowish-gray, light-olive-gray, and moderate-yellowish-brown very fine grained calcareous sandstone; sandstone fragments weather light brown to blackish brown; scattered fragments of medium-gray sandy limestone with cone-in-cone structures; weathers to dark outcrop covered with sagebrush	50. 8
Total thickness of Skull Creek member	174. 1
Lower sandstone member:	
Sandstone, grayish-yellow, very fine grained, noncalcareous; weathers to slightly curved plates that are stained light brown to moderate yellowish orange; some ferruginous layers that weather reddish brown to dark brownish gray; fucoidal markings on bedding surfaces; forms long grass-covered dip slope covered with sandstone fragments	5. 0+

UNNAMED SANDY MEMBER

The unnamed sandy member of the Colorado shale crops out on the west side of the mapped area in broad areas along Elk and Yellow Water Creeks and in a V-shaped band bisected by Pike Creek. The member is generally nonresistant except for some thin beds of sandstone that form minor dip slopes. Sparse stands of pine and ground cedar are found at places on the outcrop of the unnamed sandy member, but generally the member supports only scattered sagebrush.

The member consists principally of medium-gray to brownish-gray sandy shale interbedded with thin platy beds of yellowish-gray to olive-gray fine-grained noncalcareous sandstone. Some of the sandstone is highly ferruginous and weathers to fragments that are light brown to purplish brown and have a metallic luster. North of Pike Creek in secs. 18 and 19, T. 13 N., R. 25 E., lenses of conglomeratic sandstone composed of dark-coated quartzite pebbles are present locally 23 feet above the base of the member. Many of the sandy layers are glauconitic, and about 1½ miles north of Mosby Post Office, in the subsurface, shale 80 to 110 feet below the top of this member is in part highly glauconitic (Cobban, 1951a, p. 2177). Several thin light-greenish-gray bentonite beds and scattered ironstone concretions that weather purplish brown are found in the member.

The unnamed sandy member is about 417 feet thick in outcrops north of Pike Creek, and it is 430 feet thick (Cobban, 1951a, p. 2177) in the subsurface about 1½ miles north of Mosby Post Office in sec. 35, T. 15 N., R. 30 E.

The unnamed sandy member of the Colorado shale lies conformably on the Skull Creek member. The contact is mapped at the base of light-colored sandy shale and thin resistant sandstone beds that overlie dark shale in the upper part of the Skull Creek.

No fossils were found in the unnamed sandy member. According to Cobban (1951a, p. 2177), it apparently is equivalent to the Newcastle sandstone of the Black Hills. A sandstone bed about 20 feet above the base of the member probably is the bed that Reeves (1927, p. 47) considered a possible equivalent of the Muddy sandstone member of the Thermopolis shale of Wyoming. Because these beds apparently are unfossiliferous and their exact stratigraphic relation to the type Newcastle sandstone and Muddy sandstone members is not known, the writers have designated these rocks as the unnamed sandy member of the Colorado shale.

The detailed lithology of the unnamed sandy member of the Colorado shale is given in the following measured section.

Section of the unnamed sandy member of the Colorado shale in the NE¼NW¼ and the N½NE¼ sec. 19 and the SE¼SW¼ sec. 18, T. 13 N., R. 25 E., Petroleum County, Mont.

	Thickness (feet)
Colorado shale:	
Mowry member:	
Sandstone, yellowish-gray to light-gray, fine-grained, shaly; iron stains on bedding; contains dark-brown fish scales	10.0
Bentonite, light-olive-gray, sandy	1.0
Sandstone, yellowish-gray to light-gray, fine-grained, thin-bedded; iron stains on bedding; contains dark-brown fish scales	.8
Unnamed sandy member:	
Shale, medium-gray, sandy, fissile to blocky; contains beds, as much as 0.15 ft thick, of hard medium-gray fine-grained sandstone	50.0
Covered interval; some fragments of sandy shale and sandstone in lower part; dark-gray popcornlike outcrop of bentonitic shale about 24 ft above base	122.4
Sandstone, olive-gray, fine-grained, noncalcareous, platy; some interbedded layers of thin shale; forms minor ledge	2.4
Shale, medium-gray to brownish-gray, sandy; ferruginous platy sandstone 0.3 ft thick near base	4.8
Bentonite, light-greenish-gray, shaly	1.7

Section of the unnamed sandy member of the Colorado shale in the NE¼NW¼ and the N½NE¼ sec. 19 and the SE¼SW¼ sec. 18, T. 13 N., R. 25 E., Petroleum County, Mont.—Continued

	Thickness (feet)
Colorado shale—Continued	
Unnamed sandy member—Continued	
Shale, medium-gray to brownish-gray, sandy; contains thin beds of ironstone concretions near top	6. 5
Sandstone, yellowish-gray to olive-gray, fine-grained, thin-bedded, hard, noncalcareous; forms short dip slope	. 8
Shale, medium-gray to brownish-gray; interbedded with thin yellowish-gray sandstone, in part very ferruginous	15. 8
Sandstone, olive-gray to yellowish-gray, fine-grained; in plates as much as 0.15 ft thick; iron stained light brown to brownish black; some interbedded layers of medium-gray to brownish-gray sandy shale	1. 0
Shale, medium-gray to brownish-gray, sandy, and very thin layers of hard iron-stained olive-gray sandstone; bed of ironstones about 8½ ft above base	40. 1
Sandstone, light-olive-gray, very fine grained, very calcareous; weathers to thin light-brownish-gray rectangular plates; forms resistant dip slope	. 5
Shale, medium-gray, sandy, with thin beds of sandstone that weather light yellowish brown to olive gray; sandstone forms very light bands on otherwise dark outcrops; sparsely covered with grass	39. 5
Sandstone, yellowish-gray to light-olive-gray, fine-grained, laminated to thin-bedded, noncalcareous; capped by very ferruginous sandstone that weathers purplish brown and has a hackly fracture; fucoidal markings on bedding surfaces; forms short dip slope	. 7
Shale, medium-gray, thin lenses of olive-gray sandstone and scattered ironstone concretions; sandy in upper part; grades into overlying sandstone	21. 8
Sandstone, dark-brownish-gray, very fine grained, hard, concretionary; weathers to hackly purplish-brown fragments; forms resistant ledge	. 3
Shale, medium-gray, sandy; contains thin interbedded layers of olive-gray sandstone and scattered purplish-brown ironstone concretions	36. 9
Partly covered interval; medium-gray sandy shale and thin olive-gray sandstone; some very thin rusty-weathering bentonite beds partly exposed; lens of purplish-brown ironstones about 3 ft below top	19. 9
Sandstone, olive-gray, very fine grained, calcareous; weathers to light-brown iron-stained fragments	. 1
Shale, medium-gray, sandy; in part bentonitic; forms bare popcornlike outcrop	1. 1
Sandstone, olive-gray, laminated to thin-bedded; weathers to light-brown iron-stained fragments	12. 4
Partly covered interval; yellowish-brown to light-brown soil littered with iron-stained fragments of olive-gray very fine grained laminated to thin-bedded sandstone	15. 0

Section of the unnamed sandy member of the Colorado shale in the NE¼NW¼ and the N½NE¼ sec. 19 and the SE¼SW¼ sec. 18, T. 13 N., R. 25 E., Petroleum County, Mont.—Continued

	Thickness (feet)
Colorado shale—Continued	
Unnamed sandy member—Continued	
Sandstone, olive-gray, very fine grained, noncalcareous, slightly crossbedded, conglomeratic; composed of subrounded to well-rounded dark-coated quartzite pebbles averaging about 0.02 ft in diameter but some as much as 0.04 ft; bed is not everywhere present; forms resistant ledge that caps a dip slope	.3–.7
Sandstone, mottled olive-gray and moderate-yellowish-brown, very fine grained, shaly; forms yellowish-gray band just under crest of dip slope	3.3
Shale, mottled medium-gray and moderate yellowish-brown, slightly sandy, bentonitic; some thin lenses of shaly sandstone that weather orange brown; forms bare yellowish-gray popcornlike outcrop	19.2
Total thickness of unnamed sandy member	416.9
Skull Creek member:	
Shale, grayish-black, slightly sandy, highly fissile; forms very dark bare popcornlike outcrop at base of steep slope	3.6

MOWRY MEMBER

The Mowry member of the Colorado shale is exposed in a broad irregular north-trending band across the western part of the mapped area. Resistant sandstone about 60 to 95 feet stratigraphically above the base of the member caps a steep escarpment that overlooks outcrops of the less resistant unnamed sandy member. On the south side of McDonald and Pike Creeks a few trees grow on the lower part of the member. The upper part weathers to silver-gray outcrops nearly bare of soil and vegetation. Oval-shaped undrained depressions, as much as 1,300 feet in length, are found on the back slope of the escarpment within a few hundred feet of the escarpment face.

In the Winnett-Mosby area the Mowry member is composed principally of sandstone interlaminated with dark-gray shale. It also contains subordinate but fairly abundant bentonite in thin layers and several thin concretionary limestone beds. The sandstone is light olive gray to brownish gray, fine grained, laminated to thin bedded, and has a siliceous cement. It is fairly soft and slightly siliceous in the lower part of the member and becomes harder and more siliceous upward. The sandstone weathers to hard brittle light yellowish-gray to silver-gray chips. Thin laminae of dark-gray shale are abundant and conspicuous in the lower part of the member, but they become less abundant upward. Bentonite is found throughout the member but is most abundant in the lower part. It is light yellowish gray to pale yellowish orange and slightly to moderately sandy; some beds contain dark-yellowish-orange limonitic streaks and have crystals of gypsum at the base. The limestone is in thin yellowish-brown to brownish-gray concretionary lenses that locally have cone-in-cone structures. Fish scales and bone fragments are conspicuous and abundant in the member, particularly in the lower half.

Rubey (1929, p. 162) examined a sample of the Mowry collected near Winnett by Frank Reeves and found that it consisted of very hard dark-gray clay laminae one-eighth of an inch thick alternating with light-gray very fine grained sandstone and siltstone laminae one-quarter of an inch thick. Microscopic examination of the coarser layers showed that the grains were less than 0.2 mm in diameter and averaged about 0.04 or 0.05 mm. The grains consisted of angular quartz, fresh orthoclase and sanidine(?), zircon, and some magnetite, hornblende(?), and cryptocrystalline material. The cement probably was cryptocrystalline quartz. The clay laminae contained a small percentage of fine sand and silt.

In a section measured on the south side of Pike Creek just south of the Winnett-Mosby area, the Mowry member is 197 feet thick. Cobban (1951a, p. 2179) reported that about 1½ miles north of Mosby post office this member is 210 feet thick in the subsurface.

The Mowry member conformably overlies the unnamed sandy member of the Colorado shale. The base of the Mowry is the base of a thin bentonite bed overlain by shaly sandstone containing abundant fish scales. The contact generally is poorly exposed in the face of an escarpment formed by resistant sandstone higher in the Mowry. A change in color between bare silver-gray outcrops of the Mowry and darker outcrops of the unnamed sandy member approximately locates the contact in areas of poor exposures. Near the contact, however, rocks in both members weather dark and the contrast in color is not pronounced.

No fossils other than fish scales and bone fragments were noted in the Mowry. The Mowry member of the Colorado shale is the youngest unit of Early Cretaceous age in the Winnett-Mosby area (Cobban, 1951a, fig. 2).

The lithologic character of the Mowry is shown in the following measured section.

Section of the Mowry member of the Colorado shale in the NE¼ and the NW¼ sec. 5, T. 12 N., R. 25 E., Petroleum County, Mont.

	Thickness (feet)
Colorado shale:	
Belle Fourche member:	
Shale, dark-gray, slightly sandy	9.0
Shale, dark-gray to brownish-gray, sandy, bentonitic	2.0
Sandstone, light-olive-gray, fine-grained, hard, concretionary; blackish-brown iron staining on joints; forms a minor ledge	.2
Shale, dark-gray to brownish-gray, slightly silty, bentonitic	2.5
Bentonite, light-olive-gray to yellowish-orange	.2

Section of the Mowry member of the Colorado shale in the NE¼ and the NW¼ sec. 5, T. 12 N., R. 25 E., Petroleum County, Mont.—Continued

	Thickness (feet)
Colorado shale—Continued	
Mowry member:	
Sandstone, medium-dark-gray to yellowish-gray, fine-grained, shaly	2.0
Covered interval	5.3
Sandstone, light-olive-gray to light-gray, fine-grained, thin-bedded, iron-stained; weathers light yellowish gray	16.0
Partly covered interval; sandstone fragments in soil	15.8
Sandstone, light-olive-gray to light-gray, fine-grained, thin-bedded, iron-stained; weathers light yellowish gray	12.0
Partly covered interval; sandstone fragments	22.1
Sandstone, light-olive-gray to brownish-gray, fine-grained, thin-bedded; iron staining on bedding; weathers yellowish gray; upper part is more resistant and forms a minor break in the slope	8.9
Partly covered interval; siliceous sandstone fragments on slope; a few feet of light-yellowish-gray siliceous sandstone with iron staining on bedding exposed at base	47.0
Sandstone, dark-yellowish-gray, fine-grained, calcareous, cross-bedded; contains small concretionary lenses of dark brownish-gray limestone with cone-in-cone structures	1.0
Partly covered interval; probably shaly sandstone	9.1
Bentonite, light-olive-gray, sandy	.2
Sandstone, light-olive-gray, fine-grained, thin-bedded, siliceous; forms resistant ledge with the underlying limestone	1.4
Limestone, light-brownish-gray to dark-yellowish-brown; cone-in-cone structures	.6
Partly covered interval; probably shaly sandstone; few feet of olive-gray sandstone at top	26.0
Sandstone, light-olive-gray, fine-grained, laminated to thin-bedded, siliceous; weathers light gray to yellowish gray; iron staining on bedding; fish bones and scales; resistant unit	16.2
Bentonite, light-yellowish-gray to pale-yellowish-orange, slightly sandy; contains gypsum fragments	.4
Sandstone, light-yellowish-brown to light-brownish-gray, fine-grained, laminated to thin-bedded; abundant fish scales	2.5
Bentonite, light-yellowish-gray to pale-yellowish-orange, slightly sandy; contains gypsum fragments	.3
Sandstone, moderate-yellowish-brown, fine-grained, soft, shaly; contains abundant fish scales; weathers light yellowish gray; iron staining on joints and bedding	7.8
Bentonite, pale-yellowish-orange, sandy; dark-yellowish-orange streaks	2.0
Total thickness of Mowry member	196.6
Unnamed sandy member:	
Shale, dark-gray to grayish-black, silty; very thin streaks of hard light olive-gray fine-grained sandstone that weather light yellowish gray and have iron stains on joints; shale weathers medium gray	9.0
Bentonite, pale- to dark-yellowish-orange, sandy; contains abundant small gypsum crystals	.8

BELLE FOURCHE MEMBER

The Belle Fourche member of the Colorado shale is exposed in the Musselshell Valley for a distance of 5 miles downstream from Mosby Post Office, and in an irregular band between McDonald and Pike Creeks southwest of Winnett. In the Musselshell Valley, trees cover much of the outcrop, particularly on north-facing slopes. In the western part of the area, the Belle Fourche is exposed in low hills that are sparsely covered by sagebrush and grass. At many localities concretion beds in the upper part of the member form thin but persistent ledges, and thin sandstone beds locally form short dip slopes.

The member is composed of medium-dark-gray to dark-yellowish-gray sandy shale, in part bentonitic. Interbedded with the shale, except in the lower 60 feet, are laminae and streaks, generally less than 0.1 foot thick, of light-gray to yellowish-gray fine-grained sandstone. A conspicuous sandstone bed about 8 feet thick is present locally in this member in the western part of the area. The lower half of the Belle Fourche contains beds of bentonite ranging in thickness from 0.4 to 3.4 feet. The bentonite is grayish yellow to yellowish orange, sandy, and shaly, and some beds contain abundant flakes of mica. Abundant ironstone concretions characterize the lower 60 feet. These concretions are hard and dense and are dark gray on a fresh surface, but they weather to dark-brownish-black chips with a metallic luster and a hackly subconchoidal fracture. The concretions are generally less than 1 foot thick, are as much as 5½ feet long, and are scattered or are in irregularly spaced beds.

Cobban (1951a, p. 2182) collected the following fossils from a sandstone about 30 feet below the top of the Belle Fourche at Yellow Water Reservoir:

Inoceramus aff. *I. fragilis* Hall and Meek
Gryphaea n. sp.
Pteria sp.
Mantelliceras? sp.
Metoicoceras? sp.

Cobban (1951a, p. 2182) found *Exogyra columbella* Meek and *Gryphaea* n. sp. in the upper 23 feet of the Belle Fourche member near Mosby in secs. 2 and 11, T. 14 N., R. 30 E.

The Belle Fourche member of the Colorado shale is equivalent to the Belle Fourche shale of the Black Hills (Cobban, 1951a, p. 2182), and is the basal unit of Late Cretaceous age in central Montana.

The following section measured in the southwestern part of the area shows the lithologic character of the Belle Fourche member of the Colorado shale.

Section of the Belle Fourche member of the Colorado shale in the SE¼ and the SW¼ sec. 27, T. 13 N., R. 25 E., Petroleum County, Mont.

	Thickness (feet)
Colorado shale:	
Mosby sandstone member:	
Sandstone, light-olive-gray, fine-grained, noncalcareous; orange limonitic streaks on bedding; layers of dark-gray shale less than 0.1 ft thick in lower half; forms basal part of ledge	4. 1
Belle Fourche member:	
Shale, medium-dark-gray, sandy; interbedded with yellowish-gray fine-grained shaly sandstone in layers less than 0.1 ft thick; grades upward into overlying sandstone	25. 7
Limestone, medium-light-gray; in septarian concretions that contain thick veins of dark-brown calcite; concretions as much as 7 ft long and 1.7 ft thick; forms a conspicuous bed	1. 0+
Shale, medium-dark-gray, sandy; very thin beds of yellowish-gray fine-grained shaly sandstone	59. 8
Limestone, dark-yellowish-orange; forms bed of concretions	1. 0+
Shale, medium-dark-gray, sandy; interbedded with very thin layers of yellowish-gray shaly sandstone; scattered dark-yellowish-orange limestone concretions and oval medium-gray septarian concretions that contain veins of light-brown calcite	39. 6
Partly covered interval; some interbedded medium-dark-gray sandy shale and yellowish-gray fine-grained shally sandstone	44. 4
Shale, medium-dark-gray, sandy; thin streaks of yellowish-gray fine-grained sandstone	3. 3
Sandstone, light-gray, fine-grained, moderately hard, thin-bedded; some medium-grained sandstone in upper part; weathered surface stained by dusky-yellow streaks; forms long yellowish-gray dip slope covered with sandstone fragments	7. 9
Shale, medium-dark-gray, sandy; bentonitic in lower part; contains beds less than 0.1 ft thick of yellowish-gray fine-grained sandstone	13. 4
Bentonite, grayish-yellow to yellowish-orange, shaly	2. 0
Shale, dark-yellowish-gray, sandy; interbedded with light-gray fine-grained very thin bedded shaly sandstone; partly covered	29. 9
Bentonite, grayish-yellow to yellowish-orange, shaly	. 4
Shale, dark-yellowish-gray, sandy; interbedded with light-gray fine-grained sandstone that weathers yellowish gray to dark yellowish brown in beds generally less than 0.1 ft thick; forms nearly bare medium-gray glistening outcrop	16. 0
Bentonite, grayish-yellow, shaly; yellowish orange at base; abundant mica flakes	1. 8
Shale, medium-dark-gray, sandy; more sandy in upper two-thirds	6. 5
Sandstone, light-olive-gray, fine-grained, concretionary; weathers light yellowish gray; iron stains along joints	. 2
Shale, medium-dark-gray, sandy; bentonitic in lower half	2. 3
Bentonite, grayish-yellow, sandy, shaly	1. 4

Section of the Belle Fourche member of the Colorado shale in the SE¼ and the SW¼ sec. 27, T. 13 N., R. 25 E., Petroleum County, Mont.—Continued

	Thickness (feet)
Colorado shale—Continued	
Belle Fourche member—Continued	
Shale, medium-dark-gray, sandy; upper 25 ft contains many large dense ironstone concretions that weather dark brownish black with metallic luster; concretions are as much as 5.7 ft long and 0.8 ft thick and have hackly subconchoidal fracture	39. 8
Ironstone, dark-gray, concretionary; weathers to hard brownish-black to dark blackish-brown chips with metallic luster; concretions are as much as 1.3 ft long and 0.6 ft thick; forms irregular bed	. 6
Shale, medium-dark-gray, sandy, fissile	1. 0
Bentonite, grayish-yellow, sandy, shaly; yellowish-orange streaks	1. 0
Shale, olive-gray to moderate olive-brown, sandy	4. 8
Bentonite, grayish-yellow, very slightly sandy; granular texture; weathers to dark-gray popcornlike surface	3. 4
Total thickness of Belle Fourche member	307. 2
Mowry member:	
Sandstone, medium-gray, fine-grained, shaly; yellowish-brown iron stain on joints and bedding	13. 6+

MOSBY SANDSTONE MEMBER

The Mosby sandstone member was named in 1921 by Lupton and Lee for exposures near Mosby Post Office on the Musselshell River. They restricted the Mosby to the lower of two sandstone units commonly present in this stratigraphic interval, but they recognized that "a somewhat similar but noncalcareous bed two feet thick, usually less conspicuous, occurs 17 feet above the Mosby member on Musselshell River and at some localities closely resembles it" (Lupton and Lee, 1921, p. 263–264). Cobban (1951a, p. 2185) redefined the Mosby to include the overlying sandstone. The present writers also include in the Mosby a few feet of noncalcareous shale just above the upper sandstone. This shale is similar to the shale interbedded with the sandstone beds.

Because of their narrow outcrop patterns, the Mosby sandstone member and the overlying calcareous shale member are shown as one unit on the geologic map. In the field, however, they are very distinct and easily recognized lithologic units.

The Mosby sandstone member crops out in the bluffs bordering the Musselshell River near Mosby Post Office and is present in the western part of the Winnett-Mosby area in a belt less than ⅛ to almost 1½ miles wide extending from the north side of McDonald Creek southwestward to the valley of Pike Creek. In the Musselshell Valley, outcrops of the Mosby are marked by a conspicuous pair of ledges. Trees grow abundantly on the sandstone and extend onto the upper part of the Belle Fourche member, particularly on north-facing slopes. In the western part of the area, the Mosby forms a prominent westward-facing escarpment on which sandstone beds weather to resistant ledges.

At most localities in the mapped area the Mosby sandstone member consists of 2 ledge-forming sandstone beds, each 5 to 7 feet thick, separated by about 11 feet of sandy shale and overlain by 6 to 8 feet of shale. The sandstone is yellowish gray, very fine grained, noncalcareous, laminated to thin bedded, and commonly is slightly crossbedded and ripple marked. The sandstone beds contain partings of sandy shale. Both sandstone units contain scattered medium-gray to yellowish-gray calcareous septarian sandstone concretions as much as 3½ feet long and light-gray septarian limestone concretions that are somewhat smaller. Both types of concretions are locally very fossiliferous. The veins in the concretions are dark-brown calcite. The upper sandstone locally has a few subrounded black chert pebbles on its upper surface. Locally, the sandstone grades laterally into sandy shale containing sandstone concretions.

