Geology of the Fort Laramie Area, Platte and Goshen Counties, Wyoming

By LAURA W. McGREW

CONTRIBUTIONS TO GENERAL GEOLOGY

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GEOLOGY OF THE FORT LARAMIE AREA, PLATTE AND GOSHEN COUNTIES, WYOMING

By Laura W. McGrew

ABSTRACT

The Fort Laramie area comprises about 200 square miles along the northwest margin of the Julesburg basin in southeastern Wyoming.

Rocks exposed are the White River formation of Oligocene age, an unamed conglomerate sequence of late Oligocene and earliest Miocene age, the Arikaree formation of early and early middle Miocene age, lag boulders from deposits of post-early Miocene and pre-Pliocene age, and loess, silt, sand, and gravel deposits of Pleistocene and Recent age. Pre-Oligocene rocks in the subsurface include igneous and metamorphic rocks of Precambrian age; the Guernsey formation of Devonian and Mississippian age; the Hartville formation of Mississippian(?), Pennsylvanian, and Permian age; the Opeche shale, Minnekahta limestone, and a gypsum and red shale sequence of Permian age; the Chugwater formation of Triassic age; the Sundance and Morrison formations of Jurassic age; and the Cloverly, Thermopolis, Mowry, Frontier, Niobrara, and Pierre formations of Cretaceous age. The Fox Hills sandstone and Lance formation of Late Cretaceous age were penetrated in one well about 11 miles southeast of the Fort Laramie area.

The White River formation is exposed in Goshen Hole in the southeastern part of the map area and in the North Platte and Laramie River valleys in the north-central part of the map area. It consists of about 80 feet of variegated bentonitic claystone containing gray conglomeratic, crossbedded channel sandstone, overlain by 290 to 570 feet of orange-gray tuffaceous siltstone and silty claystone also containing gray conglomeratic, crossbedded channel sandstone beds. Vertebrate fossils from many horizons in the formation indicate an early through late Oligocene age.

Overlying the White River formation in the northwestern part of the map area and around the northwestern part of Goshen Hole is a conglomerate sequence 50 to 100 feet thick. Constituents of the conglomerate range in size from sand to boulders, which are derived in part from rocks of Precambrian age and in part from the Guernsey and Hartville formations. Vertebrate fossils indicate that the conglomerate is of late Oligocene and earliest Miocene age.

The Arikaree formation rests on the conglomerate sequence where that unit is present and directly on the White River formation elsewhere. It is as much as 700 feet thick and is divisible into three units: a lower 200- to 300-foot sequence of soft massive orange-gray tuffaceous sandstone of early and middle early Miocene age; a middle 200-foot sequence of gray tuffaceous sandstone

of late early Miocene age containing many limy sandstone and fresh-water limestone beds; and an upper 200-foot sequence of soft massive orange-gray tuffaceous sandstone of early middle Miocene age. Limy sandstone concretions and siliceous root casts are abundant throughout the Arikaree formation.

Lag boulders 3 to 4 feet in diameter rest on the Arikaree formation in the northwestern part of the map area. These are believed to have weathered out of a post-early Miocene and pre-Pliocene deposit.

Deposits of Quaternary age cover a large part of the Fort Laramie area. These deposits range in thickness from 0 to 80 feet. Units mapped include terrace deposits of sand, silt, and gravel; sand and loess deposits forming upland soils; tributary valley alluvium; and flood-plain deposits.

The so-called Laramide orogeny that produced the Laramie Mountains, Hartville uplift, Richeau Hills, and Moonshine Hills in eastern Wyoming probably reached its climax in the early Eocene. Following the orogeny, but prior to deposition of rocks of Oligocene age, the Laramide folds were extensively eroded and in many places rocks of Precambrian age were exposed. On the surface thus formed, sediments of Oligocene and younger age were deposited.

Oligocene and Miocene sediments were deposited on broad flood plains with intermittent channel cutting and filling. Northwestern Wyoming is suggested as a possible source for the volcanic ash, an important constituent of the Oligocene and Miocene deposits.

Following the deposition of rocks of early middle Miocene age in eastern Wyoming, an orogenic disturbance with extensive block faulting resulted in a conspicuous horst block bounded by the Wheatland fault system on the northwest and the Whalen fault system on the southeast. Associated regional folding resulted in a broad domal uplift now breached to form Goshen Hole, and an arch across the horst block.