Medium-gray to light-brownish-gray sandy shale with interbedded layers as much as 0.1 foot thick of light-yellowish-gray sandstone separates the 2 sandstone beds of the Mosby sandstone member. Locally, this shale contains sandy concretions similar to those in the sandstone beds. The upper shale of the Mosby is dark gray and noncalcareous.

At its type locality in the Musselshell Valley the Mosby sandstone member is about 29 feet thick and at the top of the member includes 7½ feet of shale not assigned to the Mosby by Cobban (1953a, p. 99). A transitional zone, 5 feet thick, of sandy shale and thin-bedded sandstone at the base of Cobban's measured section is assigned to the Belle Fourche member by the writers of this report. The Mosby sandstone member is also about 29 feet thick in the southwestern part of the Winnett-Mosby area.

The contact between the Mosby sandstone member and the Belle Fourche member is at the top of a transitional zone, 2½ to 5 feet thick, of interbedded sandy shale and thin-bedded sandstone.

Locally, the Mosby sandstone member contains abundant fossils, especially pelecypods and a smooth gastropod, *Pseudomelania hendricksoni* Henderson. The following fauna from the type locality near Mosby Post Office were collected and identified by Cobban (1951a, p. 2185):

Gervillia n. sp.
Inoceramus aff. *I. fragilis* Hall and Meek
Gryphaea n. sp.
Exogyra columbella Meek

Trigonocallista orbiculata (Hall and Meek)
Pseudomelania hendricksoni Henderson
Lunatia cf. *L. dakotensis* Henderson
Gyrodes conradi Meek
Anchura? sp.
Trachytriton n. sp.
Dunveganoceras aff. *D. albertense* (Warren)
Metoicoceras aff. *M. whitei* Hyatt

Ammonites from the Mosby have been described in detail by Cobban (1953b). The ammonites, *Dunveganoceras* and *Metoicoceras*, which are of very late Cenomanian age, suggest correlation with the middle part of the Greenhorn formation of the Black Hills (Cobban, 1953a, p. 99). Correlation of the Mosby sandstone member with the Greenhorn was suggested earlier by Reeves (1925, p. 91).

The detailed lithology of the Mosby sandstone member of the Colorado shale is shown in the following section.

Section of the Mosby sandstone member of the Colorado shale in the SE¼ NE¼ sec. 27 T. 13 N., R. 25 E., Petroleum County, Mont.

	Thickness (feet)
Colorado shale:	
Calcareous shale member:	
Limestone, light-yellowish-gray; occurs as highly septarian concretions that contain veins of very light yellow to white calcite crystals surrounded by dark-brown calcite; contains concretions generally 1 ft thick and about 2 ft long but some as much as 5 ft long; forms minor ledge	1. 0
Mosby sandstone member:	
Shale, dark-gray, fissile, noncalcareous; forms bare outcrop	6. 2
Sandstone, bright-yellowish-gray, very fine grained, noncalcareous; thin-bedded and platy in upper part and more massive in lower part; upper part contains small light-gray fossiliferous septarian limestone concretions that contain veins of dark-brown calcite; basal part contains scattered medium-gray to yellowish-gray calcareous slightly crossbedded sandstone concretions with abundant gastropods and pelecypods; forms prominent escarpment and dip slope	6. 8
Shale, medium-gray to light-brownish-gray, very sandy; interbedded with light-yellowish-gray to light-olive-gray noncalcareous laminated to very thin bedded sandstone; sandstone beds are lenticular and as much as 0.1 ft thick. Contains scattered light-yellowish-gray calcareous septarian sandstone concretions, 1 ft thick and 3 ft long, with dark-brown calcite veins; forms slope between the overlying and underlying sandstone beds	10. 3

Section of the Mosby sandstone member of the Colorado shale in the SE¼NE¼ sec. 27, T. 13 N., R. 25 E., Petroleum County, Mont.—Continued

	Thickness (feet)
Colorado shale—Continued	
Mosby sandstone member—Continued	
Sandstone, yellowish-gray, very fine grained, noncalcareous; in finely laminated slightly crossbedded layers as much as 0.35 ft thick; contains interbedded layers of medium-gray to light-brownish-gray sandy shale; contains a few light-yellowish-gray calcareous septarian sandstone concretions, about 1 ft thick and 3.5 ft long, with veins of dark-brown calcite; grades into overlying unit; forms the basal part of a prominent escarpment	5. 4
Total thickness of Mosby sandstone member	28. 7
Belle Fourche member:	
Shale, light-brownish-gray, sandy, noncalcareous; contains scattered lenses less than 0.1 ft thick of light-yellowish-gray very fine grained noncalcareous sandstone stained light yellowish brown by iron oxides; sandstone is more abundant in upper part; upper 2.4 ft are transitional with Mosby sandstone member	21. 0+

CALCAREOUS SHALE MEMBER

Calcareous shale that weathers very light gray and that overlies the Mosby sandstone member and underlies the Carlile member in the Winnett-Mosby area is herein designated the calcareous shale member of the Colorado shale. The type section was measured by Cobban (1953a, p. 99) on a bluff above the Musselshell River half a mile northeast of Mosby Post Office. On the geologic map the calcareous shale member is mapped with the Mosby sandstone member.

The basal 3½ feet of the calcareous shale member is noncalcareous to slightly calcareous shale that weathers light gray and has at its base a bed of closely spaced medium-gray septarian limestone concretions that weather light yellowish gray to light purplish gray and have septa of white, light-yellow, and dark-brown coarsely crystalline calcite. The concretions are as much as 1 foot thick and average about 2 feet in length, but some are as long as 5 feet. Above this gray-weathering shale is a creamy-white bentonite, about 3 feet thick, that is stained orange brown by limonite. The remainder of the calcareous shale member is mostly medium-gray calcareous shale that weathers to conspicuous very light gray outcrops. A few small white-weathering limestone concretions are present in the upper and lower parts.

The calcareous shale member is about 23 feet thick at the type locality (Cobban, 1951a, p. 2185), and the member maintains this general thickness throughout the mapped area.

The calcareous shale member conformably overlies the Mosby sandstone member, and the contact is the base of a thin but persistent bed of septarian limestone concretions.

The calcareous shale and Mosby sandstone members of the Colorado shale are equivalents of the Greenhorn formation of the Black Hills (Cobban, 1951a, p. 2185). The calcareous shale member is equivalent to the upper part of the Greenhorn, and the Mosby sandstone member is equivalent to the middle part. The only megafossils reported from the calcareous shale member in the mapped area are a few small smooth oysters of the type found in the upper part of the Greenhorn formation and in the basal part of the Carlile shale of the Black Hills; however, the member contains abundant and varied Foraminifera (Cobban 1951a, p. 2186).

The following section measured by Cobban (1953b, p. 46) shows the lithology of the calcareous shale member at the type locality.

Calcareous shale member of the Colorado shale in the N½SW¼SE¼ sec. 2, T. 14 N., R. 30 E., Garfield County, Mont.

[From Cobban (1953b, p. 46)]

	Thickness (feet)
Colorado shale:	
Carlile member:	
Limestone and shale, gray; weathers orange brown; limestone layers not more than 2 in. thick; contains a small species of smooth oyster, and fish scales, bones, and teeth	1. 3
Calcareous shale member:	
Shale, gray, calcareous; weathers to conspicuous white outcrop	15. 5
Bentonite, white with rusty stain	2. 7
Shale, dark-gray, slightly calcareous to noncalcareous; weathers gray	3. 5
Shale, gray, calcareous; contains closely spaced medium-gray calcareous septarian concretions that weather light lavender gray	1. 0
Total thickness of calcareous shale member	22. 7
Mosby sandstone member:	
Shale, dark bluish-gray, noncalcareous	7. 5

CARLILE MEMBER

The Carlile member of the Colorado shale in the Winnett-Mosby area is readily subdivided into five distinct lithologic units, which have been described by Cobban (1951a, p. 2190–2191). Because of the narrow outcrop of the basal unit, the two lowest units were mapped together. From oldest to youngest the units on the geologic map (pl. 1) are designated as the first, second, third, and fourth units of the Carlile member.

The Carlile member is widespread and well exposed in the Musselshell Valley north of Mosby Post Office, and part of the member crops out in the vicinity of Cat Creek Post Office. Rocks of this member are exposed north of Winnett along Box Elder Creek, and in the western part of the mapped area they extend from the north to the south borders.

The thickness of the Carlile member of the Colorado shale near Mosby Post Office is 310 feet (Cobban, 1951a, p. 2190). The writers did not determine the entire thickness elsewhere in the mapped area, but partial sections measured south of Yellow Water Reservoir indicate that the Carlile member is thinner there. A composite section of the Colorado shale by Lupton and Lee (1921, p. 266) shows 254 feet of strata between the top of the Carlile and the base of their "blackish sand banded with yellow clay," which probably is equivalent to the basal part of the first unit of the Carlile. About 8 miles north of Winnett, Reeves (1927, p. 46) measured 210 feet of strata between the top of the Carlile member and his Mosby sandstone; in addition to rocks of Carlile age this interval includes the calcareous shale member and the upper part of the Mosby sandstone member of this report.

The lower part of the first unit consists of 12 feet of dark-gray noncalcareous shale that weathers orange brown and contains scattered lenses, as much as 2 inches thick, of gray limestone that also weathers orange brown. The lenses are composed of minute prisms of *Inoceramus* shells. The basal part of the first unit also contains several beds of bentonite 2 to 12 inches thick.

The upper part of the first unit is composed of 36 feet of dark-bluish-gray shale. This shale is moderately resistant and over much of the area forms a bare outcrop that has a submetallic sheen. In the Musselshell Valley, however, this shale is characterized by an abundant growth of pine and juniper.

The lower part of the first unit of the Carlile member has yielded the following fauna from exposures north of Mosby Post Office in secs. 2 and 11, T. 14 N., R. 30 E. (Cobban, 1951a, p. 2190):

Inoceramus cf. *I. labiatus* (Schlotheim)
Ostrea n. sp.
Collignoniceras woollgari var. *intermedium* Haas
    woollgari var. *praecox* Haas
Scaphites patulus Cobban
Isurus cf. *I. appendiculata* (Agassiz)
    cf. *I. semiplicata* (Agassiz)
Squalicorax falcatus (Agassiz)
Ptychodus whipplei Marcou

These fossils are common to the lower unnamed member of the Carlile shale in the Black Hills. Although no fossils have been found in the upper part of the first unit, Cobban stated (1951a, p. 2190) that the lithologic character readily suggests correlation with the middle of the unnamed member of the Carlile shale of the Black Hills. In a later paper, Cobban (1953a, p. 99) also suggested a

689-268 O—63——3

correlation with at least part of the Blue Hill shale member of the Carlile of Kansas and eastern Colorado.

The second unit of the Carlile is composed of dark-gray shale that readily weathers to a medium-gray soil. This unit is characterized by abundant hard clay ironstone concretions in all except the basal 5 feet. These concretions, which generally are in irregular beds only a few inches thick, are medium gray on a fresh surface but weather moderate reddish brown to dusky red. Some of the concretions contain small grayish-orange-weathering claystone nodules, and a few have thin veins of light-yellow calcite. Also in this unit are scattered ferruginous calcareous concretions that weather to yellowish-gray to pale-yellowish-orange chips. The second unit of the Carlile member ranges in thickness from 21 feet near Mosby Post Office to almost 50 feet southwest of Yellow Water Reservoir in sec. 26, T. 13 N., R. 25 E.

The second unit forms nearly bare reddish-brown outcrops that, in the Musselshell Valley, stand out conspicuously between the tree-covered overlying and underlying units of the Carlile member. In the western part of the area the adjacent units do not support trees; however, the second unit is readily identified by its reddish-brown color.

Fossils other than *Inoceramus* are rare in the second unit of the Carlile member. The following fossils were collected by Cobban (1951a, p. 2191) from outcrops in the E½ sec. 10, T. 14 N., R. 30 E.:

Inoceramus n. sp.
Collignoniceras hyatti (Hyatt)
Scaphites carlilensis Morrow
Linuparus watkinsi Stenzel
Ptychodus whipplei Marcou

The ammonite *Collignoniceras hyatti* is a guide to rocks equivalent to the Blue Hill shale member of the Carlile of Kansas and eastern Colorado (Cobban, 1953a, p. 99). The second unit of the Carlile is almost identical lithologically with the upper part of the unnamed member of the Carlile shale in the Black Hills (Cobban, 1951a, p. 2190) and is a widespread and easily recognized zone in Upper Cretaceous rocks over much of Montana. It is on the flanks of the Little Rocky Mountains (Reeves, 1925, p. 87), on the Sweetgrass arch (Cobban, 1951a, p. 2191), on Devils Basin dome (Reeves, 1925, pl. 11), and in the Hardin area of southern Montana (Richards, 1955, p. 52).

The third unit of the Carlile is composed of dark-gray sandy shale containing very thin lenses and streaks of light- to medium-gray very fine grained sandstone. In the lower part the shale and sandstone are interlaminated, and the weathered outcrop has a banded appearance. This weathering feature is readily observed just south of State Route

18 in the SE¼ sec. 7, T. 14 N., R. 31 E. A characteristic feature of this unit is the presence of irregular beds of large yellowish-orange-weathering limestone concretions, some with cone-in-cone structures. Smaller light-gray-weathering limestone concretions also are present. Some concretions are septarian with veins of light-yellow and dark-brown calcite. The yellowish-orange-weathering concretions are most abundant in outcrops along Sage Hen Creek. In that area a conspicuous bed about 12 feet below the top of the unit contains concretions as much as 7 feet thick and 10 feet in diameter. In the area southwest of Winnett the concretions in the third unit generally weather light gray, some with a yellowish hue. The few beds of orange-weathering concretions are found in the lower part of the unit, the most conspicuous bed being about 6 feet above the base.

The third unit of the Carlile member is 93 feet thick (Cobban, 1951a, p. 2191) east of Mosby Post Office, but it thins to about 78 feet near Pike Creek in the SE¼ sec. 26, T. 13 N., R. 25 E.

In the Musselshell Valley the third unit of the Carlile crops out in the lower part of the slope that rises gradually from the outcrop belt of the second unit to a ledge or low escarpment formed by overlying rocks. In that part of the area this unit commonly is covered with pine and cedar. The outcrop band of the third unit in the western part of the mapped area is covered by scattered patches of grass and sagebrush.

No fossils have been collected from this unit of the Carlile member in the Winnett-Mosby area. Its stratigraphic position and lithologic character suggest a correlation with the Turner sandy member of the Carlile shale of the Black Hills (Cobban, 1951a, p. 2191).

The fourth unit of the Carlile member consists of light-olive-gray, light-brownish-gray, and dark-gray noncalcareous sandy shale. The shale is more sandy upward, and the upper part of the member locally contains very thin lenses of shaly sandstone. The unit contains abundant septarian limestone concretions that commonly weather light gray to light yellowish gray, but a few weather grayish orange. Dark-brown calcite comprises most of the veins, but light-yellow and white to colorless calcite commonly is present. Some veins have a layer of dark-brown calcite crystals adjacent to the walls, and the middle of the vein is more coarsely crystalline light-yellow calcite. Some concretions are geodes in which the void is partly filled by large crystals of colorless calcite. Crystals of white or brown barite are sparsely present. In general, the larger concretions are oval and the smaller ones round. Concretions as much as 4 feet thick and 10 feet long are not uncommon. This shale unit weathers to rather dark outcrops cut by light bands of concretions. The concretions may cap low pedestals of shale or weather to resistant ledges.

The fourth unit of the Carlile is 147 feet thick east of Mosby Post Office (Cobban, 1951a, p. 2191) and 113 feet thick south of the Yellow Water Reservoir in sec. 25, T. 13 N., R. 25 E.

In the Musselshell Valley, rocks of the fourth unit underlie the upper part of a slope between the second unit of the Carlile and the base of the overlying Niobrara member. East of the river the fourth unit, particularly the lower part, carries a good growth of trees. West of the river only scattered stands of trees are on the outcrop, mainly on north-facing slopes. Elsewhere in the Winnett-Mosby area, outcrops of this unit are almost bare.

In the Musselshell Valley, the basal contact of the fourth unit is about 12 feet above a conspicuous bed of yellowish-orange-weathering concretions in the upper part of the third unit. Where this bed of concretions is not present, the contact was drawn above the uppermost occurrence of orange-weathering concretions. In the western part of the Winnett-Mosby area where the color of the concretions in the third and fourth units is very similar, the contact could be located only approximately.

Fossils in the fourth unit of the Carlile member are rare. The following were the only ones reported by Cobban (1951a, p. 2191):

Inoceramus n. sp.
Baculites cf. *B. besairiei* Collignon
Scaphites sp.

On the basis of lithology and stratigraphic position this unit correlates with the Sage Breaks member of the Carlile shale of the Black Hills.

The lithology and thickness of the units of the Carlile member of the Colorado shale have been described by Cobban (1953a, p. 99) in the following measured section.

Section of the Carlile member of the Colorado shale along State Route 18, starting a quarter of a mile east of Mosby Post Office. Upper two units measured south of the highway in the SW¼SE¼ sec. 7, T. 14 N., R. 31 E., and in the NW¼NE¼ sec. 18, T. 14 N., R. 31 E.

[From Cobban (1953a, p. 99; 1953b, p. 45–46)]

	Thickness (feet)
Colorado shale:	
Niobrara member:	
Shale, gray, bentonitic; contains light-gray calcareous septarian concretions so closely spaced as to form a continuous buff ledge. Sage Hen sandy limestone of Lupton and Lee (1921)	1. 5
Carlile member:	
Fourth unit:	
Shale, dark-gray; contains numerous gray- to buff-weathering calcareous septarian concretions with veins of white, yellow, or dark-brown calcite	147. 0

Section of the Carlile member of the Colorado shale along State Route 18, starting a quarter of a mile east of Mosby Post Office. Upper two units measured south of the highway in the SW¼SE¼ sec. 7, T. 14 N., R. 31 E., and in the NW¼NE¼ sec. 18, T. 14 N., R. 31 E.—Continued

	Thickness (feet)
Colorado shale—Continued	
Carlile member—Continued	
Third unit:	
Shale, dark-gray; contains yellow-weathering calcareous concretions and cone-in-cone concretions and thin lenses of very fine grained sandstone	93.0
Second unit:	
Shale, dark-gray; readily breaks down into medium-gray soil; contains numerous clay ironstone concretions that weather maroon to rust in upper 16 ft; outcrops bare of trees; supports sagebrush	21.0
First unit:	
Shale, dark-bluish-gray; forms dark outcrops that are bare of grass but have abundant trees	36.0
Bentonite, creamy-yellow	.5
Shale, dark-gray; weathers orange brown; contains lenses, as much as 1.5 in. thick, of tan-weathering fossiliferous limestone. Contains fossils of Fairport age. (USGS Mesozoic loc. 21398; *Inoceramus* cf. *I. labiatus* (*Schlotheim*), *Ostrea* n. sp., *Collignoniceras woollgari* var. *praecox* Hass, *C. woollgari* var. *intermedium* Haas, *Scaphites patulus* Cobban, *Isurus* cf. *I. appendiculatus* (Agassiz), *Isurus* cf. *I. semiplicatus* (Agassiz), *Squalicorax falcatus* (Agassiz), *Ptychodus whipplei* Marcou	5.6
Bentonite, greenish-gray	.2
Shale, dark-gray; weathers orange brown; contains a few layers of limestone less than 0.25 in. thick	3.0
Bentonite, gray and greenish-gray, finely micaceous; weathers whitish	1.0
Limestone and shale, gray	.1
Shale, black-gray	.2
Bentonite, creamy and gray	.2
Limestone and shale, gray; weathers orange brown; limestone layers not more than 2 in. thick; contains a small species of smooth oyster, and fish scales, bones, and teeth	1.3
Total thickness of Carlile member	309.1
Calcareous shale member:	
Shale, gray, calcareous; weathers creamy white; upper part contains a few white-weathering limestone concretions	15.5

NIOBRARA MEMBER

The Niobrara member is the uppermost member of the Colorado shale in the Winnett-Mosby area. It crops out in the north-central part of the area in low rolling grass- and sagebrush-covered hills along Cat Creek and in an irregular band surrounding outcrops of older rocks near Mosby Post Office. It is also intermittently exposed in a band, as much as 3 miles wide, in the western part of the area south of Winnett, where terrace gravel and alluvium cover the member at many places.

The Niobrara member consists of a lower noncalcareous unit about 206 feet thick and an upper calcareous unit about 173 feet thick. The lower unit includes at the base a conspicuous bed of closely spaced septarian concretions, about 1 to 1.5 feet in diameter, composed of light-yellowish-gray sandy limestone with veins of white, amber, and dark-brown calcite. The concretions are imbedded in bentonitic shale that contains fibrous aragonite. This concretion bed was called the Sage Hen limestone by Lupton and Lee (1921, p. 264). It forms a low escarpment in outcrops east of the Musselshell River. The remainder of the lower unit consists of light-olive-gray shale that is slightly sandy and contains many thin bentonite beds in the lower 81 feet, becoming more sandy with few or no bentonite beds in the upper 125 feet. The bentonite beds in the lower part of the unit are all less than 0.5 foot thick, locally weather light orange brown, and contain fragments and small nodules of yellowish-gray limestone and fibrous aragonite. Several beds of locally fossiliferous concretions of various kinds occur in the upper part of the lower unit including concretions of yellowish-gray to light-gray calcareous sandstone, light-yellowish-gray to light-brownish-gray limestone with veins of amber calcite, and yellowish-gray aragonite with cone-in-cone structures. The concretions give a banded appearance to bare slopes.

Cobban (1953a, p. 99) reported a bed of phosphatic pebbles about 55 feet above the base of the member east of Mosby and suggested that it may mark a minor hiatus.

The upper calcareous unit consists of light-olive-gray to light-brownish-gray shale that weathers light orange to light yellow and is characterized by many tiny white specks on the bedding surfaces. Interbedded with the shale are a few very thin layers of bentonite. Light-grayish-yellow calcareous very fine grained sandstone occurs in small scattered nodules in the middle of the unit and in thin lenses at the top.

The Niobrara member is about 379 feet thick north of Sage Hen Creek in sec. 5, T. 14 N., R. 31 E. Cobban (1953a, p. 99) reported a thickness of 402 feet at about this locality for beds he considers equivalent to the Niobrara at the type area in Nebraska. He placed the contact between his Niobrara equivalent and the overlying Telegraph Creek formation 45 feet stratigraphically lower than the top of the Niobrara member of this report. The base of the Sage Hen limestone of Lupton and Lee (1921) is conformable with the underlying Carlile member.

Fossils collected by Cobban (1951a, p. 2193) from the Niobrara member indicate a lower faunal zone characterized by *Scaphites preventricosus* Cobban and an upper zone characterized by *Clioscaphites vermiformis* (Meek and Hayden). The following fossils were collected from beds 6 feet above the base of the member and represent the lower zone:

Inoceramus cf. *I. deformis* Meek
Anomia sp.
Scaphites preventricosus var. *sweetgrassensis* Cobban

The following species were found by Cobban in concretions in the upper, banded part of the noncalcareous unit of the member and represent the upper zone:

Inoceramus sp.
Ostrea congesta Conrad
Trigonocallista sp.
Drepanchilus sp.
Baculites asper Morton
Baculites codyensis Reeside
Clioscaphites vermiformis (Meek and Hayden)

The calcareous unit of the Niobrara yielded the following fossils typical of the upper zone:

Baculites codyensis Reeside
Clioscaphites vermiformis (Meek and Hayden)
Fish bones and scales

Cobban (1953a, p. 100) regarded as significant the occurrence of the upper Niobrara ammonite, *Clioscaphites vermiformis*, as low stratigraphically as the banded part of the noncalcareous unit of the Niobrara member. Fragments of *Desmoscaphites*, an ammonite known only from upper Niobrara or lower Telegraph Creek beds in other parts of Montana, were collected by Cobban about 95 feet below the top of the Niobrara member. Limestone concretions near the top of the member contain *Haresiceras natronense*, *H. placentiforme* var. *parvum*, *Scaphites hippocrepis*, and other fossils considered as guides to rocks equivalent to the Eagle sandstone of south-central Montana (Cobban, 1953a, p. 100). These fossils show that the upper part of the Niobrara member in the Winnett-Mosby area includes rocks that are appreciably younger than rocks called Niobrara in some other parts of Montana.

Rocks of the Niobrara member are described in the following measured section.

Section of the Niobrara member of the Colorado shale in the S½ sec. 5, T. 14 N., R. 31 E., Garfield County, Mont.

	Thickness (feet)
Telegraph Creek formation:	
Shale, light-yellowish-gray, sandy; weathers dull gray; many thin beds of ironstone concretions that weather reddish brown	6.5+
Colorado shale:	
Niobrara member:	
Shale, light-olive-gray to light-brownish-gray, very calcareous; thin lenses of light-yellowish-gray very calcareous very fine grained sandstone at top; middle part contains scattered small nodules of light-grayish-yellow very calcareous sandstone that weather bright orange brown and scattered chips of light-yellow aragonite; weathers light orange in lower part to light yellow in upper part	172.7
Shale, light-olive-gray to very light brownish-gray, sandy, noncalcareous; lower one-third contains beds of yellowish-gray to light-gray calcareous sandstone concretions, light-yellowish-gray to light brownish-gray sandy septarian limestone concretions with veins of amber calcite, and yellowish-gray aragonite concretions with cone-in-cone structures; some concretions are very fossiliferous; thin bed of bentonite about 14 ft above base; scattered large crystals of clear calcite weathering out of the shale; weathers to alternating light and dark bands	124.8
Shale, light-olive-gray to olive-gray, slightly sandy, noncalcareous	31.2
Shale, light-olive-gray to olive-gray, slightly sandy, noncalcareous; contains many beds, less than 0.5 ft thick, of olive-gray bentonite, some of which weather bright orange brown; bentonite contains light-yellowish-gray fibrous aragonite and small nodules of yellowish-gray limestone; weathers dark gray with thin light-gray bands and streaks	32.9
Shale, light-olive-gray to olive-gray, slightly sandy, noncalcareous	17.0
Limestone, light-yellowish-gray, sandy; consists of closely spaced septarian concretions with veins of dark-brown, amber, (.8) and white calcite; weathers light gray to bright grayish yellow; forms prominent ledge (Sage Hen limestone of Lupton and Lee, 1921)	.8
Total thickness of Niobrara member	379.4
Carlile member:	
Fourth unit:	
Shale, light-olive-gray to light-brownish-gray sandy, noncalcareous; locally contains very thin lenses of shaly sandstone; contains abundant light-yellowish-gray septarian limestone concretions with veins of amber and dark-brown calcite	20.0+

UPPER CRETACEOUS

TELEGRAPH CREEK FORMATION

The Telegraph Creek formation in the Winnett-Mosby area includes the strata between the top of the Niobrara member of the Colorado shale and the base of the stratigraphically lowest cliff-forming sandstone of the Eagle sandstone. In some areas, mainly east of the Musselshell River, the Eagle is almost entirely sandy shale; consequently, the Telegraph Creek and Eagle could not be differentiated, and in those areas the two formations were mapped together. In the north-central part of the area the Telegraph Creek crops out in a relatively narrow elliptical band that surrounds the post offices of Mosby and Cat Creek, and in the western part of the area it crops out in a southward-trending strip through Winnett. Over most of its outcrop area the Telegraph Creek is on the face of a rather steep escarpment capped by younger rocks. East of the Musselshell River, the member weathers to gentle nearly bare slopes deeply trenched by narrow, steep-sided gullies.

The lower part of the Telegraph Creek formation is mainly light-olive-gray to yellowish-gray noncalcareous sandy shale, interlaminated and interbedded with light-yellowish-gray fine-grained noncalcareous to very calcareous sandstone. Numerous thin layers of ironstone concretions that weather to hard moderate-yellowish-brown to light-reddish-brown chips characterize the lower part of the formation, particularly the basal 15 to 20 feet. Small hard medium-light-gray sandy limestone concretions that weather dull yellowish gray also are sparsely present in the lower part. The upper part of the Telegraph Creek is mostly light-olive-gray to yellowish-gray very fine to fine-grained noncalcareous sandstone. The sandstone is soft, but contains large hard light-gray to yellowish-gray calcareous sandstone concretions that weather bright orange yellow and locally contain veins of light-brown calcite. Ironstones are sparse in the upper part of the formation.

Four beds of bentonite, ranging in thickness from 1 to 2.3 feet, were noted in the Telegraph Creek formation in and to the east of the Musselshell Valley, but no bentonite beds were observed west of the valley. The bentonite is light olive gray to yellowish gray and shaly to locally sandy. The two thickest beds form a pair of conspicuous white bands 126 to 139 feet above the base of the formation in the rough country bordering the river. The lower bed of bentonite is 2.3 feet thick and is separated by 8.6 feet of sandstone from the upper bed, which is 1.7 feet thick. Both bentonite beds contain abundant fragments of light-yellowish-brown aragonite, some with cone-in-cone structures. The lower of the two beds was called the ivory band by Lupton and Lee (1921, p. 265), who placed the Eagle-Telegraph

Creek contact at the base of this bed in the area east of the Musselshell River.

The thickness of the Telegraph Creek formation in the Winnett-Mosby area varies according to the stratigraphic horizon chosen for the upper contact. At Winnett the Telegraph Creek is about 164 feet thick. To the north along Box Elder Creek the formation is about 130 feet thick. Along the south side of Cat Creek in T. 15 N., Rs. 28 and 29 E., the formation is about 140 feet thick. Near the Musselshell River in sec. 20, T. 14 N., R. 30 E., the lowest resistant sandstone in the Eagle is 210 feet above the base of the Telegraph Creek formation. Along the east side of the river in sec. 34 of the same township, 234 feet of strata was measured in the Telegraph Creek below the lowest resistant sandstone of the Eagle. East and north of Mosby Post Office, where the Telegraph Creek and Eagle cannot be differentiated, Cobban (1953a, p. 98) measured 527 feet of strata that he designated as rocks equivalent to the Eagle sandstone, including 45 feet that the writers place in the Niobrara.

The Telegraph Creek formation conformably overlies the Niobrara member of the Colorado shale. Noncalcareous sandy shale in the lower part of the Telegraph Creek weathers to light-yellowish-gray slopes that contrast conspicuously with the calcareous shale that weathers light orange in the upper part of the Niobrara. The contrast is accentuated by the abundant light reddish-brown ironstones in the basal part of the Telegraph Creek.

Cobban (1953a, p. 100) collected *Scaphites hippocrepis* var. *tenuis* from beds in the lower part of the Telegraph Creek-Eagle interval east of the Musselshell River. Cephalopods of the Telegraph Creek formation and Eagle sandstone have been described by Reeside (1927).

The following measured sections describe the lithology of the Telegraph Creek formation in the Winnett-Mosby area.

Section of the Telegraph Creek formation in the SE¼NW¼ sec. 7, T. 14 N., R. 27 E., Petroleum County, Mont.

	Thickness (feet)
Eagle sandstone:	
Sandstone, dusky-yellow, fine-grained, massive; lower 8 ft is nonresistant; contains hard oval sandstone concretions as much as 1.5 ft long and 0.5 ft thick; capped by a hard persistent concretionary ledge 1 to 2 ft thick; entire unit forms a prominent cliff	49. 4
Telegraph Creek formation:	
Sandstone, light-olive-gray with lenses that weather dark yellowish orange; fine grained, nonresistant; grades into overlying units	11. 6
Shale, yellowish-gray to light-olive-gray, sandy; grades upward into olive-gray to moderate-yellowish-brown fine-grained laminated to thin-bedded nonresistant sandstone; contains hard pellets and thin lenses of dark-yellowish-orange sandstone; partly covered in upper part	38. 8

Section of the Telegraph Creek formation in the SE¼NW¼ sec. 7, T. 14 N., R. 27 E., Petroleum County, Mont.—Continued

	Thickness (feet)
Telegraph Creek formation—Continued	
Sandstone, yellowish-gray, calcareous, concretionary; weathers to hard dark-yellowish-orange chips; contains veins of light-gray calcite	.3–.7
Shale, light-olive-gray to yellowish-gray, sandy; few beds as much as 0.5 in. thick of light yellowish-gray fine-grained sandstone; many beds, less than 4 in. thick, of ironstone that weather yellowish orange to moderate brown	112.4
Total thickness of Telegraph Creek formation	163.5
Colorado shale:	
Niobrara member:	
Shale, yellowish-gray to light-brownish-gray, very slightly silty, calcareous; a few very thin lenses of light-yellowish-gray fine-grained calcareous platy sandstone; weathers to a light-orange slope which contrasts rather sharply with overlying dull-yellowish-gray beds of the Telegraph Creek	22.9

•

Section of the Telegraph Creek formation in the SE¼SW¼ sec. 26, T. 15 N., R. 29 E., Petroleum County, Mont.

Eagle sandstone:	
Sandstone, yellowish-gray, fine-grained, calcareous, nonresistant; weathers bright yellowish-gray; abundant light-yellow calcite with cone-in-cone structures	1.5
Sandstone, yellowish-gray, very fine grained to fine-grained, noncalcareous, moderately hard, massive; capped by layer of large yellowish-gray fine-grained calcareous sandstone concretions as much as 6 ft long, 5 ft wide, and 3 ft thick; concretions weather dark yellowish brown and have a speckled appearance due to a coating of gray and black moss; forms a low escarpment capped by concretionary ledge	5.1
Telegraph Creek formation:	
Sandstone, light-olive-gray at the base grading to yellowish-gray at the top; very fine to fine grained, noncalcareous, nonresistant; contains large oval light-gray calcareous sandstone concretions that weather bright orange yellow; these concentric-weathering concretions are as much as 3 ft long and 2.5 ft wide; grades into overlying massive sandstone	42.7
Sandstone, olive-gray to light-olive-brown, fine-grained, noncalcareous, soft, shaly to massive; scattered ironstone concretions in lower two-thirds; layer of light-yellowish-gray very calcareous sandstone concretions as much as 0.5 ft thick about 7 ft below top that weather bright orange yellow; forms light-gray slope	23.5
Shale, light-olive-gray, sandy, noncalcareous; contains hard medium-light-gray sandy limestone concretions, ranging from 0.2 to 0.6 ft long and 0.1 to 0.3 ft thick, that weather dull yellowish gray; some scattered ironstone concretions; thin layer of light-yellowish-gray calcareous sandstone concretions about 20 ft below the top	38.2

Section of the Telegraph Creek formation in the SE¼ SW¼ sec. 26, T. 15 N., R. 29 E., Petroleum County, Mont.—Continued

	Thickness (feet)
Telegraph Creek formation—Continued	
Shale, light-olive-gray, sandy, noncalcareous; beds less than 0.2 ft thick of light-yellowish-gray noncalcareous sandstone and scattered beds as much as 0.5 in. thick of very calcareous sandstone; abundant ironstones 0.5 to 1.5 in. thick that weather to moderate-yellowish-brown to light-reddish-brown chips; ironstones most abundant in basal 15 ft; unit weathers light yellowish gray	38.4
Total thickness of Telegraph Creek formation	142.8
Colorado shale:	
Niobrara member:	
Shale, moderate-yellowish-brown, sandy, very calcareous	3.5
Sandstone, light-olive-gray to yellowish-gray, very fine grained, very calcareous, finely laminated; abundant white specks on bedding; weathers to chips stained with bright-orange streaks; a persistent bed that can be identified over most of the area	.1
Shale, light-olive-gray to dark-yellowish-brown, clayey to slightly sandy; mostly noncalcareous in lower part becoming very calcareous upward; contains gypsum crystals; weathers to light-yellowish-orange slope	20.5

EAGLE SANDSTONE

Outcrops of the Eagle sandstone are conspicuous and widespread in the Winnett-Mosby area. The Eagle crops out over much of the central and south-central parts and extends in a narrow southeastward-trending band from an area north of Cat Creek to an area southeast of Mosby Post Office.

Throughout most of the area west of the Musselshell Valley, the Eagle sandstone is readily divisible into three members—a basal cliff-forming sandstone, a middle sandy shale, and an upper sandstone and shale. From the vicinity of the Musselshell River in sec. 17, T. 15 N., R. 30 E., southeastward to sec. 22, T. 14 N., R. 31 E., both the upper and lower members grade laterally into sandy shale and cannot readily be identified; in this area also the Eagle sandstone and underlying Telegraph Creek formation cannot be differentiated.

Sandstone in the lower member of the Eagle is grayish yellow to dusky yellow, soft to moderately hard, massive, and fine grained. It contains large oval yellowish-gray calcareous sandstone concretions which attain a thickness of 3 feet and length of about 6 feet, and generally are irregularly spaced in beds that form thin ledges. These ledges are persistent for long distances, and therefore are useful horizons for obtaining structural data. Four concretionary ledges are in the lower sandstone member along Box Elder Creek in T. 15 N., R. 27 E., and in an escarpment near Winnett. The top of the lower member is capped by a layer of large hard irregularly crossbedded sandstone concretions that cap low pedestals at places on the south side of Flat Willow Creek. The lower sandstone of the Eagle is about 80 feet thick near Winnett, increases in thickness to about 106 feet, and includes some shaly sandstone a few miles to the northeast in sec. 26, T. 15 N., R. 29 E. Farther to the east the sandstone grades into sandy shale, and the lower member becomes correspondingly thinner. Along the Musselshell River opposite the mouth of Flat Willow Creek the member is about 37 feet thick; in sec. 31, T. 14 N., R. 31 E., it is 16 feet thick; and along the outcrop north of sec. 22 of the same township it is not recognizable.

The middle member of the Eagle sandstone is composed of about 73 feet of olive-gray sandy shale interbedded with very thin beds of yellowish-gray to olive-gray fine-grained shaly sandstone. Scattered in the shale are large oval concretions of medium-dark-gray fine-grained calcareous sandstone and small concretions of light-reddish-brown to yellowish-brown ironstone. Crystals of gypsum are found in the shale.

The upper member of the Eagle consists of a lower resistant sandstone and an upper unit of soft friable sandstone and sandy shale. The lower sandstone is generally 20 to 25 feet thick, is light yellowish gray to olive gray, and is fine grained. It is soft and friable near the base, but is capped by a layer of hard light-yellowish-gray calcareous fine- to medium-grained slightly crossbedded sandstone concretions that weather medium brown. Some of these concretions are as much as 10 feet long and 4 feet thick. Eastward from the Musselshell Valley the lower sandstone grades laterally into sandy shale.

The upper unit of the upper member of the Eagle consists of yellowish-gray to olive-gray fine-grained soft shaly sandstone and sandy shale. Scattered in the unit are medium-light-gray to-light olive-gray fine-grained calcareous sandstone concretions that weather yellowish to brownish gray. Also present are a few medium-gray septarian limestone concretions that weather light brownish gray and contain shell fragments. The upper part of the Eagle contains several thin but conspicuous beds of medium-gray calcareous ironstone concretions that weather moderate yellowish brown to reddish brown. Very thin lenses of polished subrounded pebbles of black chert and dark-olive-gray phosphatic material are found in the shale about 5 feet above the base of the upper member and also near the top of the formation. The upper unit of the upper member of the Eagle is 85 to 90 feet thick in the mapped area.

A composite section of the Eagle sandstone measured in secs. 26 and 35, T. 15 N., R. 29 E., and secs. 4, 5, and 9, T. 14 N., R. 29 E., shows a thickness of about 288 feet.

West of the Musselshell River the Eagle is characterized by a prominent escarpment, in places as high as 50 feet, formed by the lower member. The upper member also forms an escarpment, but generally it is less pronounced. The middle member generally weathers to low, rolling country trenched by deep, steep-sided gullies. East of the river the upper and lower sandstone members are thinner and in some areas absent, and the formation weathers to rolling country of rather low relief.

The contact between the Eagle sandstone and the Telegraph Creek formation is gradational and is placed at the base of the lowest cliff-forming sandstone. Where the sandstone in the Eagle-Telegraph Creek sequence becomes less resistant and grades to sandy shale, the contact rises stratigraphically, and the nonresistant shaly sandstone and sandy shale are arbitrarily included in the Telegraph Creek formation.

Reeside (1927) has described cephalopods found in the Eagle sandstone, including specimens collected in or near the Winnett-Mosby area. Fossils collected by Cobban (1953a, p. 100) from the Eagle east of Mosby Post Office include long-ranging species found in both the Eagle and the overlying Claggett shale.

The first of the following measured sections shows the lithology of the Eagle in an area where the formation is divisible into three members, and the second shows the Eagle and the Telegraph Creek formation in an area east of the Musselshell River where the two formations cannot be differentiated.

Composite section of the Eagle sandstone: basal part measured in the SE¼SW¼ sec. 26; lower and middle parts in the NW¼NE¼ and the SE¼SE¼ sec. 35, T. 15 N. R. 29 E.; upper part in the SW¼SW¼ sec. 4, the SE¼SE¼ sec. 5, and the NW¼NW¼ sec. 9, T. 14 N., R. 29 E., Petroleum County, Mont.

	Thickness (feet)
Claggett shale:	
Shale, dark-olive-gray, clayey, bentonitic	5.0
Eagle sandstone:	
Upper member:	
Partly covered interval; mostly yellowish-gray sandy shale; scattered ironstone concretions and small dark chert and phosphatic pebbles	31.5
Ironstone concretions, medium-gray, calcareous; weather moderate yellowish brown to reddish brown	.3
Shale, olive-gray to yellowish-gray, sandy	10.5
Ironstone concretions, medium-gray, calcareous; weather moderate yellowish brown to reddish brown; form resistant bed	.5
Sandstone, olive-gray to yellowish-gray, fine-grained, shaly to blocky; upper part interbedded with olive-gray to yellowish-gray sandy shale; contains scattered concretions of hard medium-light-gray to light-olive-gray fine-grained calcareous sandstone that weather yellowish to brownish gray and have poorly developed cone-in-cone structures; contains some oval medium-gray septarian limestone concretions that weather light brownish gray and contain shell fragments; contains scattered large gypsum crystals; weathers yellowish gray	32.4
Shale, olive-gray, sandy; interbedded with very thin layers of yellowish-gray fine-grained shaly sandstone; very thin lenses of dark-olive-gray to black subrounded chert and phosphatic pebbles 0.02 to 0.05 ft in diameter in upper half; gypsum crystals in the sandstone layers; shale grades into overlying unit; lower half partly covered	9.3
Sandstone, olive-gray and yellowish-gray, fine-grained, non-resistant in lower part becoming more indurated upward; capped by irregular layer of hard light-yellowish-gray calcareous sandstone concretions as much as 6 ft long, 3.5 ft wide, and 2.5 ft thick; forms conspicuous cliff nearby	23.9
Middle member:	
Shale, olive-gray, sandy; interbedded with very thin beds of soft yellowish-gray to olive-gray fine-grained shaly sandstone; sandstone becomes more abundant in upper 20 ft; a few medium-dark-gray calcareous sandstone concretions that weather yellowish-brown and are as much as 3.5 ft long, 2.5 ft wide, and 1 ft thick; scattered small yellowish-brown to reddish-brown ironstone concretions; some gypsum crystals in the shale	73.5

Composite section of the Eagle sandstone: basal part measured in the SE¼SW¼ sec. 26; lower and middle parts in the NW¼NE¼ and the SE¼SE¼ sec. 35, T. 15 N. R. 29 E.; upper part in the SW¼SW¼ sec. 4, the SE¼SW¼ sec. 5, and the NW¼NW¼ sec. 9, T. 14 N., R. 29 E., Petroleum County, Mont.—Continued

	Thickness (feet)
Eagle sandstone—Continued	
Lower member:	
Sandstone, yellowish-gray, fine-grained, slightly calcareous, friable in part, soft to moderately hard; contains hard concretionary layers of very calcareous crossbedded sandstone that form discontinuous ledges; upper part capped by crossbedded sandstone concretions; some carbonaceous shale in upper part; thin layer of yellowish calcite about 6 ft above base; forms a cliff	34.0
Sandstone, olive-gray to yellowish-gray, fine-grained, shaly, and sandy shale; contains scattered ironstone concretions that weather reddish brown; becomes more sandy in upper part and grades into overlying sandstone	64.3
Shale, olive-gray, clayey, bentonitic; calcite chips in upper part	1.3
Sandstone, yellowish-gray, calcareous, nonresistant; weathers bright yellowish gray; abundant light-yellow calcite with cone-in-cone structures	1.5
Sandstone, yellowish-gray, very fine grained to fine-grained, noncalcareous, moderately hard, massive; capped by layer of large yellowish-gray fine-grained calcareous sandstone concretions as much as 6 ft long, 5 ft wide, and 3 ft thick; concretions weather dark yellowish brown and have a speckled appearance due to a coating of gray and black moss; forms a minor escarpment capped by concretionary ledge	5.1
Total thickness of Eagle sandstone	288.1
Telegraph Creek formation:	
Sandstone, light-olive-gray to yellowish-gray, very fine grained to fine-grained, noncalcareous, nonresistant; contains large oval light-gray calcareous sandstone concretions, as much as 3 ft long and 2.5 ft wide, that weather orange yellow; concretions are concentric weathering; weathers light gray near base, becomes yellowish gray upward, and grades into overlying massive sandstone	42.7

Section of the Eagle sandstone and Telegraph Creek formation, undifferentiated, in the S½ sec. 5 and the NW¼ sec. 4, T. 14 N., R. 31 E., Garfield County, Mont.

[From Cobban (1953a, p. 98)]

	Thickness (feet)
Claggett shale:	
Shale, dark-gray; contains iron-stained calcareous septarian concretions at base	6
Eagle sandstone and Telegraph Creek formation, undifferentiated:	
Shale, gray; weathers light gray; contains two 6-in. layers of bentonite and 2 beds of gray calcareous concretions	107
Shale, gray; contains rusty-weathering ferruginous concretions and scattered gray calcareous concretions	243
Bentonite, creamy-gray, granular; abundant aragonite	2

Section of the Eagle sandstone and Telegraph Creek formation, undifferentiated, in the S½ sec. 5 and the NW¼ sec. 4, T. 14 N., R. 31 E., Garfield County, Mont.—Con.