Test wells drilled for oil and gas in the area have not been productive. The possibility of subsurface folds southeast of the Hartville uplift-Moonshine Hills-Richeau Hills lineament may be investigated in future tests. Rocks of Cretaceous age east of the Fort Laramie area may contain stratigraphic oil traps. Higher than normal uranium content has been detected in some rock and water samples from strata of Oligocene and Miocene age in the area. Terrace gravels are local sources for road surfacing and riprap materials.

INTRODUCTION

The Fort Laramie area includes about 200 square miles in Platte and Goshen Counties, Wyo. (fig. 1). It comprises the Fort Laramie, Register Cliff, Eagles Nest, and Rockeagle 7½-minute quadrangles (pl. 1). Fort Laramie, the only town in the map area, is in the northeastern corner on U.S. Highway 26. An oiled county road connects Fort Laramie National Monument and Fort Laramie. The Antelope Gap road provides access to the southwestern part of the area from Wheatland, Wyo. Many graveled and graded dirt roads traverse the area, and unimproved dirt roads and trails make jeep travel possible in many areas of rough terrain.

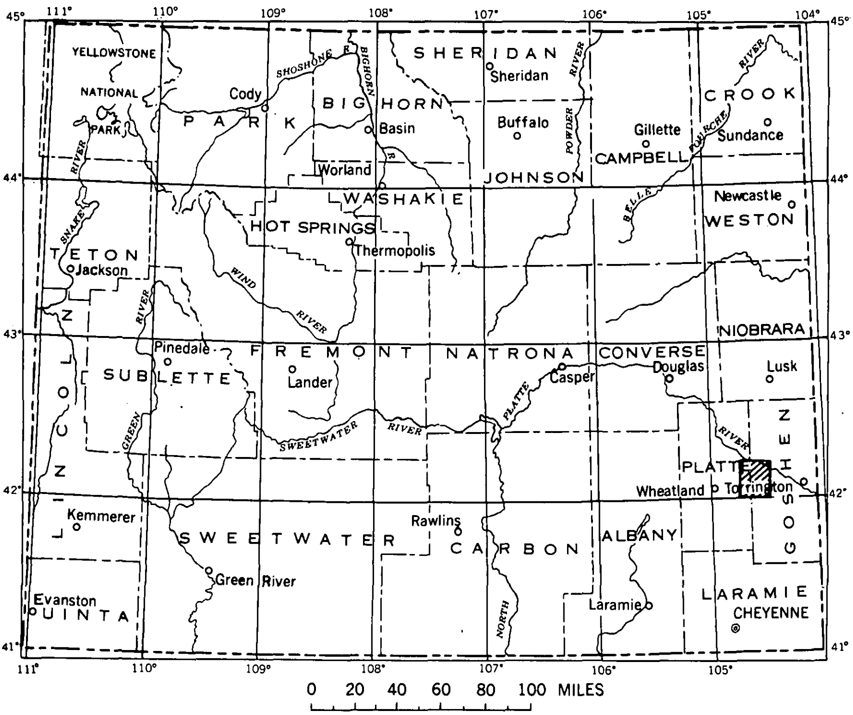

FIGURE 1.—Index map of Wyoming showing location of the Fort Laramie area.

Geologic investigations in the Fort Laramie area were part of the program for development of the Missouri River basin, and had the primary purpose of determining the relation of late Tertiary normal faults to possible oil and gas traps in pre-Tertiary rocks. Both lithology and fauna of Tertiary strata were examined in detail to establish mappable rock units that could be utilized in interpreting the fault structures. In addition, comparisons were made between rocks exposed in the Fort Laramie area and uranium-bearing rocks of the same age in other parts of Wyoming.

Physiographically the area is in a westward part of the High Plains, extensively dissected in strata of Oligocene and Miocene age. A conspicuous escarpment as much as 200 feet high in the southeastern part of the area forms a segment of the western rim of Goshen Hole, a topographic basin resulting from the breaching of a broad domal uplift (Schlaikjer, 1935, no. 4, p. 121). Along the north boundary of the map area, the North Platte River has cut a meandering course on a broad flood plain, bordered in many places by nearly

vertical cliffs as much as 150 feet high. Flowing northeastward through the north half of the area are the Laramie River and its main tributary in this vinicity, Deer Creek; these streams also have broad flood plains bordered by conspicuous exposures. Intermittent tributary streams of the Laramie River have cut deep canyons, some of the most prominent of which are Little Cottonwood and Cottonwood Draws, and Eagles Nest Canyon. Cherry Creek and many intermittent streams drain eastward into Goshen Hole.