	Thickness (feet)
Eagle sandstone and Telegraph Creek formation, undifferentiated—Con.	
Shale, gray, sandy; weathers buff; contains calcareous concretions that weather buff, tan, or brown	86
Shale, gray, sandy; weathers light gray; contains numerous rusty-weathering ferruginous concretions	44
Total thickness of Eagle sandstone and Telegraph Creek formation, undifferentiated	482
Colorado shale:	
Niobrara member:	
Shale, gray, slightly calcareous; weathers orange brown; contains thin layers and lenses of siltstone and a few lenses of very fine grained sandstone; a few small limestone concretions in uppermost part	45

CLAGGETT SHALE

The Claggett shale crops out in the south-central part of the mapped area in several broad irregular areas, and in the eastern and north-central parts in a narrow V-shaped band, the apex of which is to the east. In the eastern and north-central parts of the area, the Claggett generally weathers to nearly bare slopes below a hogback formed by overlying rocks. Southeast of Mosby Post Office, the formation is covered with trees that make a dark band discernible for long distances. Elsewhere, the Claggett forms nearly bare rolling country with exposures of dark glistening shale and thin light-colored bands of powdery bentonite.

The Claggett is composed of brownish-gray marine shale with many layers of bentonite in the lower 85 feet. The bentonite is grayish yellow, granular, and contains abundant light-yellow to light-brown aragonite. Limestone concretions as much as 3 feet long are numerous in the upper part of the Claggett, where they are scattered in the shale or occur in irregularly spaced beds. The concretions are septarian with veins of light-yellow and brown calcite. Most of these weather bright yellowish brown, but some weather light reddish brown; concretions in the lower part of the formation generally are light gray. Abundant pebbles of black-coated chert or dark-olive-gray phosphatic material are found at or near the base of the Claggett and are similar to pebbles in the uppermost part of the Eagle sandstone.

Cobban (1953a, p. 98) measured a thickness of 430 feet for the Claggett shale along State Route 18 east of Mosby Post Office. A sample log shows the Claggett is 360 feet thick in the California Co. Peterson 1 well in the center of NW¼NE¼ sec. 13, T. 15 N., R. 30 E., and an electric log shows that the Claggett is about 345 feet thick

689-268 O—63——4

in the Amerada Petroleum Corp. Northern Pacific B–1 well in the center of NW¼NW¼ sec. 1, T. 14 N., R. 32 E.

The Claggett shale lies conformably on the Eagle sandstone. In areas of poor exposures the uppermost thin bed of ironstone concretions in the Eagle was mapped as the contact.

Bowen (1915, p. 99) reported the following fossils from the Claggett shale in central Montana:

Baculites ovatus
Baculites compressus
Inoceramus barabini
Leda evansi

The lithology of the Claggett shale is shown in the following section.

Section of the Claggett shale in the S½ sec. 5 and the NW¼ sec. 4, T. 14 N., R. 31 E., Garfield County, Mont.

[From Cobban (1953a, p. 98)]

	Thickness (feet)
Judith River formation:	
Sandstone and shale, in thin interbedded layers; soft, very fine grained; weathers light buff gray	48. 0
Claggett shale:	
Shale, dark-gray; contains iron-stained calcareous septarian concretions with veins of brown and yellow calcite; a few thin layers of bentonite in lower 94 ft	347. 0
Bentonite, grayish-yellow, granular; some aragonite at base	3. 0
Shale, dark-gray; contains 14 layers of bentonite, all less than 1 ft thick	42. 4
Bentonite, yellowish; some aragonite	3. 5
Shale, dark-gray	2. 5
Bentonite, yellowish; abundant aragonite	2. 0
Shale, dark-gray; contains scattered ferruginous concretions; 6-in. layer of bentonite near top	23. 5
Pebble layer; polished black-coated chert pebbles as much as 0.75 in. across and perforated buff phosphatic pebbles as much as 2 in. across	±. 1
Shale, dark-gray; contains iron-stained calcareous septarian concretions at base	6. 0
Total thickness of Claggett shale	430. 0
Eagle sandstone:	
Shale, gray; weathers light gray; contains two 6-in. layers of bentonite and 2 beds of gray calcareous concretions	107. 0

JUDITH RIVER FORMATION

The Judith River formation crops out in a narrow band in the north-central and eastern parts of the Winnett-Mosby area as a pair of locally prominent sparsely timbered hogbacks separated by low badlands. In the south-central part of the area, a broad irregular band of rocks of the Judith River formation weathers to low hills and prominent cuestas.

The formation is divisible into a lower member of shallow-water marine sandstone and shale; a middle member of nonresistant nonmarine sandstone, siltstone, and mudstone; and an upper member, probably nonmarine, composed mainly of sandstone.

The lower member is 78 feet thick; the lower 48 feet of this member consists of thinly interbedded sandy shale and friable light-yellowish-gray very fine grained sandstone. These rocks are overlain gradationally by 30 feet of sandstone that is like the sandstone in the lower part of the member, but is more resistant, slightly coarser grained, and slightly calcareous. The sandstone layers average about 0.3 foot thick, and some are finely crossbedded. Hard nodules less than 0.2 foot in diameter of coarse-grained brown-weathering ferruginous sandstone are scattered throughout the upper part of the lower member. The nodules weather out of the sandstone leaving a pitted surface. Capping the lower member is a layer, as much as 7 feet thick, of hard light-brown to brownish-gray medium- to coarse-grained thin-bedded ferruginous sandstone that is in part concretionary and at places weathers to angular reddish-brown blocks.

The middle member of the Judith River is 140 feet thick, and consists of gray to greenish-gray sandstone, siltstone, and mudstone. Carbonized plant fragments, silicified wood, thin beds of carbonaceous shale, and hard ironstone concretions are conspicuous in this member. The ironstone concretions are medium gray, weather light reddish brown to purplish black, and break into subconchoidal chips.

The upper member of the Judith River consists of a massive sandstone 10 feet thick overlain by 45 feet of sandstone, sandy siltstone, and mudstone. The lower sandstone is light yellowish gray to light yellowish brown, fine grained, and weathers light brown to yellowish brown. Sandstone, siltstone, and mudstone in the upper part of the member are yellowish gray and olive gray. Also present are thin beds of carbonaceous shale and scattered small ferruginous sandstone concretions.

The Judith River formation is 273 feet thick a few miles east of Mosby Post Office just north of State Route 18 (Cobban, 1953a, p. 98). It increases in thickness to about 500 feet in the vicinity of the Judith River (Bowen, 1915, p. 101), about 60 miles northwest of the mapped area.

The Judith River is conformable on the Claggett shale, and the contact is well defined by a change of color and lithology from light-yellowish-gray sandstone and sandy shale of the lower part of the Judith River to brownish-gray fissile shale of the Claggett.

Bowen (1915) described in detail the faunas of the Judith River formation in central Montana. A sandstone containing profuse oyster shells is the top of the formation in secs. 13 and 24, T. 13 N., R. 30 E., and in sec. 18, T. 13 N., R. 31 E.

The lithologic character of the Judith River formation is shown in the following measured section.

Section of the Judith River formation in the NW¼ sec. 4, T. 14 N., R. 31 E., Garfield County, Mont.

[From Cobban (1953a, p. 98)]

	Thickness (feet)
Bearpaw shale:	
Shale, medium-gray, silty to sandy: weathers brownish gray; contains brown-weathering ferruginous and calcareous concretions; two 6-in. layers of bentonite in the upper part	276
Judith River formation:	
Upper member:	
Sandstone, siltstone, and mudstone, gray; some carbonaceous shale and ferruginous nodules	45
Sandstone, buff, fine-grained, massive; forms yellowish-tan timbered hogback	10
Middle member:	
Sandstone, siltstone, and mudstone, gray to greenish-gray, soft; contains ferruginous nodules and some carbonaceous shale; erodes to badlands	140
Lower member:	
Sandstone, buff, fine-grained; in part concretionary; forms timbered hogback	30
Sandstone and shale, in thin interbedded layers; soft, very fine grained; weathers light buff gray	48
Total thickness of Judith River formation	273
Claggett shale:	
Shale, dark-gray; contains iron-stained calcareous septarian concretions with veins of brown and yellow calcite; a few thin layers of bentonite in lower 94 ft	347

BEARPAW SHALE

The Bearpaw shale is exposed in the Musselshell Valley in the northern part of the Winnett-Mosby area and over a broad expanse in the eastern part of the area. The Bearpaw generally weathers to low rolling country, but locally sandstone beds in the lower part form low narrow ridges. The soil has a brownish-gray hue broken by light-gray bands of bentonite, and it supports sparse sagebrush and locally small trees.

The Bearpaw is predominantly medium-gray to brownish-gray marine shale which is silty to sandy in the upper and lower parts. The lower part contains thin beds of moderate-yellowish-brown to brownish-gray fine- to medium-grained nonresistant sandstone in which are very thin streaks of light-brownish-gray shale. Hard brownish-gray sandy concretions as much as 3.5 feet long and 2.5 feet thick are present in the sandstone. The formation also contains many ferruginous concretions that weather moderate brown, and medium-gray limestone concretions that weather yellowish gray to brownish gray. The concretions, many of which are very fossiliferous, are widely scattered at some horizons and at others are so closely spaced as to form almost continuous beds. The Bearpaw is characterized by abundant beds of greenish-gray to yellowish-gray bentonite, ranging in thickness from a few inches to about 2.5 feet. Some are micaceous and contain fragments of light-colored aragonite.

According to Cobban (1953a, p. 101), the formation is 1,318 feet thick along State Route 18. Surface measurements and subsurface data from the Amerada Petroleum Corp. Northern Pacific B–1 well indicate that the Bearpaw is about 1,165 feet thick in sec. 1, T. 14 N., R. 32 E.

The Bearpaw shale is conformable on the Judith River formation. Sandy shale and shaly sandstone in the upper part of the Bearpaw comprise a transitional zone between open-water marine deposits of the Bearpaw and near-shore marine deposits of the overlying Fox Hills formation. Badgley[1] assigned the transitional beds to the Fox Hills, but because of their lithologic similarity to the Bearpaw, the writers placed them in the Bearpaw.

Marine fossils, particularly ammonites, of Late Cretaceous age are abundant in the Bearpaw shale. The following faunas were identified by J. B. Reeside, Jr.:

Inoceramus sagensis Owen
Nucula planimarginata Meek and Hayden
Corbula sp.
Didymoceras sp.

Bowen (1915, p. 102) reported *Baculites ovatus*, *Baculites compressus*, *Scaphites nodosus*, and *Leda evansi* from similar concretions; however, W. A. Cobban states (written communication, 1959) that the identification of *Baculites ovatus* is an error, and *Scaphites nodosus* is properly *Acanthoscaphites nodosus*. In addition, bones identified by D. H. Dunkle as remains of the plesiosaur were found in several concretions.

The following stratigraphic section shows the lithology of the Bearpaw shale.

---

[1] Badgley, E. K., Jr., 1953, Correlation of some Late Cretaceous and early Tertiary sediments in eastern Montana: Wyoming Univ., unpublished M. A. thesis, p. 11.

Section of the Bearpaw shale in secs. 3 and 4, T. 14 N., R. 31 E., Garfield County, Mont.

[From Cobban (1953a, p. 98)]

	Thickness (feet)
Fox Hills formation:	
Bearpaw shale:	
Shale, dark-gray; weathers brown or gray; basal and uppermost parts slightly sandy; contains brownish-weathering sandy calcareous concretions	155. 0
Bentonite, greenish-gray; base micaceous	1. 5
Shale, dark-gray; contains several beds of gray- or brown-weathering calcareous concretions and a few thin layers of bentonite	152. 0
Shale, dark-gray; in part bentonitic; largely weathered to dark gumbo soil barren of vegetation; contains several thin beds of yellowish-tan claystone concretions	55. 0
Shale, dark-gray; contains gray-weathering calcareous concretions, rusty-weathering ferruginous concretions, and scattered gray cone-in-cone layers	194. 0
Bentonite, cream to olive; some aragonite	1. 0
Shale, dark-gray; contains rusty-weathering ferruginous concretions; brown- and gray-weathering calcareous concretions 15 ft above base	85. 0
Shale, dark-gray; contains some gray calcareous concretions and about 12 beds of bentonite as much as 1 ft thick	104. 0
Shale, dark-gray; contains ferruginous concretions and about 6 beds of bentonite as much as 8 in. thick	134. 0
Shale, gray, bentonitic; 2-ft bed of bentonite near top	13. 5
Shale, dark-gray	28. 5
Bentonite, gray	2. 5
Shale, dark-gray	74. 0
Bentonite, greenish-gray; contains buff aragonite	3. 0
Shale, dark-gray; contains a thin layer of bentonite in middle	37. 5
Bentonite, yellowish	1. 5
Shale, medium-gray, silty to sandy; weathers brownish; contains brown-weathering ferruginous and calcareous concretions; two 6-in. layers of bentonite in upper part	276. 0
Total thickness of Bearpaw shale	1, 318. 0
Judith River formation:	
Sandstone, siltstone, and mudstone, gray; some carbonaceous shale and ferruginous nodules	45. 0

FOX HILLS FORMATION

The Fox Hills formation crops out in the northern and eastern parts of the Winnett-Mosby area. Along the Musselshell River and Cottonwood and Calf Creeks it forms ledges and narrow benches above the deeply dissected country underlain by the Bearpaw shale. In the eastern part of the area the formation weathers to rolling grass-covered country. Because of poor exposures, the Fox Hills could not be differentiated from the overlying Hell Creek formation near the east border of the area in secs. 35 and 36, T. 14 N., R. 32 E., and in the northwest corner of T. 13 N., R. 32 E.

The Fox Hills is composed mostly of light-yellowish-gray to olive-gray very fine grained to fine-grained sandstone that ranges from friable to moderately hard. Several beds in the upper part of the formation are capped by large slightly crossbedded calcareous sandstone concretions that weather light brownish gray. Very small fragments of dark-olive-gray claystone are common in much of the formation. Ironstone concretions and small nodules of light-brownish-gray sandstone are scattered throughout the sandstones. Both types of concretions weather bright yellowish orange. Carbonaceous material is abundant along the bedding planes in the lower part.

Southeast of State Route 18 the formation consists of a lower sandstone as much as 100 feet thick and an upper sandstone 35 to 40 feet thick separated by about 5 feet of light-brownish-gray sandy shale. The upper sandstone weathers very light gray, and in areas north and east of the Winnett-Mosby area probably is equivalent to the Colgate member of the Fox Hills as described by Dobbin and Reeside (1930, p. 17).

The Fox Hills is about 63 feet thick in sec. 10, T. 15 N., R. 30 E., and the formation seems to maintain this general thickness in the Musselshell Valley. About 141 feet of beds assigned to the Fox Hills was measured in the eastern part of the area in sec. 33, T. 14 N., R. 32 E.

The contact between the Fox Hills formation and the Bearpaw shale is transitional and is mapped at the change from brownish-gray sandstone and shale in the upper part of the Bearpaw to light-yellowish-gray sandstone in the lower part of the Fox Hills. The color change is very evident from a distance.

The Fox Hills formation is the uppermost marine deposit of Cretaceous age in central Montana. No fossils were collected, but shell impressions and carbonized plant fragments were noted. Bowen (1919, p. 16) collected a single species of *Lingula* from this formation in the SW¼ sec. 1, T. 14 N., R. 32 E.

The following sections show the change in lithologic character of the Fox Hills formation in the Winnett-Mosby area.

Section of the Fox Hills formation in the SE¼SE¼ sec. 10, T. 15 N., R. 30 E., Garfield County, Mont.

	Thickness (feet)
Hell Creek formation:	
Siltstone, brownish-black to purplish-brown, very carbonaceous; bentonitic; coaly streaks in upper part; forms conspicuous light-purplish-gray band	8.8
Shale, dark-olive-gray, silty, bentonitic; contains very thin layers of light-yellowish-gray fine-grained sandstone that includes some carbonaceous material	7.0

Section of the Fox Hills formation in the SE¼SE¼ sec. 10, T. 15 N., R. 30 E., Garfield County, Mont.—Continued

	Thickness (feet)
Fox Hills formation:	
Sandstone, light-yellowish-gray, fine-grained, friable to moderately hard; near top is hard lenticular bed, 1 to 3 ft thick, of yellowish-gray fine-grained calcareous sandstone that weathers light brown; stained light purplish gray by slope wash; forms nearly vertical face	10. 9
Sandstone, mottled olive-gray, brownish-gray, and light-yellowish-gray, very fine grained to fine-grained, friable; locally very finely laminated; contains bright-yellow to orange-brown streaks of friable sandstone and small orange-weathering ironstone concretions; some light-colored flakes of mica; carbonaceous material and worm tracks on bedding planes; harder in upper 5 ft and capped by large brownish-gray-weathering slightly crossbedded sandstone concretions; forms steep slope	18. 3
Sandstone, light-olive-gray, very fine grained, laminated; inclusions of dark-olive-gray claystone; few lenses about 0.5 ft thick and 2 ft long of hard light-gray fine- to medium-grained calcareous slightly crossbedded sandstone which weathers light brownish gray	11. 0
Sandstone, light-olive-gray, very fine grained; many very small dark-olive-gray claystone fragments; abundant plant impressions that are less numerous in upper part; some small shell impressions; upper two-thirds contains scattered light brownish-gray fine-grained sandstone nodules which weather bright yellowish orange, are oval to round, and 0.2 to 0.5 ft in diameter; weathers very light yellowish gray	22. 7
Sandstone, light-olive-gray, fine-grained, calcareous, concretionary; weathers very light reddish gray; marks approximate contact between light-colored beds above and darker colored beds below	. 2
Total thickness of Fox Hills formation	63. 1
Bearpaw shale:	
Sandstone, olive-gray, very fine grained to fine-grained; interbedded with yellowish-gray fine-grained laminated sandstone; some carbonaceous material; gradational into overlying beds	15. 3
Shale and claystone, olive-gray, silty to sandy; contains streaks, 0.1 to 0.3 ft thick, of moderate-olive-brown very fine grained sandstone containing some calcareous concretions; some zones, as much as 1.5 ft thick, of olive-gray fine-grained shaly sandstone with hard yellowish-brown calcareous sandstone concretions that weather with metallic luster on joints; unit becomes more sandy upward	25. 7

Section of the Fox Hills formation in the NE¼SE¼ sec. 33, T. 14 N., R. 32 E., Garfield County, Mont.

	Thickness (feet)
Hell Creek formation:	
Shale, dark-olive-gray, silty, bentonitic; with laminae of light-yellowish-gray fine-grained sandstone	2.0+
Fox Hills formation:	
Sandstone, light-gray to light-yellowish-gray, medium-grained, noncalcareous, massive; contains scattered ferruginous sandstone nodules about 0.4 ft in diameter that weather orange brown; weathers to conspicuous very light gray outcrop; contact with overlying Hell Creek formation is irregular	36.5
Shale, light-brownish-gray, sandy, noncalcareous	5.0
Sandstone, light-grayish-yellow, fine-grained, shaly in upper 40 ft; upper part contains lenses of iron-stained sandstone; lower 57 ft is massive and is capped by layer of hard platy sandstone concretions that weather yellowish brown; weathers to low hogback	99.7
Total thickness of Fox Hills formation	141.2
Bearpaw shale:	
Shale, brownish-gray, sandy, with laminae of sandstone; partly covered	5.0+

HELL CREEK FORMATION

The Hell Creek formation is well exposed in rough, deeply dissected country along the Musselshell River in the northern part of the area, and it forms most of the divides adjacent to Calf Creek in the eastern and northeastern parts. Trees are common on the formation in rough country, particularly on north-facing slopes; elsewhere, the Hell Creek weathers to gently rolling grass-covered country surmounted by a few sandstone-capped ridges and buttes.

The Hell Creek formation is composed of nonmarine sandstone, siltstone, and shale. The sandstone beds are the most conspicuous units and make up approximately half of the formation. They are light gray, yellowish gray, and olive gray, fine to medium grained, and locally calcareous. Most of the sandstone is nonresistant, but it contains hard slightly crossbedded concretions that weather to light-brownish-gray or light-yellowish-brown ledges or to large loglike masses. Lenses of conglomerate composed of subangular pebbles and cobbles of hard calcareous sandstone, and in places small fragments of shale, fill shallow channels in the sandstone. The conglomerate lenses commonly are about 2 feet thick and about 190 feet above the base of the formation. Most of the shale of the Hell Creek is light yellowish gray to dark olive gray and brownish black and is silty to sandy. Dark carbonaceous shale, some of which is bentonitic, occurs mainly in the lower part of the formation. Most of the shale is interbedded with very thin layers of light-yellowish-gray fine-grained sandstone. A few beds of brownish-black to purplish-brown very carbonaceous siltstone containing coaly streaks are found in the basal part of the Hell Creek. Crystals of gypsum generally are abundant on the outcrops of the carbonaceous beds.

The Hell Creek formation is an estimated 300 feet thick in the Winnett-Mosby area; however, the upper part is not present. Rocks now assigned to the Hell Creek formation are reported by Thom and Dobbin (1922, p. 145) to be about 550 feet thick in Garfield County. Measured sections by Badgley[2] show that the Hell Creek is slightly less than 350 feet thick near the Missouri River in T. 21 N., R. 37 E., and about 480 feet thick east of the Winnett-Mosby area in T. 16 N., R. 38 E.

The contact between the Hell Creek and Fox Hills formations was mapped at the base of dark-olive-gray shale and brownish-black to purplish-brown siltstone that immediately overlie light-yellowish-gray or light-gray sandstone assigned to the upper part of the Fox Hills. Thick lenticular yellowish-brown ledge-forming sandstone beds overlie this dark basal part of the Hell Creek.

In the Winnett-Mosby area the Hell Creek formation apparently is for the most part conformable on the Fox Hills formation. At two localities in the E½ sec. 7, T. 16 N., R. 30 E., channels in the Hell Creek have cut out the basal carbonaceous shale and siltstone of the Hell Creek and eroded the upper part of the Fox Hills. At these localities yellow-brown sandstone of the Hell Creek rests directly upon the Fox Hills. Just north of the report area in sec. 36, T. 17 N., R. 29 E., a channel filled with light-colored Hell Creek sandstone has cut into the basal carbonaceous beds of the Hell Creek, but no channeling was noted at the base of the carbonaceous zone.

A disconformity or angular unconformity between the Hell Creek and the Fox Hills formations has been described by many writers, but Dobbin and Reeside (1930, p. 25) have found that faulting, slumping, or crossbedding had been misinterpreted as an unconformity at many places. They concluded that the contact between the two formations is everywhere virtually transitional. Erosion channels that are common within Fox Hills and Hell Creek strata (Thom and Dobbin, 1924, p. 486), are, according to Dobbin and Reeside (1930, p. 25), the result of contemporaneous erosion and redeposition and are chronologically unimportant.

The Hell Creek strata represent the youngest beds of Late Cretaceous age in central Montana. No fossils were collected by the writers, but fragments of dinosaur bones and fresh-water invertebrates were noted at many localities. A molluscan fauna collected in Garfield and Rosebud Counties by Badgley[3] and identified by L. S. Russell includes the genera *Sphaerium*, *Lioplacodes*, *Unio*, *Viviparus*,

---

[2] Badgley, E. K., Jr., 1953, op. cit., pl. 1.
[3] Badgley, E. K., Jr., 1953, op. cit., p. 19.

Campeloma, and *Physa*. Vertebrate teeth and bones collected by Badgley and identified by P. O. McGrew include *Triceratops*, *Annatesaurus*(?), and *Myledaphus* (achimaeroid shark).

The following measured section of the Hell Creek formation shows its lithologic character in this area.

Partial section of the Hell Creek formation in the SE¼SE¼ sec. 10, T. 15 N., R. 30 E., Garfield County, Mont.

	Thickness (feet)
Hell Creek formation:	
Sandstone, yellowish-gray, fine- to medium-grained, calcareous, moderately hard; contains lenses of conglomeratic sandstone 2 ft thick; harder layers cap low pedestals	10. 5
Sandstone, yellowish-gray, fine-grained, nonresistant, micaceous; contains channel 3 to 9 ft deep filled with subangular pebbles and cobbles of hard light-olive-gray calcareous sandstone	11. 0
Shale, olive-gray to yellowish-gray, sandy, interbedded with soft yellowish-gray fine-grained sandstone and brownish-gray calcareous sandy shale; some sandstone beds in the upper part contain cannonball concretions of hard light-gray fine-grained sandstone that weather light brownish gray	36. 0
Sandstone, light-olive-gray, fine-grained, shaly, with lenticular beds of hard light-gray slightly crossbedded sandstone; contains very calcareous concretionary sandstone masses, as much as 2.5 ft thick, that weather light yellowish orange	6. 0
Shale, brownish-gray, carbonaceous	3. 0
Sandstone, light-yellowish-gray, fine- to medium-grained, calcareous, massive, salt-and-pepper appearance; forms prominent escarpment capped by concretionary ledge of sandstone that weathers light brownish gray	29. 5
Shale, light-olive-gray, slightly silty	5. 8
Sandstone, yellowish-gray, fine-grained, nonresistant; contains thin laminae of brownish-gray carbonaceous shale; contains small oval concretions of hard light-gray fine-grained slightly crossbedded sandstone that weather brownish gray	3. 3
Shale, olive-gray, sandy, with 1-ft bed of brownish-gray carbonaceous shale at base	10. 5
Shale, dark-olive-gray; weathers light olive gray; contains thin beds of yellowish-gray fine-grained sandstone with partings, as much as 0.05 ft thick, of brownish-gray very carbonaceous shale; sandstone more abundant in upper part; elsewhere this unit contains loglike concretionary masses as much as 10 ft long and 2 ft thick	15. 0
Shale, brownish-gray, slightly sandy, carbonaceous	2. 4
Shale, light-olive-gray, slightly silty, bentonitic	5. 5
Sandstone, yellowish-gray, fine-grained, nonresistant, with small concretionary nodules of light-gray fine-grained sandstone that weather yellowish orange	8. 2
Shale, olive-gray to brownish-gray, slightly carbonaceous	1. 0
Sandstone, olive-gray, fine-grained; contains hard lenticular yellowish-gray fine-grained slightly crossbedded layers, as much as 2.5 ft thick, near base	7. 3

Partial section of the Hell Creek formation in the SE¼SE¼ sec. 10, T. 15 N., R 30 E., Garfield County, Mont.—Continued

	Thickness (feet)
Hell Creek formation—Continued	
Shale, olive-gray, slightly sandy; contains thin interbedded layers of fine-grained sandstone that weather bright orange in upper part	5.5
Shale, light-yellowish-gray to olive-gray, interbedded with brownish-gray bentonitic carbonaceous shale; scattered gypsum crystals; forms a conspicuous banded outcrop	11.5
Sandstone, bright-orangish-gray, fine- to medium-grained; contains some carbonaceous interbedded layers; abundant mica flakes	7.8
Shale, brownish-gray to brownish-black, carbonaceous, very fissile; and mottled olive-gray and yellowish-brown to brownish-gray slightly carbonaceous sandy shale that grades to siltstone in upper part	6.0
Shale, light-olive-gray; contains bright-orange-weathering very fine grained sandstone in beds less than 0.2 ft thick, which are most abundant at base	2.4
Shale, olive-gray to brownish-black, slightly sandy, bentonitic; forms conspicuous light-purplish-gray outcrop	4.5
Sandstone, mottled light-yellowish-gray, brownish-gray, and light-olive-gray, fine- to medium-grained, nonresistant; weathers light olive gray; grades into overlying shale; forms minor break in slope	5.8
Siltstone, brownish-black to purplish-brown, very carbonaceous, bentonitic; coaly streaks in upper part; forms conspicuous light-purplish-gray band	8.8
Shale, dark-olive-gray, silty, bentonitic; contains laminae of light-yellowish-gray fine-grained sandstone with some carbonaceous material	7.0
Measured thickness of Hell Creek formation	214.3
Fox Hills formation:	
Sandstone, light-yellowish-gray, fine-grained, friable to moderately hard; near top is lenticular bed, 1 to 3 ft thick, of hard yellowish-gray fine-grained calcareous sandstone that weathers light brown; stained light purplish gray by slope wash; forms nearly vertical face	10.9

QUATERNARY

TERRACE DEPOSITS

Terrace deposits are found mainly in the Musselshell Valley and along Flat Willow Creek and its large tributaries in the central and western parts of the area. Except for a few remnants on the east side, most of the deposits in Musselshell Valley are west of the river, generally upstream from the mouth of Sage Hen Creek. Eight terrace levels ranging from 40 to 635 feet above the river were recognized in the Musselshell Valley. The lowest and youngest is designated as the first terrace level; the highest and oldest as the eighth.

Deposits at seven principal levels border Flat Willow Creek and its large tributaries in the western part of the area. The terraces gradually converge upstream with the alluvium in the valley of Flat Willow Creek, and terraces bordering the major tributaries of

Flat Willow Creek also converge upstream. The lowest and youngest level along Flat Willow Creek is designated as the first terrace level, and the highest and oldest as the seventh. The first terrace level along Flat Willow Creek correlates with the second terrace level in the Musselshell Valley.

Scattered gravel deposits are at heights of 20 to 120 feet above adjacent streams in the drainage basin of Yellow Water Creek above Yellow Water Reservoir near the west side of the area. Some are terrace deposits of Yellow Water Creek, but others seem to be small pediment deposits adjacent to a cuesta formed by the Mowry member of the Colorado shale. Because the deposits are isolated, they were not correlated with deposits along nearby creeks; on the geologic map they are designated as undifferentiated terraces.

The terrace deposits are mostly about 8 feet thick, but they range in thickness from a thin veneer to more than 60 feet. They are composed of gravel interbedded with lesser amounts of fine to very coarse sand and are generally capped by a layer of silt or clay 1 to 5 feet thick. The gravel generally is composed of pebbles less than 2 inches in diameter, but cobbles as much as 9 inches in length are scattered throughout most deposits. The pebbles are subangular to subrounded, but a few are well rounded. Rarely are the deposits well sorted. Igneous rocks, probably derived from the Crazy, Little Belt, and Castle Mountains, constitute the dominant rock type in most of the terraces in the Musselshell Valley. Limestone also is a major constituent together with some sandstone, chert, ironstone, quartzite, and shale. The gravel in the terraces along Flat Willow, Box Elder, and McDonald Creeks generally is predominantly limestone with subordinate amounts of sandstone, igneous rock, ironstone, and chert, probably derived mostly from the Big Snowy and Judith Mountains. Locally derived sandstone and ironstone constitute a high percentage of the gravel in some terraces along Elk and Yellow Water Creeks. In general, the deposits are unconsolidated, but lenses of gravel cemented by calcium carbonate are present locally in deposits at all levels.

No fossils that would aid in dating the terrace deposits were found. Glacial erratics are found on the terraces, but no till is interbedded with the gravels. Glacial boulders lie scattered on all terraces except terraces at the first and second levels in the Musselshell Valley, which indicates that the terrace deposits at the first and second levels were laid down following the glacial advance responsible for the erratics. Alden (1932, p. 81) correlated the advance as Illinoian or Iowan(?) and correlated the terraces from about the third through the fifth levels west of the Musselshell River and north of Flat Willow Creek with his No. 2 bench of early or middle Pleistocene age (Alden, 1932, p. 51).

The height and location of the terraces in the Musselshell Valley and in the drainage basin of Flat Willow Creek are summarized in table 2.

TABLE 2.—*Terraces and alluvium in the Musselshell Valley and Flat Willow Creek drainage basin, Winnett-Mosby area*

Terrace level	Height above river or adjacent creek (feet)[1]	Location of principal deposits
		Musselshell Valley
Qtm_8	635	Cat Creek-Flat Willow Creek divide just south of State Route 18.
Qtm_7	540–585	Along State Route 18 at the Cat Creek road.
Qtm_6	505–540+	Along State Route 18 near the Cat Creek road and north of Cottonwood Creek.
Qtm_5	400–450+	Between Cat and Flat Willow Creeks and north of Haley Coulee.
Qtm_4	245–425	Do.
Qtm_3	145–295	West side of the Musselshell River from the south border of the area downstream to Cottonwood Creek, and along Sage Hen and Cat Creeks.
Qtm_2	70–200	West side of the Musselshell River from the south border of the area downstream to Cottonwood Creek; east side of the river from the south border of the area to Molynik Coulee.
Qtm_1	40–55	East side of the Musselshell River from the south border of the area downstream to Molynik Coulee.
Qal	0–25	Valley flood plain.
		Flat Willow Creek drainage basin
Qt_7	385–400	On the Elk Creek-McDonald Creek divide in the northwest corner of the area.
Qt_6	110–175	North side of Pike Creek.
Qt_5	50–345	North side of Pike Creek and on the McDonald Creek-Box Elder Creek divide northeast of Winnett.
Qt_4	25–295	North side of Pike Creek, north of Elk Creek near Petrolia Reservoir, and on the north side of McDonald Creek.
[2]Qt_3	60–245	North sides of Flat Willow, Elk, and McDonald Creeks.
[2]Qt_2	40–150	North sides of Flat Willow and McDonald Creeks, lower valley of Box Elder Creek, and upper valley of Elk Creek.
Qt_1	20–150	North sides of McDonald, Elk, and Yellow Water Creeks; west side of Box Elder Creek; and along Flat Willow Creek mostly downstream from Petrolia Reservoir.
Qt	20–120	Undifferentiated terraces along Yellow Water Creek upstream from Yellow Water Reservoir.
Qal	0–60±	All major creek valleys; includes slope wash against valley sides and low terraces in valley bottoms.

[1] Height above stream increases downstream.
[2] Terraces at levels Qt_2 and Qt_3 are undifferentiated in the upper valley of Elk Creek.

GLACIAL DEPOSITS

Cobbles and boulders of rock types that do not crop out in the Winnett-Mosby area are scattered over roughly half of the area on both sides of the Musselshell River, as shown in figure 2. Reeves (1927, p. 42) and Alden (1932, p. 81–82) suggested that the boulders and cobbles are glacial erratics rafted into this area by ice in a marginal lake impounded in the Musselshell Valley during Pleistocene time. However, Knechtel (1942, p. 933–934) believed that the erratics may have been deposited directly by an ice sheet. The erratics are concentrated in the Musselshell Valley, but a few are found as far west as Winnett. They are most plentiful on the east side of the river along the Calf Creek-Musselshell River divide and at the base of a hogback outlining the south flank of the Cat Creek anticline. Most of the boulders are at altitudes of 2,550 to 3,050 feet above sea level; most of those at lower altitudes are about 110 feet above the river, except for some that seem to have been moved to lower altitudes by man or let down by erosion.

Granitic and gneissic rocks comprise about 52 and 34 percent, respectively, of the larger boulders. Boulders of limestone, dolomite, sandstone, quartzite, and basic igneous rocks also are present. Most of the boulders are 4 feet or less in diameter, but 1 boulder 8 feet long was observed. No till is associated with the erratics; in fact, no till has been found south of the Missouri River in this general area. The boulders near Mosby Post Office were regarded by Alden (1932, p. 81) as having been deposited during the Illinoian or early Wisconsin stage of glaciation.

LANDSLIDE MATERIAL

South of Flat Willow Creek in T. 13 N., R. 28 E., 4 landslides, the largest of which is about 1 mile long and as much as 1,100 feet wide, are in the Claggett shale just below a cuesta formed by the lower sandstone of the Judith River formation. A small landslide along the south wall of the valley of Calf Creek, in sec. 11, T. 16 N., R. 30 E., is the result of oversteepening of a slope on the Bearpaw shale below the Fox Hills formation.

SLOPE WASH

Slope wash was mapped at three places in the Musselshell Valley between the mouth of Flat Willow Creek and State Route 18. The deposits are adjacent to, and at places transitional with, alluvium bordering the Musselshell River. They are composed of fine sand and silt eroded from adjacent areas by sheet wash and short, intermittent streams and deposited in old, poorly preserved, high-level meander scars cut by the river.

Along the lower valley of Flat Willow Creek sediment washed from the steep valley sides is being deposited on the alluvial fill in the

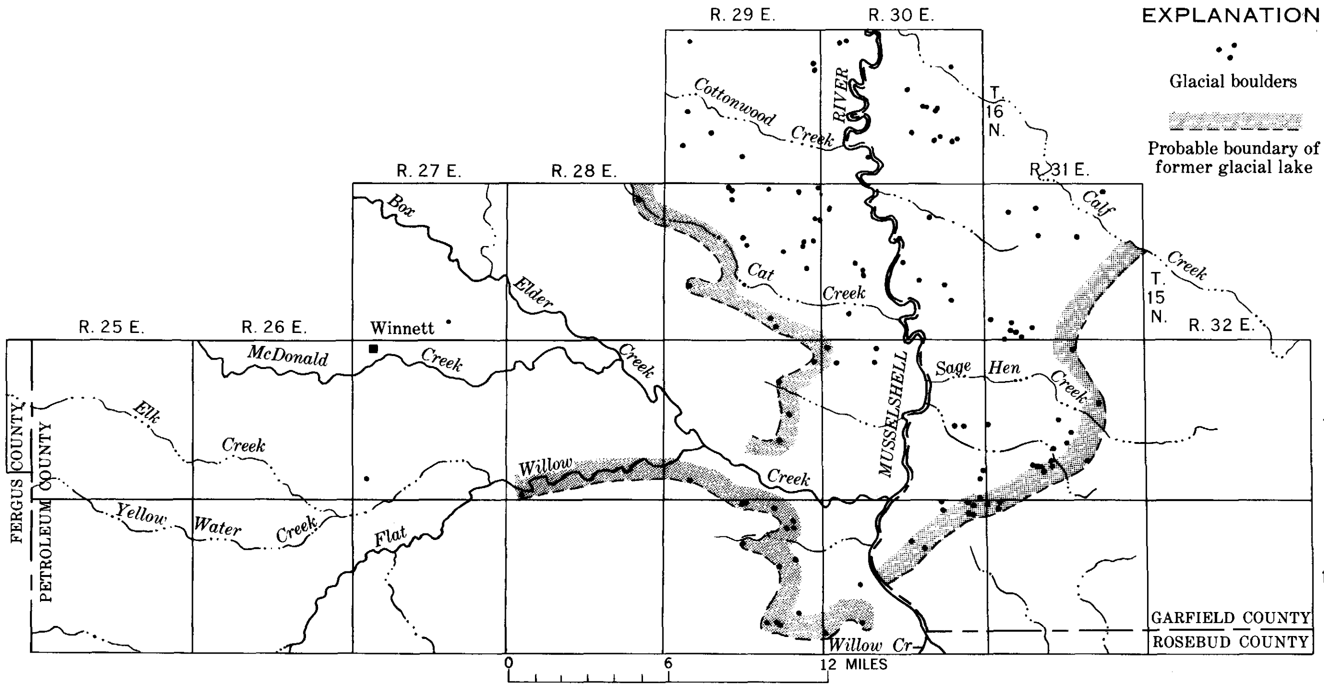

Figure 2.—Sketch map showing distribution of glacial boulders in the Winnet-Mosby area.

stream valley. Because these deposits are narrow and their boundaries difficult to determine, they were included with the alluvium.

ALLUVIUM

Alluvial deposits of silt, sand, and gravel cover the flood plains of the Musselshell River and the larger creeks in the area. Included with the alluvium in the Musselshell Valley are low terraces, which stand as much as 25 feet above the mean water level of the river. Alluvium along the Musselshell River ranges in width from about 300 feet in the southern part of the area where the river crosses resistant sandstone of the Judith River formation to more than 4,000 feet in areas underlain by shale. Alluvium that borders the large creeks in the western part of the area also varies in width depending upon the resistance to erosion of the underlying bedrock. In general, the alluvium is wide along the west side of the area where the streams flow across soft shale, but it narrows markedly where the streams cross more resistant sandstone and sandy shale in the Telegraph Creek and Eagle formations. Along Yellow Water, Elk, and Flat Willow Creeks, terraces that stand as much as 10 feet above the adjacent stream have been mapped with the alluvium. Alluvium along the lower reaches of Flat Willow Creek also includes slope wash deposited against the steep-valley walls.

IGNEOUS ROCKS

Ultramafic igneous rocks have been intruded into the Cretaceous strata in the western part of the Winnett-Mosby area as dikes, sills, and plugs. Except for a small dike in sec. 16, T. 13 N., R. 27 E., the igneous intrusions are in T. 13 N., Rs. 25 and 26 E. and T. 14 N., Rs. 24 and 25 E. In general, the dikes strike N. 55°–65° E., which is subparallel to faults in the area; however, small dikes in sec. 16, T.13 N., R. 27 E., and sec. 36, T. 14 N., R. 25 E., are oriented in a northwesterly direction. At several places magma intruded along all or part of a preexisting fault. Some examples are a dike at the northeast end of a fault that enters the mapped area on the west side of sec. 18 and extends northeast to sec. 9, T. 13 N., R. 25 E.; a dike just to the south along a fault that offsets the contact between the Mowry and Belle Fourche members of the Colorado shale; and a dike at the southwest end of a long fault that extends from the SW¼ sec. 2, T. 13 N., R. 25 E., northeastward to the southern part of sec. 27, T. 14 N., R. 26 E. In general, the dikes are 2 to 5 feet thick and are bordered by a zone of baked host rock 10 to 20 feet thick. The dikes commonly weather to linear ridges that rise 5 to 10 feet above the surrounding country.

Igneous plugs in the mapped area are in plan elongated irregular masses that form prominent buttes standing as much as 200 to 300 feet

689-268 O—63——5

above the surrounding country. A group of three plugs intrudes a highly faulted area in and near the northeast corner of sec. 1, T. 13 N., R. 25 E., and sec. 6, T. 13 N., R. 26 E. The central and largest plug is in plan about 3,700 feet long and as much as 300 feet wide. Several dikes cut the sedimentary rocks south of these plugs, but do not connect with them at the surface. A prominent butte in the SE¼ sec. 13, T. 14 N., R. 24 E., is formed by an igneous plug about 2,000 feet long and as much as 200 feet wide. Three small plugs crop out along the north side of Elk Creek in the NE¼SE¼ sec. 12, T. 14 N., R. 24 E., and in the NW¼SW¼ sec. 7 and the SW¼SW¼ sec. 9, T. 14 N., R. 25 E.

Two sills that consist of an unusual type of ultrabasic rock described by Ross (1926) as nephelite-hauynite-alnoite intrude the basal part of the Mowry member of the Colorado shale in the eastern part of sec. 6 and the west-central part of sec. 5, T. 14 N., R. 25 E. The larger sill extends for about 6,000 feet, is 2 to 4 feet thick, and is bordered by a baked zone as much as 20 feet thick. A third sill intrudes the basal part of the Mowry member in the south-central part of sec. 27, T. 14 N., R. 25 E.

Igneous rock exposed in the Winnett-Mosby area generally is highly weathered, light yellowish gray, reddish yellow, or brick red, porphyritic with a fine-grained groundmass, and contains inclusions of sedimentary rock. P. C. Franks (written communication, 1956), Kansas State Geological Survey, examined thin sections of the igneous rock, and the following is a summary of his report.

1. *Sample from igneous plug in the SE¼SE¼ sec. 13, T. 14 N., R. 24 E.*—This rock apparently is a highly altered fine-grained mica-peridotite. The major constituents are bleached biotite or phlogopite, serpentine, chlorite, and calcite. Minor constituents are tremolite-actinolite(?), sphene(?), and magnetite. Serpentine is present as minute disseminations in the groundmass, but mainly is concentrated in oval masses as much as 5 mm long and 3 mm wide. The masses are transected by irregular cracks that suggest the former presence of olivine. Traces of hematite line the cracks. Biotite or phlogopite is present in the groundmass as subhedral blocks, 0.1 to 0.15 mm long and about 0.05 mm wide, that commonly have bent lamellae and show no preferred orientation. Calcite also is present as irregular optically continuous patches and seemingly has replaced part of the groundmass.

2. *Sample from dike in the NW¼SE¼ sec. 7, T. 13 N., R. 26 E., south side Yellow Water Reservoir.*—This rock is composed mainly of granular calcite in grains 0.01 to 0.1 mm in diameter or as oval patches as much as 5 mm long. Some of the masses of calcite are optically continuous and commonly are ringed by limonite stain. Accessory minerals include chalcedonic quartz, chlorite, sericite(?), serpentine, limonite, magnetite, and biotite. The quartz, which occurs in oval masses,

has feathery extinction. The borders of the quartz masses commonly present lobate outlines against the calcite groundmass; locally, the quartz remains as inclusions in calcite-filled masses. Traces of biotite are associated with the quartz as anhedral and subhedral books that are partly altered to chlorite on their shredded ends. Minor amounts of serpentine, together with coarsely crystalline plagioclase feldspar, also fill oval patches in the calcite groundmass. Traces of magnetite are present as small irregular lobate blebs, and limonite stains much of the rock. The texture is similar to that of the sample from the igneous plug discussed above.

3. *Sample from igneous plug in the N½NW¼ sec. 1, T. 13 N., R. 26 E.*—This rock is composed of grains 0.01 to 0.1 mm in diameter and is made up principally of calcite with a lesser amount of quartz and minor amounts of disseminated weathered biotite, limonite stain, and feldspar. Some of the calcite is in optically continuous patches haloed by limonite stain. Quartz forms small angular fragments, rounded grains, and cryptocrystalline masses. Some quartz grains are partly replaced by calcite, and minor amounts occur as remnant inclusions in calcite masses. Biotite is present as small books which differ in pleochroism and color; the colors are predominantly browns but include some green. Sericite or fine-grained muscovite occurs in trace amounts as small elongate books, and highly weathered very fine grained flakes of chlorite are disseminated through areas of limonite stain. Hematite occupies oval masses similar to those filled by calcite; and feldspar, both orthoclase and plagioclase, occurs as small anhedral grains. The rock may be a product of extensive alteration of a sedimentary inclusion in an igneous rock.

A sample from a dike in the NE¼SW¼ sec. 16, T. 13 N., R. 27 E., examined by C. S. Ross, of the Geological Survey (written communication, 1955), consists of well-sized detrital materials, of which quartz is dominant, together with feldspar, biotite, muscovite, fine-grained rock fragments, and interstitial calcite. Ross states that this rock might best be described as a graywacke. Based on its mineralogic similarity to the sample from the igneous plug in sec. 1, T. 13 N., R. 26 E., this sample also might be a highly altered sedimentary inclusion in an igneous rock.

STRUCTURE

The Winnett-Mosby area includes parts of two major structural features in central Montana—the Blood Creek syncline to the north and the Big Snowy anticlinorium to the south (pl. 3). A narrow belt of steeply dipping rocks crosses the northeastern part of the area and marks the boundary between these two structural features. Elsewhere in the area, the sedimentary rocks are not greatly deformed by folding. The structural features in the mapped area are shown on the geologic map (pl. 1) by contour lines drawn on the base of the Colorado shale at 100-foot intervals. Structural relief in the Winnett-Mosby area, most of which is due to regional dip to the east-northeast, is greater than 5,000 feet.