Fieldwork was done during the summer of 1955. The accompanying map (pl. 1), however, also includes mapping done by the writer during the summers of 1950 and 1951 as partial fulfillment of the requirements for the degree of Master of Arts at the University of Wyoming. Field mapping was done on aerial photographs at a scale of approximately 1:31,680, and the data were transferred to U.S. Geological Survey 7½-minute topographic quadrangle base maps at a scale of 1:24,000. Stratigraphic sections were measured by steel tape and Brunton compass, and well data were obtained from sample and electrical logs.

H. M. Babcock of the U.S. Geological Survey provided aerial photographs of the area. Dorothy Taylor Sandberg assisted in the field during the summer of 1955. G. E. Lewis identified the larger vertebrate fossils, and R. W. Wilson of the University of Kansas identified the rodent and lagomorph fossils.

Fossil vertebrates collected prior to 1955 were identified in part by the writer with the advice of P. O. McGrew of the University of Wyoming and in part by T. M. Stout of the University of Nebraska; these fossils are in the University of Wyoming collections.

STRATIGRAPHY

Rocks exposed in the Fort Laramie area range in age from Oligocene to Recent. Pre-Oligocene rocks penetrated in the subsurface include rocks of Precambrian age; the Guernsey formation of Devonian and Mississippian age; the Hartville formation of Mississippian(?), Pennsylvanian, and Permian age; the Opeche shale, Minnekahta limestone, and a gypsum and red shale sequence of Permian age; the Chugwater formation of Triassic age; the Sundance and Morrison formations of Jurassic age; and the Cloverly formation, Thermopolis and Mowry shales, Frontier and Niobrara formations, and Pierre shale of Cretaceous age.

Rocks ranging in age from Precambrian through Early Cretaceous are exposed a few miles northwest of the area in the Hartville uplift. A few isolated exposures of Precambrian rocks and the Guernsey and Hartville formations are also present about 1 mile west of the Fort Laramie area. The Lance formation of Late Cretaceous age is exposed a few miles southeast of the area in Goshen Hole; well data show that the Lance is underlain by the Fox Hills sandstone, also of Late Cretaceous age.

On the basis of studies made of sample, electric, and drillers logs, the formations penetrated in test wells for oil and gas drilled in and near the Fort Laramie area are correlated on plate 2.

The author studied the Moonshine Hills surface section to the south of the Fort Laramie area (fig. 2) and logs of wells drilled in or near the area (table 1; pl. 2). The stratigraphic descriptions and thicknesses of pre-Oligocene rocks used in the composite stratigraphic section (pl. 3) and in the stratigraphic discussions below are taken from these studies and from published data (Denson and Botinelly, 1949; Love and others, 1949; 1953).

PRECAMBRIAN ROCKS

Rocks of Precambrian age are exposed in the Hartville uplift to the northwest where they consist of gneiss, schist, phyllite, quartzite, and limestone intruded by coarse-grained granite, ultrabasic rocks, and pegmatite dikes (Denson and Botinelly, 1949). A few isolated outcrops of Precambrian gneiss, schist, granite, and quartzite are present just west of the map area.

CAMBRIAN(?) SYSTEM

A reddish-brown nonfossiliferous conglomeratic quartzite that unconformably overlies Precambrian rocks in the Hartville area has been considered by Denson and Botinelly (1949) to be Cambrian in age largely because of its stratigraphic position. In the northern part of the Hartville area, the quartzite is about 60 feet thick, but it thins southward and is absent about 12 miles northwest of the Fort Laramie area (Denson and Botinelly, 1949; Love and others, 1953).