The Blood Creek syncline is a broad rather shallow eastward-plunging structural depression north of the Big Snowy anticlinorium and the Judith and Moccasin Mountain uplifts. The northeastern part of the Winnett-Mosby area lies in the syncline, the axis of which is north of the mapped area. Steeply dipping strata on the northern flank of the Big Snowy anticlinorium flatten out northward into the Blood Creek syncline and within 1 mile become nearly horizontal; however, minor flexures locally interrupt the gentle northward dip.

The Big Snowy anticlinorium is a broad rectangular uplift that extends southeastward from the Big Snowy and Judith Mountain uplifts on the west to Porcupine dome. The Big Snowy anticlinorium is part of Sonnenberg's (1956, p. 78) larger structural feature, the central Montana platform. The north and south margins of the anticlinorium are marked by belts of steeply inclined strata and a series of asymmetrical anticlines.

The segment of the anticlinorium that lies east of the Big Snowy and Judith Mountain uplifts, including the part in the Winnett-Mosby area, is known as the Cat Creek-Devils Basin uplift (Reeves, 1927, p. 61). The uplift is an eastward-tilted block which is bounded on the north by the Cat Creek anticline and Alice dome and on the south, in part, by Devils Basin, Big Wall, and Melstone domes. Sedimentary rocks in the central part of the uplift are folded into many anticlines.

The Cat Creek-Devils Basin uplift probably represents a compound horst in the basement rocks (Thom, 1923, p. 10) that rose intermittently during much of Paleozoic and Mesozoic time. In detail the uplift probably is a series of horsts, grabens, and tilted fault blocks. The compound horst probably is bounded on the north by a fault or fault zone in the basement rocks that underlie the Cat Creek anticline and on the south by a fault zone along the trend of Devils Basin, Big Wall, and Melstone domes. Differential vertical movement of the fault blocks in the basement complex folded the overlying crustal strata and formed the present structural features on the Cat Creek-Devils Basin uplift. Folding is most pronounced on the north and south margins of the uplift, where the Cat Creek anticline and Devils Basin dome were formed.

Cooper (1956), Sonnenberg (1956), and Sandberg and Hammond (1958) showed that central Montana has been structurally active during much of Paleozoic and Mesozoic time and that deposition of most Paleozoic and Mesozoic sedimentary rocks in this part of the

State was influenced by ancestral structural features that had the positions and trends of the present surface structures. In general, however, the present structural features of the Cat Creek-Devils Basin uplift are reversed from those that existed in Paleozoic time. The area of the present Big Snowy anticlinorium was primarily a depositional trough during the Late Devonian (Sandberg and Hammond, 1958, p. 2330) and Late Mississippian epochs (Sonnenberg, 1956, pl. 2). During Late Mississippian time, deposition of the Tyler formation within the trough was restricted primarily to areas located along the trends of present anticlines (Cooper, 1956, p. 83). The later reversal in the structure may indicate a change in the direction of vertical movement of structural blocks in the basement complex.

The existence of a fault or fault zone in basement rocks below the Cat Creek anticline cannot be proved by present data. The axial plane of the Cat Creek anticline is nearly vertical or inclined slightly toward the north or steep limb rather than shifted to the south at depth (Thom, 1923, p. 10), as might be expected by the asymmetry of the fold. Thom (1923, p. 10) cited the orientation of the axial plane as evidence that the anticline passes into a fault at depth. However, Reeves (1927, p. 66) attributed the orientation to thinning of the strata on the steep flank during folding.

Tectonic movements that formed the Big Snowy anticlinorium apparently began during or after Paleocene time, inasmuch as the Fort Union formation of Paleocene age is folded on the south flank of Devils Basin dome (Reeves, 1931, p. 147). Alpha and Fanshawe (1954, p. 76) suggested that folding and faulting were contemporaneous with post-Eocene igneous intrusions, such as those in the Crazy Mountains north of Livingston, Mont., and that the deformation could have occurred as late as middle Oligocene.

The igneous activity in the Winnett-Mosby area is not precisely dated, but it seems likely that it was a late stage of the tectonic activity and therefore is Eocene or slightly younger in age.

ANTICLINES

CAT CREEK ANTICLINE

The dominant structural feature in the Winnett-Mosby area is the Cat Creek anticline. Bowen (1914, pl. 19) originally applied the name to a major fold extending from Black Butte at the east end of the Judith Mountains, southeastward for about 65 miles to a point about 10 miles east of the Musselshell River. Lupton and Lee (1921, p. 270) and a few subsequent writers restricted the name to the southeastern part of the fold enclosed by outcrops of the Eagle sandstone and including three small subsidiary folds known as West, Mosby, and East domes. In this report the name Cat Creek anticline designates the major marginal fold along the north flank of the Cat Creek-Devils Basin uplift, which follows the usage of Bowen.

The Cat Creek anticline strikes about N. 70° E. across the north-central and east-central parts of the area. Along most of its length the anticline is strongly asymmetrical with the steep flank on the northeast. At the southeast end, mostly east of the Musselshell River, the width of the anticline increases considerably, and beds on the south flank are tilted as steeply as 23°. West of the river, beds on the south flank dip 1° to 6° into a syncline along Box Elder Creek. On the steep northeast flank of the anticline, generally within ¼ to ½ mile of the axis, the beds dip 25° to 45°, with dips locally as much as 57°. The steep flanks of the anticline are well defined by prominent hogbacks formed by the Eagle sandstone and sandstone beds in the Judith River formation.

Structural relief along the part of the Cat Creek anticline in the Winnett-Mosby area, from a low point at the southeast end of the anticline to the structurally highest point on Mosby dome, is greater than 2,200 feet, but the structural closure is only about 600 feet.

Alined on the axis of the Cat Creek anticline are a series of en echelon elongate folds which include in the Winnett-Mosby area the south flank of Oiltana dome, all of West, Mosby, and East domes, and a small dome at the southeast end of the anticline herein named Sage Hen dome.

Sage Hen dome.—Faulted beds in the uppermost part of the Eagle sandstone and the basal part of the Claggett shale compose the surface rocks on the crest of Sage Hen dome in sec. 25, T. 14 N., R. 31 E., and resistant sandstone beds in the Judith River formation are conspicuously exposed in a narrow graben on the south flank. Structural closure on Sage Hen dome is less than 100 feet.

East dome.—East dome is a fold about 2 miles long mainly in secs. 1 and 12, T. 14 N., R. 31 E., and secs. 6 and 7, T. 14 N., R. 32 E. It is part of a larger fold that also includes Mosby dome to the northwest. Structural closure on East dome is slightly less than 100 feet. The saddle separating Mosby and East domes is too shallow to be shown by the 100-foot structure contour interval on plate 1. East dome is outlined on its northeast and east flanks by a low escarpment formed by the Sage Hen limestone member of Lupton and Lee (1921), which is the basal bed of the Niobrara member of the Colorado shale. The Mosby sandstone member of the Colorado shale forms a ledge on much of the southwest side. The calcareous shale and Carlile members of the Colorado shale are well exposed in fault blocks on the crest of the dome.

Mosby dome.—Mosby dome trends northwest for about 4 miles mostly in the S½ T. 15 N., R. 30 E. This anticline includes two separate domes, the principal one at the corner of secs. 16, 17, 20, and 21, T. 15 N., R. 30 E., and the second one east of the Musselshell River in secs. 26 and 27 of the same township. The eastern dome has been called the Middle High by Hadley (1956, fig. 2) and Antelope dome by some other geologists.

Mosby dome is strongly asymmetrical with dips as steep as 56° on the steep northeast limb. On the gentle southwest limb, dips of 1° to 4° are common. The southeast end of Mosby dome is poorly defined, and the strata flatten out southeastward along the axis into an area of very low dips extending to East dome. Structural relief between the crest of Mosby dome and a structural saddle to the northwest is more than 500 feet.

The Musselshell River crosses the dome and much of the crest is covered by alluvium. The Belle Fourche member of the Colorado shale is exposed on either side of the river below an enclosing escarpment capped by the Mosby sandstone member. Numerous small faults displace the beds on the steep northeast flank of Mosby dome, and some of the faults cross the axis at the surface.

West dome.—West dome is a complexly faulted northwest-trending fold about 3¾ miles long in the N½ T. 15 N., R. 29 W. The fold consists of two small domes connected by an anticline. The eastern dome has surface closure of slightly more than 300 feet, and the western dome of more than 100 feet. Dips on the gentle southwest limb range from 1° to 7°, and dips on the steep limb near the east end of the fold are as much as 40°.

The first unit of the Carlile member of the Colorado shale is the stratigraphically lowest unit that crops out on the east end of West dome. The upper part of the Carlile and the lower part of the Niobrara members are at the surface on the west end, and various units of the Carlile are exposed in horsts, grabens, and tilted fault blocks in the middle of the structure.

A small fold with less than 100 feet of surface closure lies on the axis of the Cat Creek anticline in sec. 12, T. 15 N., R. 28 E., about 3 miles west of West dome. This anticlinal fold is separated from West dome by an area of nearly flat beds. Several northeast-trending faults cut the north flank of the fold at the surface, but drillers' logs indicate that they do not offset the axis at depth.

Area northeast of Winnett.—Rocks in the northern part of T. 15 N., R. 27 E., and the NW¼ T. 15 N., R. 28 E., on the north border of the mapped area, dip southeast generally 5° to 12°. These rocks lie west of a narrow structural saddle in sec. 3, T. 15 N., R. 28 E., and on the south side of Brush Creek and Oiltana domes, the crests of which are north of the Winnett-Mosby area (pl. 3). According to Reeves (1927, p. 3), the saddle is about 900 feet structurally below the crest of Oiltana dome, which is 2 miles to the northwest. Rocks ranging from the upper part of the Belle Fourche member of the Colorado shale to the Eagle sandstone are exposed in the belt of dipping beds.

FLAT WILLOW ANTICLINE

The Flat Willow anticline is a sinuous poorly defined fold that plunges at an average of 100 feet per mile from a point near the west side of the mapped area in sec. 29, T. 14 N., R. 25 E., eastward to the NW¼ T. 13 N., R. 27 E., a distance of about 15 miles. Numerous faults cross the anticlinal axis, and closure against faults is found at several places on the south flank of the anticline in the SW¼ T. 14 N., R. 26 E., and in the northern part of T. 13 N., R. 26 E.

Rocks from the Skull Creek member to the Niobrara member of the Colorado shale crop out along the axis of Flat Willow anticline, but, on much of the fold, alluvium and terrace deposits conceal the bedrock.

PIKE CREEK ANTICLINE

Pike Creek anticline is a broad southeastward-plunging anticlinal nose whose axis extends across the southwest corner of the area from sec. 30 to sec. 36, T. 13 N., R. 25 E., a distance of about 5¼ miles. Dips on the northeast flank are 4° to 16°, and dips on the southeast flank are 1° to 7°. In sec. 8, T. 13 N., R. 25 E., the strike of outcropping rocks changes from northwest to about north, and the dip increases to as much as 27° locally. The anticlinal axis plunges an average of about 250 feet per mile. The oldest rocks exposed on the Pike Creek anticline in the area belong to the Skull Creek member of the Colorado shale. A hogback formed by the Mowry member sharply outlines the anticlinal nose.

FOLDS NEAR RATTLESNAKE BUTTE

Outcropping rocks near Rattlesnake Butte, in the S½ T. 13 N., R. 28 E., are folded into small northwest-plunging anticlines that are cut by northeast-trending faults. Dips on the flanks of the folds mostly range from less than 1° to about 5°, but, adjacent to faults, dips as much as 22° were measured. Structural closure at the surface on these minor folds is everywhere less than 100 feet. The upper part of the Claggett shale and the lower sandstone member of the Judith River formation are the deformed surface rocks.

OTHER FOLDS

Thom and Dobbin (1922, p. 148–149) described an anticline which they called the Garfield anticline extending from the southeast end of the Cat Creek anticline northeastward for approximately 44 miles.

Along this anticline at Calf Creek they recognized a West Calf Creek dome, a part of which is in the NE¼ T. 14 N., R. 32 E. The upper part of the Bearpaw shale is exposed in this small flexure, but at the contour interval used on plate 1 the fold is poorly defined. Structural closure at the surface appears to be very slight, but detailed structural data in that general area are lacking.

SYNCLINES

A broad syncline lies, in part, along the lower valley of Box Elder Creek south of the Cat Creek anticline. The axis of this syncline extends from sec. 19, T. 15 N., R. 27 E., southeastward for about 12 miles to sec. 13, T. 14 N., R. 28 E., and plunges to the southeast an average of about 35 feet per mile. Dips on both flanks range from less than 1° to about 3°. The Eagle sandstone and Claggett shale crop out along the synclinal axis except in parts of T. 14 N., R. 28 E., where these rocks are covered by terrace deposits. Because of low dips and locally poor exposures, the position of the axis was only approximately located.

A small structural depression in secs. 7 and 8, T. 15 N., R. 28 E., is about 1½ miles long and trends southeast. Four faults characterized by small vertical displacement, offset the basal part of the Claggett shale in the trough of the syncline. On the northern limb the Eagle sandstone dips as much as 13°. Structural closure is slightly more than 100 feet.

FAULTS

Two belts of en echelon northeast-trending faults cross the Winnett-Mosby area, one along the Cat Creek anticline and the other in an arcuate band across the southern part of the area. The two belts merge to the east at the nose of the Cat Creek anticline. All the faults appear to be normal faults with observed dips of 40° to 82° on the fault planes. Along the steep northeast flank of the Cat Creek anticline resistant sandstone in the Eagle sandstone and the Judith River formation is offset and the faults are located readily, but in adjacent soft shale they are commonly invisible except on aerial photographs. In the shale the fault trace is often marked by thin plates of striated or slickensided calcite. The maximum stratigraphic displacement measured on any of the faults was about 415 feet. Several faults along the west side of the area have been invaded by magma which formed dikes.

FAULTS ALONG THE CAT CREEK ANTICLINE

The belt of faults along the Cat Creek anticline is part of a major fault zone, about 100 miles long, that extends from the west end of the Cat Creek anticline southeastward to Porcupine dome. On

West, Mosby, and East domes the belt of faults lies along and north of the axis of the anticline; farther west on the south flanks of Brush Creek and Oiltana domes, the crests of which lie north of the mapped area, the faults are found south of the anticlinal axis. In the last-named areas, 16 faults have been mapped, all but one of which are downthrown on the northwest side. Most of these faults offset the lower member of the Eagle sandstone, and their traces are easily located.

The crest of West dome is broken into horsts, grabens, and tilted fault blocks by 12 faults which trend N. 50°–65° E. In addition, several faults that do not cross the axis of the dome offset steeply dipping strata on the northeast flank. The fault traces are easily mapped on the east end of the dome, but on the west end they are difficult to locate. Most of the faults on West dome are downthrown on the southeast side, but several have the downthrown side on the northwest. Stratigraphic throws of 20 to 85 feet were measured at the surface near the northeast end of some faults. The stratigraphic throw on some faults is as much as 145 feet in the subsurface. According to limited electric log data, the faults do not extend below the upper part of the Kootenai formation on West dome.

Two faults that cut the crest of West dome show apparent reversal in the direction of throw along their traces. One of these faults extends from the NE cor. sec. 19, T. 15 N., R. 29 E., northeastward to the NW¼ sec. 10, and the apparent hinge point is about half a mile from the northeast end of the fault. The other fault cuts the east end of West dome from the SW¼ sec. 14, T. 15 N., R. 29 E., northeastward for slightly more than 1.5 miles, and dies out at the surface in the Claggett shale. Appreciable strike slip near the northeast end of the fault planes probably caused the apparent reversal in the direction of throw along the two faults.

Hogbacks formed by the sandstone beds of the Eagle sandstone and the Judith River formation along the steep limb of the Cat Creek anticline northwest of West dome are offset by numerous faults that trend N. 10°–30° E. at the northeast ends of their traces and N. 50°–65° E., at the southwest ends. With one exception, all the faults are downthrown on the southeast side.

Fewer faults cut Mosby dome than West dome, and for the most part the amount of stratigraphic displacement along the fault planes at the surface is considerably less at Mosby dome than at West dome. Most faults on Mosby dome are short and have stratigraphic displacements of 5 to 75 feet. All the faults are downthrown on the southeast side. Two large faults that cut the northwest end of the dome in secs. 17, 18, and 19, T. 15 N., R. 30 E., bring the upper part of the Belle Fourche member of the Colorado shale against the third unit of the Carlile member, giving a maximum stratigraphic displacement of about 150 feet. This fault has been tentatively identified in nearby wells where it has a stratigraphic displacement of 125 feet. The longest fault crossing Mosby dome extends from the SW¼ sec. 19 northeastward for about 2¾ miles and dies out beneath the flood plain of the Musselshell River in sec. 16, T. 15 N., R. 30 E. The Mosby sandstone member of the Colorado shale is offset 1,600 feet laterally along the fault. Electric logs indicate additional faults in the subsurface on Mosby dome that either do not extend to the surface or were not recognized at the surface because of poor exposures. The Morrison of Late Jurassic age is the stratigraphically lowest formation that is faulted in the subsurface on Mosby dome according to electric log interpretations.

Most fault traces on Mosby dome strike N. 50°–65° E., but some change to a more northerly direction at their northeast ends where they cut the steep limb of the Cat Creek anticline, as shown particularly by a fault in the W½ sec. 25, and one in the NE¼ sec. 22, T. 15 N., R. 30 E.

Faults that cross East Dome have excellent surface expressions, for they offset varied lithologic units of the Mosby sandstone, calcareous shale, and Carlile members of the Colorado shale. The fault traces trend N. 60°–65° E. at their southwest ends and curve to the north at their northeast ends. Stratigraphic displacements of most of the faults range from 10 to 50 feet, and the faults are downthrown on the southeast side. Three large faults, ranging in length from about 1 to 2.5 miles, mainly in the southwestern part of T. 15 N., R. 31 E., cut the steeply dipping beds on the northeast flank of East dome. The displaced strata range from the lower unit of the Carlile member of the Colorado shale to the lower part of the Hell Creek formation. Along one of the faults in the E½ sec. 32, T. 15 N., R. 31 E., the apparent horizontal displacement is about 650 feet southwestward along the southeast side of the fault, and the lower part of the Bearpaw shale is in contact with beds in the upper part of the Claggett shale. Faults cutting the crest of East dome apparently do not extend to a great depth, for electric logs indicate that neither the lower sandstone member of the Colorado shale nor the Swift formation of Late Jurassic age is offset.

A fault zone extends from the southeast end of the Cat Creek anticline S. 80° E. to the east border of the Winnett-Mosby area in the northeast corner of T. 13 N., R. 32 E. The fault traces strike N. 40°–60° E. In general, the faults nearest the anticline are downthrown on the southeast side, and those near the east border of the area are downthrown on the northwest.

The southeast side of Sage Hen dome is broken by a narrow graben. Vertical displacement on a fault 4 miles long, bounding the north side of this graben brings the lower part of the Bearpaw shale against the upper part of the Claggett shale. The Judith River formation is conspicuously exposed within the graben. A large fault in secs. 27, 28, 32, and 33, T. 14 N., R. 32 E., transects the Bearpaw shale, Fox Hills formation, and lower part of the Hell Creek formation and offsets the Fox Hills about 4,700 feet to the southwest on the southeast side of the fault.

FLAT WILLOW-RATTLESNAKE BUTTE FAULT ZONE

The Flat Willow-Rattlesnake Butte fault zone is an arcuate belt about 45 miles in length consisting of northeast-trending en echelon faults. It extends from the west boundary of the Winnett-Mosby area in sec. 25, T. 14 N., R. 24 E., southeastward through the Rattlesnake Butte area to the south-central part of T. 13 N., R. 29 E., and from there northeastward to a junction with the fault zone along the Cat Creek anticline in the southeast corner of T. 14 N., R. 31 E. In the western part of the mapped area, the fault zone is parallel to the axis of the Flat Willow anticline, and the faults strike N. 45°–60° E. Four large faults laterally offset the axis of the anticline for distances of about 250 to 5,000 feet. In general, faults that cut the axis are downthrown on the southeast side, but in a highly faulted area north and northeast of Yellow Water Reservoir most of the faults are downthrown on the northwest side. A fault crossing the SE¼ sec. 36, T. 14 N., R. 25 E., passes southwestward into a fracture intruded by igneous rock.

South of Flat Willow Creek in the central part of T. 13 N., R. 27 E., the lower member of the Eagle sandstone is broken into tilted blocks by faults that dip 52° to 78° northwest or southeast. The maximum stratigraphic displacement on a fault in secs. 11, 14, 15, and 16 of that township is 125 feet.

In the Rattlesnake Butte area the faults in the Flat Willow-Rattlesnake Butte fault zone are 1¼ to 4 miles in length and trend N. 40°–60° E. They are easily located by the abrupt offset of resistant sandstone in the Judith River formation. Dips of the fault planes were measured at two localities: a fault in the northern part of sec. 36, T. 13 N., R. 28 E., dips 75° southeast, and a fault in the NW¼ sec. 27 of the same township dips 45° in the same direction.

In the vicinity of the Musselshell River, en echelon faults in the Flat Willow-Rattlesnake Butte fault zone trend N. 25°–45° E. and are downthrown on the northwest side. The faults break the Judith River formation into sharply tilted blocks. Dips of 46° to 75° were measured on fault planes in this area. The maximum stratigraphic displacement measured on any fault in the Winnett-Mosby area is 415 feet on a fault extending from sec. 35, T. 13 N., R. 30 E., northeastward for 6 miles to sec. 7, T. 13 N., R. 31 E. At several localities along this fault, beds in the upper part of the Judith River are in contact with a bed of bentonite about 400 feet above the base of the Bearpaw shale.

FAULTS NORTH OF PIKE CREEK ANTICLINE

A northeast-trending fault, downthrown on the southeast side, enters the mapped area in sec. 6, T. 13 N., R. 25 E., and apparently connects with a fault in the Flat Willow-Rattlesnake Butte fault zone having an opposite direction of throw; however, the location of the hinge point of this possible pivotal fault is concealed by alluvium. The northeast end of a fault crossing the NW¼ sec. 18, T. 13 N., R. 25 E., is invaded by dike rock; several other nearby faults are also intruded by dikes.

JOINTS

The Eagle sandstone and the Mowry and unnamed sandy members of the Colorado shale are prominently jointed in the western part of the Winnett-Mosby area. Erosion along joints that strike about N. 50°–60° E. has produced a conspicuous linear pattern. The joints are subparallel to the trend of the faults. At many places, particularly in shale, the joints contain veins of very light gray to white calcite. Oval-shaped undrained depressions that are common on the Mowry outcrops seem to be localized in highly jointed areas.

ECONOMIC GEOLOGY

OIL AND GAS

Oil is found at West, Mosby, and East domes on the Cat Creek anticline, and the producing areas are known collectively as the Cat Creek oil field. One abandoned well in the Rattlesnake Butte area has yielded oil in commercial quantities, and shows of oil and gas have been found in several wells on the Flat Willow anticline. The locations and status, as of July 1, 1959, of all wells drilled in the mapped area that were actually noted in the field are shown either on the geologic map (pl. 1) or on the inset map of West dome and part of Mosby dome. The status of the wells is from the records of the Geological Survey, Conservation Division, Billings, Mont. Data on selected wells in the area are listed in table 3.