TABLE 1.—*List of test wells for oil and gas*

[Status of wells: all are abandoned

Map No. (pl. 2, fig. 2)	Location				Geologic structure	Operator	Lease and well No.
	Sec.	Township N.	Range W.	County			
1 [a]	SE¼SE¼NE¼ 2	24	66	Platte	"Grayrocks"	General Petroleum.	84-2-P
2 [a]	SE¼SE¼NE¼ 13	25	66	do		Walt Adams	Mamma Sick 1.
3 [a]	SE¼NE¼ 23	26	65	Goshen	"Wheatland"	Eddie Fisher	Govt. 1
4 [a]	NE¼NE¼ 23	26	65	do	do	Gem Oil Co	Federal 2
5	NE¼NW¼NE¼ 3	23	67	Platte	do	G. E. Hall	Loomis 1
6	NW¼SW¼ 7	23	66	do		Padon and Padon	Swan 1
7	NW¼NW¼NW 12	23	67	do		do	Swan 2
8	N½SW¼ 17	24	66	do		Dividend Refining Co.	Johnson 1
9	NW¼SE¼ 18	24	66	do		Sohio Petroleum	Phifer 1
10	339 ft E., 330 ft N. SW cor. SE¼ NW¼. 15	24	66	do	"Grayrocks"	General Petroleum.	34-15-G
11	SE¼NE¼NE¼ 32	22	63	Goshen		C. W. Teator	Blunt 1
12 [a]	E½SW¼SW¼ 29	25	65	Platte		Seaboard Oil	L. F. Wilson 1

[a] Also shown on plate 1.
[b] Based on electric log.
[c] Based on sample study.
[d] Based on unpublished sample study by oil company geologist.
[e] Based on driller's log.

DEVONIAN AND MISSISSIPPIAN SYSTEMS

GUERNSEY FORMATION

The Guernsey formation was named and described by Smith (1903) as consisting of massive gray limestone underlain by a sandstone which contains 3 to 20 feet of nearly white conglomeratic quartzite at the base. The type section is northeast of Guernsey, Wyo., where the formation is 143 feet thick. Smith (1903) reported the thickness of the formation as ranging from 75 to 200 feet and attributed the variation in thickness to erosion prior to the deposition of the overlying Hartville formation. Love, Henbest, and Denson (1953) show the Guernsey formation to range in thickness from 300 feet near Lance Creek, Wyo., to 0 feet about 15 miles south of the Fort Laramie area. The Guernsey formation was penetrated in test wells 2, 10, and 12 (table 1), and was shown on a sample log of well 10 (Love and others, 1953, sec. 6) to consist of 146 feet of white, light-gray, and pink dolomite and limestone with silty and sandy beds near the base. In sec. 27, T. 25 N., R. 66 W., in the Moonshine Hills west of the Fort Laramie area, a nearly complete section of the Guernsey formation is 107 feet thick. Here the formation consists of 24 feet of yellowish-

drilled in or near the Fort Laramie area
except well 3, which was junked]

Ground elevation (feet)	Total depth (feet)	Depth to base of Tertiary (feet)	Pre-Tertiary rocks penetrated	Reported shows: Type	Reported shows: Depth (feet)	Reported shows: Formation	Completion date
5,094	2,257	1,235?	Frontier to Sundance [b]				June 1949
4,650	2,257	615?	Sundance to Precambrian.[e]				(?)
4,530	3,125	(?)	Mowry(?) to (?)				July 1954
4,500	3,871	1,020?	Pierre to Hartville [b d]				May 1955
4,849	1,925	1,200	Sundance to Chugwater.[d]				June 1950
5,010	4,399	1,050	Pierre to Morrison [b]	Oil	4,297 to 4,355	Cloverly	Nov. 1956
4,910	3,907	1,207	do.[b c]				Mar. 1957
4,933	3,819	1,003	Pierre to Morrison(?) [e]	Gas	3,410	Thermopolis (muddy sandstone member).	1937
				Oil	3,417	do	
				Gas	3,798	Sundance(?)	
4,858	3,033	880?	Pierre to Sundance(?)[b]				Oct. 1956
5,140	5,342	1,360?	Pierre to Precambrian[b e]				Aug. 1942
4,454	8,230	Lance on surface.	Lance to Thermopolis [d]				July 1950
4,916	3,842	1,410	Mowry to Precambrian [b c].	Oil	1,450 to 1,510	Thermopolis (muddy sandstone member).	Feb. 1957

tan sandy, silty dolomite overlain by 83 feet of massive gray cherty limestone containing stringers of red siltstone.