Several exploratory wells have been drilled since 1950 on previously untested structural features. The Seaboard Oil Co. Holly 7–30–G well in the NW¼SW¼SW¼ sec. 30, T. 14 N., R. 32 E., was drilled in 1950 on Sage Hen dome. This well penetrated the Madison

TABLE 3.—*Selected oil wells and dry holes in the Winnett-Mosby area, Montana, as of July 1, 1959*

[Symbols used below: Kh, Hell Creek formation; Kb, Bearpaw shale; Kj, Judith River formation; Kcl, Claggett shale; Ke, Eagle sandstone; Kt, Telegraph Creek formation; Kc, Colorado shale; Kk, Kootenai formation; Jm, Morrison formation; Je, Ellis group; Pa, Amsden formation of former usage; Mh, Heath formation; Mo, Otter formation; Mk, Kibbey sandstone; PMb, Big Snowy group; Pq, Quadrant formation; Mm, Madison group; Mc, Charles formation; Mmc, Mission Canyon limestone; Є, Cambrian rocks; P, production; OS, oil show; GS, gas show; D&A, dry and abandoned; POW, producing oil well; AP, abandoned producer; OSI, oil well shut-in; WW, water well; WIW, water injection well; status of wells as of July 1, 1959]

No. on plate 1	Location–Range and section	County	Geologic structure	Operator and lease	Elevation (feet)	Geologic formation: Surface	Geologic formation: Lowest	Production or shows at depth(s), in feet, and in formation indicated	Total depth (feet)	Status	Year
				T. 13 N.							
				Continental Oil Co.:							
1	25 E., Cen. SW¼NW¼ 3	Petroleum	Flat Willow	Olsen-Federal Land Bank 1	3,194	Kc	Mo		2,450	WW	1957
2	25 E., Cen. NW¼SE¼ 3	do	do	Lancelle 1	3,196	Kc	Mh		2,519	WW	1956
3	25 E., Cen. SE¼SE¼ 3	do	do	Miles Jackson Inc. Olson 1	3,171	Kc	Mo		2,572	D&A	1958
4	25 E., NW¼SW¼ 10	do	do	E. G. Lewis Development Co. Rowley 1.	3,200	Kc	Je		1,460	D&A	1920
5	25 E., SE¼SW¼SW¼ 28	do	Pike Creek	Wayne Petroleum Corp. Bervim 1.		Kc	Pq		1,675	D&A	1921
6	26 E., SE¼NW¼NE¼ 3	do	Flat Willow	Oregon-Flatwillow Development Co. 2.		Kc	Je	OS at 1,320 from Kk	2,194	D&A	1935
7	26 E., SE¼SE¼NE¼ 3	do	do	Ike W. Taylor and others McGlenn 1.	3,075	Kc	Mk		3,401	D&A	1954
8	26 E., SE¼SW¼NE¼ 3	do	do	R. F. Hamilton King 1		Kc	Pa		1,901	D&A	1953
9	26 E., Cen. SE¼NE¼ 4	do	do	Phillips Petroleum Co. King & Sons 2.	3,189	Kc	Mh		2,771	WW	1958
10	26 E., Cen. SE¼NW¼ 4	do	do	Miles Jackson Inc. Buelow 1	3,157	Kc	Mo		2,767	D&A	1958
11	27 E., SE¼SE¼NE¼ 15	do		Ike W. Taylor Fraser 1	3,266	Ke	Je		2,865	WW	1946
12	28 E., NE¼SW¼SE¼ 22	do	Rattlesnake Butte.	McAlester Fuel Co. Schwartz 1–3.	3,360	Kcl	Je?	P at 2,780 from Kk	3,238	AP	1959
13	28 E., SE¼NE¼NE¼ 27	do	do	Dave Schrock and others Clauson 1.		Kcl	Je		2,708	D&A	1947
14	28 E., NW¼NW¼NE¼ 27	do	do	Ike W. Taylor Clauson 2	3,328	Kj	Mk	OS at 2,660 from Kk	4,670	D&A	1949
15	28 E., NE¼SW¼NE¼ 27	do	do	McAlester Fuel Co. Clauson A–1.	3,252	Kcl	Mh		4,118	D&A	1956
16	32 E., Cen. NW¼SW¼ 1	Garfield		Amerada Petroleum Corp. Northern Pacific RR. 1.	3,097	Kb	Mmc		6,120	D&A	1957

T. 14 N.

17	25 E., NW¼NW¼NE¼ 14	Petroleum		A.M.Z. Oil Co. Boyd 1		Kc	Pq		1,735	D&A	1924
18	25 E., Cen. SE¼SE¼ 23	do	Flat Willow	Phillips Petroleum Co. King & Sons 1.	3,200	Kc	Mh		2,204	WW	1958
19	25 E., NW¼SE¼NW¼ 29	do	do	Herbert D. Hadley Govt. 1	3,346	Kc	Mc		3,003	D&A	1959
20	25 E., NE¼SW¼NW¼ 35	do	do	Brundage and others Teague 1		Kc	Je?	OS at 700 and 1,013	1,503	WW	1946
21	26 E., NE¼NW¼NE¼ 5	do		Continental Oil Co. Teigen 1	3,082	Kc	Mh		2,731	D&A	1956
22	26 E., SE¼NW¼NE¼ 20	do	Flat Willow	Oregon-Montana Oil Co. Faragher 1.	3,187	Kc	Pq	OS at 2,010 and 2,040 from Pq.	2,460	D&A	1924
23	26 E., SE¼SE¼SE¼ 25	do	do	O'Dillo Rogge Hill 1		Kc	Je		2,108	WW	1950
24	26 E., [1] NW¼SW¼NW¼ 29	do	do	Whaley Oil Co. Siebert 1	3,092	Kc	Pq	OS at 867 from Kk; OS and GS at 976 and 1,060 from Kk.	2,000	D&A	1923
25	26 E., Cen. SE¼NE¼ 35	do	do	Continental Oil Co. Hill 1	3,092	Kc	Mh		2,998	D&A	1956
26	27 E., Cen. NW¼NW¼ 4	do		Hose-Austen Drilling Corp. Bratten 1.	2,959	Kt	Mo		3,525	D&A	1957
27	27 E., Cen. NE¼SE¼ 24	do	Flat Willow	Flank Oil Co. Freed 1	3,005	Ke	Mo		4,005	WW	1959
28	28 E., Cen. SE¼SE¼ 6	do		Hose-Austen Drilling Corp. Bohn 1.	2,844	Ke	Mo		3,710	D&A	1957
29	28 E., Cen. SE¼NE¼ 21	do	Flat Willow	Black Hawk Oil Co. Kistner 1		Kcl	Pq		3,800	D&A	1933
30	29 E., SW¼SW¼NE¼ 2	do		American Climax Petroleum Corp. Wise 1.	3,045	Kcl	Mh		3,897	D&A	1959
31	29 E., Cen. NW¼NE¼ 29	do	Flat Willow	Flank Oil Co. Hansen 1	2,667	Ke	Mo		3,817	D&A	1959
32	29 E., W½SW¼NW¼ 29	do	do	Seattle-Flatwillow Oil Co. Powell 1.		Ke	Kk	OS and GS at 620 from Kc; OS at 2,196 from Kk.	2,220	D&A	1922
33	30 E., NE¼SE¼NE¼ 1	Garfield	Cat Creek	Cherry Kidd Northern Pacific RR. 2.	2,730	Kc	Je	P at 1,791 from Je	1,793	POW	
34	30 E., S½SE¼NE¼ 2	do	do	McCoy Oil Co. Hanlon 1		Kc	Je		1,769	D&A	1950
35	31 E., SW¼SW¼NW¼ 5	do	do	Central Montana Oil Co. Northern Pacific RR. 1.	2,706	Kc	Je		1,909	WW	1946
36	31 E., SE¼SW¼NW¼ 6	do	do	William M. Hanlon: York-Montana 4–10	2,751	Kc	Je	P at 1,820 from Je	1,838	POW	
37	31 E., NE¼NW¼SW¼ 6	do	do	York-Montana 3–7	2,690	Kc	Je	P at 1,781 from Je	1,795	OSI	195?
38	31 E., Cen. SE¼SE¼ 7	do	do	Richfield Oil Corp. Northern Pacific RR. 1.	2,673	Kc	Mo		3,130	D&A	1956
39	31 E., SW¼NW¼NW¼ 9	do	do	East Flank Oil Co. Northern Pacific RR. 1.	2,732	Ke	Je		2,908	D&A	1946
40	31 E., SW¼NE¼SW¼ 17	do	do	Allen Barnes Northern Pacific RR. 1.	2,739	Kc	Pa		3,265	WW	1949
41	32 E., Cen. NW¼NW¼ 1	do		Amerada Petroleum Corp. Northern Pacific RR. B–1.	2,891	Kb	Mmc		6,588	D&A	1951
42	32 E., NW¼SW¼SW¼ 30	do	Cat Creek	Seaboard Oil Co. Holly 7–30–G	2,980	Kcl	Mm		5,131	D&A	1950

No. on plate 1	Location–Range and section	County	Geologic structure	Operator and lease	Elevation (feet)	Geologic formation		Production or shows at depth(s), in feet, and in formation indicated	Total depth (feet)	Status	Year
						Surface	Lowest				
				T. 15 N.							
43	27 E., Cen. SE¼SE¼ 14	Petroleum		Flank Oil Co. Guenon 1	2,852	Ke	Mo		3,809	D&A	1959
				California Co:							
44	28 E., SW¼SE¼NE¼ 2	do	Cat Creek	Green 1–B	2,930	Kt	Kk		2,125	D&A	1924
45	28 E., NE¼SE¼NE¼ 12	do	do	Van Tassel 7–B	2,856	Kc	Mm	P at 1,747 from Kk; OS at 2,029 from Jm?	4,124	AP	1926
46	29 E., S½SW¼SW¼ 4	do	do	Hadley and others Hunt-Fradd	2,834	Kc	Je		2,062	D&A	1949
47	29 E., Cen. SE¼SE¼ 6	do	do	Cat Creek Oil Venture Carlson 1		Kc	Je		2,197	D&A	1946
48	29 E., NW¼NW¼SW¼ 8	do	do	Continental Oil Co. Post 1–A	2,838	Kc	Kk	P at 1,716 from Kk	1,731	AP	1935
49	29 E., NW¼SE¼NE¼ 9	do	do	Utah Southern Oil Co: Chamberlain 21	2,832	Kc	Je	P at 1,797 from Jm	2,010	POW	
50	29 E., S½SE¼NE¼ 9	do	do	Chamberlain 16	2,820	Kc	Je	OS at 1,195 and 1,678 from Kc; OS at 1,745 from Jm, P at 1,828 from Je.	1,927	OSI	1953
51	29 E., NW¼NE¼SE¼ 9	do	do	Chamberlain 23	2,816	Kc	Mm		4,380	WIW	1958
52	29 E., SW¼NW¼NW¼ 10	do	do	Spencer Ferguson Drilling Co. Harlan 1.	2,910	Kc	Je		2,080	WW	1949
53	29 E., SE¼SW¼NW¼ 10	do	do	Continental Oil Co. Harlan 12	2,853	Kc	Je	P at 1,890 from Je	1,918	POW	------
54	29 E., N½SE¼SE¼ 10	do	do	Ike W Taylor Schwartz and others 8.	2,896	Kc	Pa	OS at 1,385, 1,500, 1,590, and 1,638.	2,685	D&A	1951
				Continental Oil Co.:							
55	29 E., NW¼NW¼SW¼ 10	do	do	Continental 26	2,837	Kc	Je		1,912	D&A	1946
56	29 E., SW¼SW¼SE¼ 11	do	do	Continental 23	2,830	Kc	Je		1,881	D&A	1949
57	29 E., SE¼SE¼SW¼ 11	do	do	56 Petroleum 16	2,861	Kc	Je	P at 1792 from Jm	1,944	POW	------
58	29 E., SW¼SW¼SW¼ 12	do	do	Continental 10	2,804	Kc	Je		1,757	D&A	1949
59	29 E., NE¼NE¼NE¼ 14	do	do	Continental 17	2,805	Kc	Je		1,757	D&A	1949
60	29 E., Cen. SW¼SE¼ 29	do		Flank Oil Co. Coxon 1	2,902	Ke	Mh		3,710	D&A	1959
61	30 E., Cen. NW¼NE¼ 13	Garfield		California Co. Peterson 1	2,998	Kh	Є		8,096	D&A	1954
				Farmers Union Central Exchange:							
62	30 E., SW¼NW¼SW¼ 16	Petroleum	Cat Creek	State 3	2,626	Kc	Je	P at 1,506 from Je	1,532	POW	------
63	30 E., NW¼SW¼SW¼ 16	do	do	State 4	2,623	Kc	Je	P at 1,463 from Je	1,488	POW	------
64	30 E., S½SW¼SW¼ 16	do	do	State 2	2,572	Kc	Je	P at 1,446 from Je	1,471	POW	------
65	30 E., SW¼SW¼SW¼ 16	do	do	State 1	2,570	Kc	Je	P at 1,461 from Je	1,480	POW	------
				Continental Oil Co.:							
66	30 E., SE¼NE¼SE¼ 17	do	do	Brown 12	2,634	Kc	Je	P at 1,500 from Je	1,525	POW	------
67	30 E., S½NE¼SE¼ 17	do	do	Brown 13	2,650	Kc	Je	P at 1,547 from Je	1,579	OSI	19??
68	30 E., N½NW¼SE¼ 17	do	do	Brown 16	2,710	Kc	Je		1,673	D&A	1946
69	30 E., NE¼SE¼SE¼ 17	do	do	Brown 15	2,635	Kc	Je	P at 1,444 from Je	1,474	POW	------
70	30 E., NW¼SE¼SE¼ 17	do	do	Brown 14	2,531	Kc	Je	P at 1,402 from Je	1,429	OSI	195?

71	30 E., SW¼SE¼SE¼ 17	do	do	Brown 11	2,515	Kc	Je	P at 1,425 from Je	1,451	OSI	195?
72	30 E., S½SW¼SE¼ 17	do	do	Brown 17-A	2,537	Kc	Je	P at 1,032 from Kk	1,475	POW	
73	30 E., SW¼SW¼NE¼ 21	do	do	William M. Hanlon Mitchell 2	2,503	Kc	Je	OS at 1,030 from Kk; P at 1,355 from Jm.	1,460	POW	
74	30 E., NW¼NW¼NW¼ 21	do	do	Farmers Union Central Exchange Fifer 1.	2,526	Kc	Je	OS at 766 from Kc; OS at 981, 998, and 1,093 from Kk; P at 1,393 from Je.	1,396	POW	
75	30 E., Cen. SE¼NW¼ 21	do	do	California Co., Charles 4	2,465	Kc	Є	OS at 1,355 from Jm; OS at 1,415 from Je.	5,705	D&A	1943
76	30 E., SE¼SE¼NW¼ 21	do	do	Pacific Petroleum Ltd. Charles 3	2,489	Kc	Je	OS at 1,005 from Kk	1,448	D&A	1946
77	30 E., NW¼NW¼SE¼ 21	Garfield	do	R. C. Tarrant Butler-Hunt 1	2,481	Kc	Jm	OS at 1,012, 1,058, and 1,127 from Kk; P at 1,322 from Jm.	1,331	AP	1951
				British Dominion Oil Co.:							
78	30 E., E½NW¼SW¼ 21	Petroleum	do	Charles 2	2,500	Kc	Jm	OS at 1,373 from Jm	1,385	D&A	1946
79	30 E., SE¼NW¼SW¼ 21	do	do	Charles 1	2,505	Kc	Je	OS at 1,110 from Kk; OS at 1,375 from Jm; OS at 1,510 from Je.	1,521	D&A	1946
				Continental Oil Co.:							
80	30 E., NE¼SE¼NW¼ 26	Garfield	do	Continental 5	2,712	Kc	Je		1,730	D&A	1949
81	30 E., NW¼SE¼NW¼ 26	do	do	Continental 1	2,639	Kc	Je	P at 1,588 from Je	1,613	POW	
82	30 E., N½SW¼NW¼ 26	do	do	Continental 2	2,648	Kc	Je	P at 1,599 from Je	1,624	POW	
83	30 E., NW¼SW¼NW¼ 26	do	do	Continental 3	2,745	Kc	Je	P at 1,713 from Je	1,736	OSI	195?
84	30 E., NE¼SW¼NE¼ 27	do	do	Ike W. Taylor Jackson 1	2,523	Kc	Pa		2,042	D&A	1948
85	30 E., NE¼NE¼SE¼ 27	do	do	A. B. Cobb, Northern Pacific RR. 1.	2,625	Kc	Mm		3,572	D&A	1946
86	30 E., NE¼NE¼SW¼ 27	do	do	Continental Oil Co. Northern Pacific RR. 1.	2,472	Kc	PMb	OS at 1,020 from Kc; OS at 1,130 from Kk; OS at 1,920 from Pa.	3,105	D&A	1951
87	30 E., Cen. SW¼SW¼ 27	do	do	Ike W. Taylor Northern Pacific RR. 1.	2,481	Kc	Mo		3,000	D&A	1954
88	30 E., S½NE¼NE¼ 31	Petroleum	do	Moser and others Moser 1-B		Kc	Jm		2,445	WW	1940
89	30 E., NE¼NE¼NE¼ 34	Garfield	do	Absaroka Oil Development Co. Nordquist 1-B.		Kc	Je	OS at 1,180 and 1,198	2,425	D&A	1923
				Texas Co.:							
90	30 E., NW¼NE¼NW¼ 35	do	do	Northern Pacific RR. 2	2,700	Kc	Je		1,904	D&A	1946
91	30 E., SW¼NE¼SE¼ 35	do	do	Northern Pacific RR. 1	2,695	Kc	Je		2,200	D&A	1946
92	30 E., Cen. SE¼SE¼ 36	do	do	State 1	2,733	Kc	Je		1,905	D&A	1946
93	31 E., S½SW¼SW¼ 31	do	do	East Dome Oil Venture Northern Pacific RR. 1.		Kc	Je	OS at 1,856 from Je	1,882	D&A	1947

[1] Well location indefinite because position of line between secs. 29 and 30 uncertain.

689-268 O—63——6

group (Mississippian) and was abandoned at a depth of 5,131 feet. The small fold in the northeast corner of the mapped area, known as West Calf Creek dome, was tested in 1951 by the Amerada Petroleum Corp. Northern Pacific B–1 well, in the center of the NW¼NW¼ sec. 1, T. 14 N., R. 32 E. This well was drilled to the Mission Canyon limestone (Mississippian) and abandoned at a depth of 6,588 feet. The Amerada Petroleum Corp. also explored, without success, to a depth of 6,120 feet rocks as old as the Mission Canyon in its Northern Pacific 1 well in the center of the NW¼SW¼ sec. 1, T. 13 N., R. 32 E. Rocks in the Blood Creek syncline were tested in 1954 in the California Co. Peterson 1 well in the center of the NW¼NE¼ sec. 13, T. 15 N., R. 30 E., but failed to yield shows of oil or gas. This well, which is the deepest in the Winnett-Mosby area, was drilled into Cambrian rocks to a depth of 8,096 feet.

CAT CREEK OIL FIELD

Production.—Oil was discovered on Mosby dome in 1920, and from then to July 1, 1959, wells drilled in the Cat Creek field totaled 466, of which 167 were dry (table 4). On July 1, 1959, 91 wells were producing oil.

All the oil produced from West dome and most of the oil produced from Mosby dome is pumped through a 4-inch pipeline to Winnett, and from there it is shipped by railroad to a refinery in Billings, Mont. Some oil produced from Mosby and East domes is processed at a small refinery on East dome.

The cumulative production from 1920 to January 1, 1959, from the Cat Creek oil field was 19,237,913 barrels.[3] Production declined steadily from a yearly high of 2,201,917 barrels in 1922 to 114,756 barrels in 1944. Oil was discovered in the Swift formation of Late Jurassic age in 1945 and production increased to 586,307 barrels in 1947. Since that date, however, the production has again steadily declined, and only 171,250 barrels of oil was produced from the Cat Creek field in 1958. The yearly production records for 1920–58, compiled from reports of the Montana State Oil and Gas Conservation Commission, are shown below.

Crude oil production of the Cat Creek field, 1920–58

Year	Barrels	Year	Barrels
1920	236, 833	1940	181, 687
1921	1, 350, 529	1941	171, 521
1922	2, 201, 917	1942	137, 649
1923	2, 080, 826	1943	118, 950
1924	1, 529, 202	1944	114, 756
1925	1, 234, 456	1945	130, 691
1926	1, 003, 233	1946	483, 691
1927	775, 699	1947	586, 307
1928	610, 732	1948	510, 292
1929	487, 554	1949	459, 978
1930	414, 814	1950	398, 262
1931	356, 934	1951	324, 857
1932	312, 060	1952	270, 755
1933	262, 250	1953	208, 576
1934	236, 018	1954	200, 453
1935	292, 750	1955	173, 599
1936	254, 239	1956	163, 998
1937	223, 606	1957	164, 754
1938	211, 877	1958	171, 250
1939	195, 676		

[3] Montana State Oil and Gas Commission statement of crude oil production and valuation in all Montana fields, 1958.

TABLE 4.—*Status of wells drilled for oil and gas in the Cat Creek oil field and Rattlesnake Butte area, Montana, as of July 1, 1959*

Area	Producing geologic unit	Producing wells		Abandoned producing wells	Dry and abandoned wells	Drilling wells [1]	Total
		Active	Shut-in				
Cat Creek field							
East dome	Colorado shale	0	0	0	0		0
	Lower sandstone member of Colorado shale (First Cat Creek sand of Reeves, 1925)	0	0	0	2		2
	Second Cat Creek sand of the Kootenai formation	0	0	0	5		5
	Morrison formation	0	0	0	0		0
	Swift formation	18	1	0	[2] 9		28
Mosby dome	Colorado shale	0	0	0	4		4
	Lower sandstone member of Colorado shale (First Cat Creek sand of Reeves, 1925)	0	0	3	2		5
	Second Cat Creek sand of the Kootenai formation	5	3	22	37		67
	Morrison formation	4	2	0	3		9
	Swift formation	16	9	2	[2] 24		51
West dome [3]	Colorado shale	1	2	6	11		20
	Lower sandstone member of Colorado shale (First Cat Creek sand of Reeves, 1925)	32	32	55	14		133
	Second Cat Creek sand of the Kootenai formation	10	11	[4] 30	38	2	91
	Morrison formation	3	4	0	3		10
	Swift formation	2	2	0	[2] 16	1	21
Rattlesnake Butte area							
	Colorado shale	0	0	0	1		1
	Lower sandstone member of Colorado shale (First Cat Creek sand of Reeves, 1925)	0	0	0	0		0
	Second Cat Creek sand of the Kootenai formation	0	0	1	2		3
	Morrison formation	0	0	0	0		0
	Swift formation	0	0	0	[2] 3		3

[1] Recorded as in the oldest producing zone penetrated.
[2] Includes wells drilled through the Swift formation of Late Jurassic age.
[3] Wells that produced from both the lower sandstone member of the Colorado shale and the Second Cat Creek sand of the Kootenai formation are recorded as producing from the lower sandstone.
[4] Includes one abandoned producing well in the Third Cat Creek sand of the Kootenai formation, not normally a producing zone.

Secondary recovery.—A pilot water-flood project was initiated on West dome in May 1957 and suspended in October 1958. Water from the Third Cat Creek sand in the Kootenai formation was injected into the lower sandstone member of the Colorado shale (First Cat Creek sand of Reeves, 1925) and into the Second Cat Creek sand in the Kootenai formation in four wells in the SW¼SE¼ sec. 11 and in the NW¼NE¼ and NE¼NW¼ sec. 14, T. 15 N., R. 29 E. According to the Geological Survey, Conservation Division, Billings, Mont., 302,000 barrels of water was injected and an estimated 40,200 barrels of oil was recovered as a result. In the fall of 1959 a full-scale peripheral water-flood in the First and Second Cat Creek sands was begun on the western part of West dome.

Mosby dome.—The discovery well in the Cat Creek field was drilled by the Frantz Oil Corp. in February 1920 on Mosby dome in the

SW¼SE¼NW¼ sec. 21, T. 15 N., R. 30 E. The initial oil production was about 10 barrels daily from the Second Cat Creek sand in the Kootenai formation. A few wells also produced oil from the lower sandstone member of the Colorado shale (First Cat Creek sand of Reeves, 1925). In October 1945, the Farmers Union discovered oil in the Fifer 1 well in the NW¼NW¼NW¼ sec. 21, T. 15 N., R. 30 E., in sandstone of the Swift formation. This stimulated exploration of deeper horizons throughout the Cat Creek field, resulting in new production, particularly on Mosby and East domes, from the Swift and from lenticular sandstone in the Morrison formation. As of July 1, 1959, 136 wells had been drilled for oil on Mosby dome; of these, 66 were commercially productive. About 10 percent of the oil taken from the Cat Creek field has come from Mosby dome. As of July 1, 1959, 25 wells were actively producing on this dome; of these, 5 were obtaining oil from the Second Cat Creek sand, 4 from the Morrison, and 16 from the Swift.

West dome.—Discovery of oil on West dome was made by the Frantz Oil Corp. in May 1920 in a well in the NE¼SE¼NE¼ sec. 14, T. 15 N., R. 29 E. The initial daily production was about 200 barrels from the lower sandstone member of the Colorado shale (First Cat Creek sand), but later the output increased to about 2,500 barrels a day (Reeves, 1927, p. 72). Oil in the Second Cat Creek sand in the Kootenai formation was discovered on West dome in July 1922, and many wells producing from the First Cat Creek sand were deepened to the Second Cat Creek sand. Reeves (1927, p. 72) reported that good production was obtained from the Second Cat Creek sand in the wells on the crest of the dome, but wells structurally lower encountered water. Following the discovery of oil in Jurassic rocks on Mosby dome, many wells were drilled to the Morrison and Swift formations on West dome, but only a few produced oil. A small amount of oil also has been found in 9 wells drilled into faults or sandy zones in the Colorado shale above the lower sandstone member. As of July 1, 1959, 275 wells had been drilled on or adjacent to West dome, including the small anticline along the township line between T. 15 N., Rs. 28 and 29 E.; of these, 190 were commercial producers. West dome has yielded about 85 percent of the total amount of oil produced in the Cat Creek field. On July 1, 1959, 48 wells were in active production on West dome; of these, 1 was obtaining oil from the Colorado shale, 32 from the First Cat Creek sand, 10 from the Second Cat Creek sand, 3 from the Morrison, and 2 from the Swift.

East dome.—East dome is the youngest producing area in the Cat Creek field. Before 1946 only a few wells had been drilled on this dome, and all had encountered fresh water in the Cat Creek sands. In April 1946, oil was found in the Swift formation in the William M. Hanlon

York-Montana 1 well in the NE¼NE¼SW¼ sec. 6, T. 14 N., R. 31 E. The initial yield from this well was about 140 barrels a day of 51.1° API gravity oil. As of July 1, 1959, 35 wells have been drilled on or adjacent to East dome, and of these, 19 wells were commercial producers, all in the Swift formation. East dome has contributed about 5 percent of the total production to January 1, 1959, from the Cat Creek field.

RATTLESNAKE BUTTE AREA

The only oil produced outside the Cat Creek field in the Winnett-Mosby area has been in the Rattlesnake Butte area. Seven wells have been drilled, and three had shows of oil in the Second Cat Creek sand in the Kootenai formation. Only the McAlester Fuel Co. Schwartz well 1-3, formerly the Ike W. Taylor well, drilled in July 1945, in the NE¼SW¼SE¼ sec. 22, T. 13 N., R. 28 E., produced oil in commercial quantities. The initial production of this well was 40 barrels a day of 28.2° API gravity oil, and before the well was abandoned in 1959, it had yielded 5,158 barrels of oil. The stratigraphically lowest formation tested in the Rattlesnake Butte area is the Kibbey sandstone (Mississippian).

FLAT WILLOW ANTICLINE

Shows of oil and gas have been encountered in the First and Second Cat Creek sands in several wells on the Flat Willow anticline, but no oil or gas in commercial quantities has been found. The stratigraphically lowest formation that has contained oil on the anticline was logged as the Quadrant formation (Pennsylvanian) in the Oregon-Montana Oil Co. Faragher 1 well in the NW¼NE¼ sec. 20, T. 14 N., R. 26 E., but the driller's log indicates that the oil show was in rocks of the Heath formation of Late Mississippian age. The Charles formation of Early Mississippian age is the oldest formation penetrated in wells on the Flat Willow anticline. The Herbert D. Hadley Govt. 1 well in the NW¼SE¼NW¼ sec. 29, T. 14 N., R. 25 E., drilled in 1959, was abandoned in this formation at a depth of 3,003 feet.

PRODUCING ZONES

Four formations have produced commercial quantities of oil in the Winnett-Mosby area at depths ranging from about 500 to 2,150 feet. Shows of gas have been reported from the Mosby sandstone member of the Colorado shale at West dome, and a gas show was reported from a sandstone in the Kootenai formation in a well in the N½NE¼NE¼ sec. 14, T. 15 N., R. 29 E.; however, no commercial quantities of gas are in this area, and no gas is associated with the oil. Water has been found in all producing sandstones except perhaps those in the Morrison formation, and particularly large quantities are found in the Third Cat Creek sand in the Kootenai formation.

Colorado shale.—The Colorado shale does not normally yield oil except for the lower sandstone member; however, nine wells on West dome have produced small quantities of oil from fault planes or sandy zones in the shale. In the N½ sec. 9, T. 15 N., R. 29 E., 6 wells produced oil from the Colorado shale at depths of 500 to 800 feet, and 1 well obtained a small yield at 1,293 to 1,304 feet below the surface, about 15 feet above the top of the lower sandstone member. One other well that has produced oil from the Colorado shale is in the SW¼NW¼NW¼ sec. 13, T. 15 N., R. 29 E.

The lower sandstone member of the Colorado shale (First Cat Creek sand of Reeves, 1925) is the first thick sandstone penetrated in wells drilled in the Cat Creek field. In outcrop along the west side of the Winnett-Mosby area the member is about 70 feet thick; however, well sample logs show that the First Cat Creek sand is about 30 to 45 feet thick in the Cat Creek field. In most wells fresh water replaces oil in the First Cat Creek sand as the oil is withdrawn.

Kootenai formation.—The Kootenai formation contains oil in two zones known locally as the Second Cat Creek and Third Cat Creek sands. The top of the Second Cat Creek sand is about 115 to 180 feet below the top of the Kootenai formation. In general, the Second Cat Creek sand on East dome is thin and commonly is a single sandstone bed, whereas on Mosby and West domes it consists of 2 to 4 sandstones separated by shale in a zone 40 to 110 feet thick. The individual sandstone units of the Second Cat Creek sand range in thickness from 10 to 60 feet, but generally they are about 20 feet thick. The sandstone units change thickness very abruptly, and few can be traced with certainty beyond very short distances (pl. 2). The Second Cat Creek sand has yielded large quantities of oil on Mosby and West domes.

The Third Cat Creek sand, the basal unit of the Kootenai formation, generally is the thickest and most persistent of the Cat Creek sands; it lies 25 to 50 feet below the base of the Second Cat Creek. The Third Cat Creek is not normally a commercial oil-producing zone, but locally it yields small quantities of oil together with large volumes of fresh water. The California Co. Van Tassel 5–B well, in the NW¼SW¼NE¼ sec. 12, T. 15 N., R. 28 E., initially produced about 3 barrels of 50° Baumé gravity oil and more than 300 barrels of water per day from this sandstone. In the subsurface at the Cat Creek field the Third Cat Creek sand ranges in thickness from about 25 to 100 feet. Thicknesses in excess of 100 feet given on some drillers' logs may include part of the Morrison formation. In many localities the basal part of the Third Cat Creek and the upper of the Morrison formation consist of interbedded lenticular sandstone and sandy shale, and without sample logs the contact is indeterminate.

Morrison formation.—The Morrison formation is composed of dark-red, gray, and greenish-gray shale, mudstone, siltstone, and sandstone. A coal bed is present just below the Third Cat Creek sand at most localities near Lewistown, and this coal is reported in several wells on Mosby dome. In the Cat Creek field the Morrison is reported to be about 120 to 260 feet thick, but the variation in thickness is due in part to inconsistency in picking the top of the formation. Oil is produced from sandstone beds in the Morrison at West and Mosby domes, and good shows of oil have been obtained at East dome. The principal producing sand, called locally the Brindley, lies 175 to 210 feet below the top of the Third Cat Creek sand (pl. 2). It is a gray to greenish-gray shaly sandstone or locally sandy siltstone which is 5 to 55 feet thick. This sand, named for the Brindley lease on Mosby dome, has not been identified in surface exposures of the Morrison formation.

Swift formation.—The oldest rocks presently yielding commercial quantities of oil in the Cat Creek field are in the Swift formation of Jurassic age. The oil is in medium-gray to greenish-gray calcareous glauconitic fine- to medium-grained sandstone, in part shaly, in the uppermost part of the Swift. Drillers' logs show that in the oil field this sandstone ranges in thickness from 20 to 63 feet. It is underlain by greenish-gray calcareous shale and sandy siltstone. The top of the Swift is 1,735 to 2,145 feet below the surface at West dome, 1,400 to 1,720 feet at Mosby dome, and 1,745 to 1,840 feet at East dome.

CHARACTER OF THE OIL

Crude oil from the Cat Creek field ranges in gravity from 47° to 51° API. Oil from the Second Cat Creek sand in the Kootenai formation is about 2° lower in gravity than that from the lower sandstone member of the Colorado shale (First Cat Creek sand). Drillers' logs record the gravity of oil from the Swift as 51° API; the only recorded gravity for oil from the Morrison is 49° API. Two samples of crude oil from the Cat Creek field were analyzed by Crawford and Larsen (1943, table 2), and yielded the following data: The sample of oil from the First Cat Creek sand had a gravity of 50.4° API, 0.22 percent sulfur, a carbon residue of 0.6 percent, a total gasoline content of 68.3 percent, and a Saybolt universal viscosity of −32 seconds; the Second Cat Creek sand oil had a gravity of 47.8° API, 0.48 percent sulfur, a carbon residue of 0.7 percent, a total gasoline content of 58.2 percent, and a Saybolt universal viscosity of 32 seconds. The abandoned producing well in the Rattlesnake Butte area, the McAlester Fuel Co. Schwartz 1–3 well, in the SW¼SE¼ sec. 22, T. 13 N., R. 28 E., produced 28.2° gravity oil from the Second Cat Creek sand. The driller's log reports a show of 27.6° gravity oil from the Second Cat Creek sand in the Ike W. Taylor Clauson 2 well in the NW¼NE¼ sec. 27 of the same township.

POSSIBLE DEEPER PRODUCING ZONES

Shows of oil have been found in rocks below the Jurassic Swift formation in several wells in the Winnett-Mosby area. On Mosby dome in the Continental Oil Co. Northern Pacific 1 well in the NE¼NE¼SW¼ sec. 27, T. 15 N., R. 30 E., a show of oil was reported in the Amsden formation [of former usage in central Montana] which has been redefined as the Devils Pocket formation, Alaska Bench limestone, and Cameron Creek formation (Gardner, 1959, fig. 2). To the southwest in the Rattlesnake Butte area in the Ike W. Taylor Clauson 2 well, in the NW¼NW¼NE¼ sec. 27, T. 13 N., R. 28 E., Nieschmidt (1953) found zones of oil stain and saturation in the dolomitic part of the Amsden formation. South of this area, dolomite in the same stratigraphic sequence yields oil in the Big Wall field, Musselshell County, and in the Northwest Sumatra field of Rosebud County. Rocks in the Alaska Bench limestone and Cameron Creek formation, and possibly in the Devils Pocket formation, seem to offer good possibilities for oil production in the Winnett-Mosby area, but these rocks are restricted to the southern and western parts of the area owing to erosion before deposition of strata of the Ellis group (Nieschmidt, 1953).

A possible oil-producing zone in the Ellis group below the Swift formation is the Piper limestone, the middle member of the Piper formation. This limestone, which also has been designated the Firemoon limestone member of the Piper by Nordquist (1955, p. 101), is productive in the Northwest Sumatra field, Rosebud County, and in the Wolf Springs field in northeast Yellowstone County. No oil shows have been reported in the Piper in the Winnett-Mosby area, but this unit occurs under nearly the entire area (Rayl, 1956, fig. 5).

A favorable zone for deeper production within the Winnett-Mosby area is the nonmarine part of the Heath formation. This part of the Heath, designated the Tyler formation by Mundt (1956, p. 46), locally contains channel sandstones that produce substantial quantities of oil in the Northwest Sumatra, Big Wall, and Melstone fields to the south of the mapped area (p. 50). The distribution of sandstones in the Tyler formation of Mundt (1956) in the Winnett-Mosby area is not known, but Cooper (1956, fig. 2) indicated that they are in the subsurface along part of the Cat Creek anticline.

A thick sequence of limestone, dolomite, and anhydrite, comprising the Madison group of Mississippian age, is in the subsurface of the Winnett-Mosby area. Its potential as an oil-producing zone in central Montana is largely untested, but the prolific production obtained from these rocks in other parts of Montana has stimulated interest in the Madison group in this area.

BENTONITE

Numerous beds of bentonite are in the Cretaceous rocks of the Winnett-Mosby area, but they are thickest and most abundant in the Upper Cretaceous shales, particularly the Claggett and Bearpaw. The bentonites, which range in thickness from less than 1 foot to about 4 feet, are light olive gray to grayish yellow on a fresh surface and weather light olive gray to pale yellowish orange. Most are the swelling variety and form peculiar popcornlike weathered surfaces generally littered with fragments of aragonite, selenite, or mica. The weathered bentonites are shaly to mealy in texture, somewhat sandy, and on weathering are mottled by limonite stain.

The bentonites in the Claggett shale generally are more abundant in the basal part, and those in the Bearpaw are distributed in general throughout the middle and upper parts of the formation.

SAND AND GRAVEL

Mixed sand and gravel is readily available from the many terrace deposits in the Winnett-Mosby area. Some sand and gravel used for road metal is dug from pits in a terrace deposit at the seventh level just north of State Route 18 adjacent to the road to Cat Creek Post Office. A deposit in secs. 14 and 23, T. 15 N., R. 29 E., contains sufficiently low percentages of shale, ironstone, and chert to be used locally for concrete aggregate. Several gravel pits have been dug in the terraces bordering McDonald and Flat Willow Creeks adjacent to paved highways in the area.

Friable sandstones of the Fox Hills and Hell Creek formations of Late Cretaceous age are a source of sand, and just north of the mapped area along State Route 18, in sec. 31, T. 15 N., R. 32 E., the Fox Hills has been quarried, crushed, and mixed with asphalt for use as paving material on the highway.

REFERENCES CITED

Alden, W. C., 1932, Physiography and glacial geology of eastern Montana and adjacent areas: U.S. Geol. Survey Prof. Paper 174, 133 p.

Alpha, A. G., and Fanshawe, J. R. 2d., 1954, Tectonics of northern Bighorn Basin area and adjacent south-central Montana, *in* Richards, P. W., ed., Billings Geol. Soc. Guidebook, 5th Ann. Field Conf., Pryor Mountains—Northern Bighorn Basin, Montana, 1954: p. 72–79.

Bauer, C. M., and Robinson, E. G., 1923, Comparative stratigraphy in Montana: Am. Assoc. Petroleum Geologists Bull., v. 7, no. 2, p. 159–178.

Bowen, C. F., 1914, Coal discovered in a reconnaissance survey between Musselshell and Judith, Montana: U.S. Geol. Survey Bull. 541, p. 329–337.

———1915, The stratigraphy of the Montana group, with special reference to the position and age of the Judith River formation in north-central Montana: U.S. Geol. Survey Prof. Paper 90, p. 95–153.

Bowen, C. F., 1919, Gradations from continental to marine conditions of deposition in central Montana during the Eagle and Judith River epochs: U.S. Geol. Survey Prof. Paper 125–B, p. 11–21.

Cobban, W. A., 1951a, Colorado shale of central and northwestern Montana and equivalent rocks of Black Hills: Am. Assoc. Petroleum Geologists Bull., v. 35, no. 10, p. 2170–2198.

———1951b, Scaphitoid cephalopods of the Colorado group: U.S. Geol. Survey Prof. Paper 239, 42 p., 21 pl.

———1953a, An Upper Cretaceous section near Mosby, Montana, *in* Parker, J. M., ed., Billings Geol. Soc. Guidebook 4th Ann. Field Conf., Little Rocky Mountains, Montana and southwestern Saskatchewan, 1953: p. 98–101.

———1953b, Cenomanian ammonite fauna from the Mosby sandstone of central Montana: U.S. Geol. Survey Prof. Paper 243–D, p. 45–55, 12 pl.

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. 1011–1043.

Cooper, G. G., 1956, The Tyler formation and basement faulting [Mont.] *in* Foster, D. I., ed., Billings Geol. Soc. Guidebook, 7th Ann. Field Conf., Central Montana, 1956: p. 82–85.

Crawford, J. G., and Larsen, R. M., 1943, Occurrences and types of crude oils in Rocky Mountain region: Am. Assoc. Petroleum Geologists Bull., v. 27, no. 10, p. 1305–1334.

Dobbin, C. E., and Erdmann, C. E., 1955, Structure contour map of the Montana Plains: U.S. Geol. Survey Oil and Gas Inv. Map OM 178–B.

Dobbin, C. E., and Reeside, J. B., Jr., 1930, The contact of the Fox Hills and Lance formations: U.S. Geol. Survey Prof. Paper 158, p. 9–25.

Fenneman, N. W., 1931, Physiography of Western United States: New York, McGraw-Hill, 534 p.

Gardner, L. S., 1950, Geology of the Button Butte-Forestgrove area, Fergus County, Montana: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 106.

———1959, Revision of Big Snowy group in central Montana: Am. Assoc. Petroleum Geologists Bull., v. 43, no. 2, p. 329–349.

Hadley, H. D., 1956, Cat Creek oil field, Petroleum and Garfield Counties, Montana, *in* Foster, D. I., ed., Billings Geol. Soc. Guidebook, 7th Ann. Field Conf., Central Montana, 1956: p. 98–103.

Knechtel, M. M., 1942, Snake Butte boulder train and related glacial phenomena, north-central Montana: Geol. Soc. America Bull., v. 53, no. 6, p. 917–935.

Lupton, C. T., and Lee, Wallace, 1921, Geology of the Cat Creek oil field, Fergus and Garfield Counties, Montana: Am. Assoc. Petroleum Geologists Bull., v. 5, no. 2, p. 252–275.

Mundt, P. A., 1956, The Tyler and Alaska Bench formations [Mont.], *in* Foster, D. I., ed., Billings Geol. Soc. Guidebook, 7th Ann. Field Conf., Central Montana, 1956: p. 46–51.

Nieschmidt, C. L., 1953, Subsurface stratigraphy of the Heath shale and Amsden formation in central Montana: U.S. Geol. Survey Oil and Gas Inv. Chart OC–50.

Nordquist, J. W., 1955, Pre-Rierdon Jurassic stratigraphy in northern Montana and Williston basin, *in* Lewis, P. J., ed., Billings Geol. Soc. Guidebook, 6th Ann. Field Conf., Sweetgrass arch and Disturbed belt, Montana, 1955: p. 96–106.

Perry, E. S., 1931, Ground water in eastern and central Montana: Montana Bur. Mines and Geology Mem. 2, 59 p.

Perry, E. S., 1932, Artesian wells as a source of water for the Winnett irrigation project, Montana: Montana Bur. Mines and Geology Misc. Contr. 1, 5 p.

Rayl, R. L., 1956, Stratigraphy of the Nesson, Piper, and Rierdon formations of central Montana, *in* Foster, D. I., eds., Billings Geol. Soc. Guidebook, 7th Ann. Field Conf., Central Montana, 1956: p. 35–45.

Reeside, J. B., Jr., 1927, The cephalopods of the Eagle sandstone and related formations in the western interior of the United States: U.S. Geol. Survey Prof. Paper 151, 87 p., 45 pl.

——— 1944, Maps showing thickness and general character of the Cretaceous deposits in the western interior of the United States: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 10.

Reeves, Frank, 1925, Geology and possible oil and gas resources of the faulted area south of the Bearpaw Mountains, Montana: U.S. Geol. Survey Bull. 751, p. 71–114.

——— 1927, Geology of the Cat Creek and Devils Basin oil fields and adjacent areas in Montana: U.S. Geol. Survey Bull. 786–B, p. 39–95.

——— 1931, Geology of the Big Snowy Mountains, Montana: U.S. Geol. Survey Prof. Paper 165, p. 135–149.

Richards, P. W., 1955, Geology of the Bighorn Canyon-Hardin area, Montana and Wyoming: U.S. Geol. Survey Bull. 1026, 93 p.

Ross, C. P., Andrews, D. A., and Witkind, I. J., compilers, 1955, Geologic map of Montana: U.S. Geol. Survey.

Ross, C. S., 1926, Nephelite-haüynite-alnoite from Winnett, Montana: Am. Jour. Sci., 5th ser., v. 11, p. 218–227.

Rubey, W. W., 1929, Origin of the siliceous Mowry shale of the Black Hills region: U.S. Geol. Survey Prof. Paper 154, p. 153–170.

Sandberg, C. A., and Hammond, C. R., 1958, Devonian system in Williston basin and central Montana: Am. Assoc. Petroleum Geologists Bull., v. 42, p. 2293–2334.

Smith, H. R., 1962, Geology of the Melstone-Sumatra area, central Montana: U.S. Geol. Survey Oil and Gas Inv. Map OM–211.

Sonnenberg, F. P., 1956, Tectonic patterns of central Montana, *in* Foster, D. I., ed., Billings Geol. Soc. Guidebook, 7th Ann. Field Conf., Central Montana, 1956: p. 73–81.

Stanton, T. W., and Hatcher, J. B., 1905, Geology and paleontology of the Judith River beds: U.S. Geol. Survey Bull. 257, 174 p., 19 pl.

Thom, W. T., Jr., 1923, The relation of deep-seated faults to the surface structural features of central Montana: Am. Assoc. Petroleum Geologists Bull., v. 7, no. 1, p. 1–13.

Thom, W. T., Jr., and Dobbin, C. E., 1922, Oil and gas prospects in Garfield County, Montana: Am. Assoc. Petroleum Geologists Bull., v. 6, no. 2, p. 144–150.

——— 1924, Stratigraphy of Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. America Bull., v. 35, no. 3, p. 481–505.

Wingerter, Hugh, and Mercer, L. A., 1951, Alternate road log Grass Range to Sand Springs, *in* Billings Geol. Soc. Guidebook, 2d Ann. Field Conf., 1951: p. 50–54.

INDEX

[Italic page numbers indicate major references]