Denson and Botinelly (1949) and Love, Denson, and Botinelly (1949) divided the Guernsey formation into two units; and Love, Henbest, and Denson (1953) determined the age of these units. The lower unit, of Late Devonian age, has a pink arkose bed 4 feet thick at the base, overlain by about 35 feet of purple to gray thin-bedded slabby dolomite interbedded with hard purple dolomitic shale and siltstone. The upper unit, of Early Mississippian age, consists of about 135 feet of hard gray coarsely bedded cherty dolomite which grades upward into blue-gray coarsely crystalline cherty limestone. This upper unit was correlated with the Madison limestone of central Wyoming and the Pahasapa limestone of the Black Hills region.

MISSISSIPPIAN(?), PENNSYLVANIAN, AND PERMIAN SYSTEMS

HARTVILLE FORMATION

The Hartville formation was named and defined by Smith (1903) as including the rocks between the top of the Guernsey formation and the base of the Opeche shale. The type area is the Hartville uplift

where Smith (1903) reported it to consist of 700 feet of gray limestone with minor proportions of sandstone and shale. Condra and Reed (1935) divided the Hartville formation into Divisions I through VI, from youngest to oldest. A thickness map by Love, Henbest, and Denson (1953) shows the Hartville formation to be more than 1,450 feet thick near Agate, Nebr., about 12 miles east of the Wyoming line, and to thin westward to 650 feet along the east flank of the Laramie Mountains. Within and near the Fort Laramie area the formation ranges in thickness from 882 to 1,140 feet.

The Hartville formation is exposed in the Hartville uplift northwest of the Fort Laramie area, and the lower 655 feet of the formation crops out in the Moonshine Hills in T. 25 N., R. 66 W., west of the area. Brief and generalized lithologic descriptions of the divisions, on the basis of the work of Love, Henbest, and Denson (1953) and on well and surface information in and near the Fort Laramie area, are as follows:

Division VI consists of 43 to 100 feet of red and gray quartzitic sandstone. A sample study of well 10 (table 1) showed that Division VI is 43 feet thick, contains some red silty shale at the base, and becomes limy in the upper half. In the Moonshine Hills, Division VI is 59 feet thick, and consists of white to grayish-white, medium- to coarse-grained, crossbedded, hard quartzitic to soft limy sandstone with yellow and red mottling. Division VI is apparently equivalent in part to the Bell sands, or drillers', and other sandstone units, which contain small quantities of oil along the southeast margin of the Powder River Basin, and in part to the Darwin sandstone member at the base of the Amsden formation in the Wind River Mountains (Love, and others, 1953).

Divisions V and IV could not be separated north of their type areas because of facies changes (Love, and others, 1953); hence they were described as one unit. In the Hartville uplift, the unit consists of 150 to 300 feet of interbedded red shale, gray limestone, thin beds of white to pink fine-grained dolomite, and sandstone. The lower 75 feet is predominantly a gray massive ledge-forming limestone, and the upper part is predominantly red silty and limy shale with some limy sandstone and dolomitic limestone beds. One-hundred and ninety-four feet of Divisions V and IV was penetrated in well 10 (table 1): the lower 40 feet is gray limestone, and the upper 154 feet is predominantly red silty shale with some limestone, limy sandstone, and dolomitic limestone beds. In the Moonshine Hills, Divisions V and IV are 287 feet thick: the lower 95 feet is predominantly gray cherty silty limestone with red mottling and banding, and some limy sandstone beds, and the upper 192 feet is predominantly red limy siltstone containing some thin limestone, dolomite, and sandstone beds.

Division III consists of 130 to 330 feet of gray to light-gray limestone and dolomite interbedded with lesser amounts of calcareous shale and siltstone and some sandstone. Some red sandstone and cherty limestone are present near the base. Some of the sandstone beds within Division III have been correlated with the Leo sands of drillers which produce oil in the Lance Creek and Little Buck Creek fields. In well 10, Division III is composed of 144 feet of dolomite with a few beds of limy and dolomitic sandstone, limestone, shale, and anhydrite. In the Moonshine Hills Division III is 180 feet thick and composed mainly of gray to light-gray dolomite interbedded with lesser amounts of thin limy and dolomitic sandstone, cherty limestone, and some siltstone.

Division II is composed of 160 to 320 feet of gray to light-gray dolomite and limestone with some sandstone, anhydrite, and red and gray shale. Lenticular gray crossbedded quartzitic sandstone beds are present near the base. About 25 feet below the top of Division II, a gray to pink chert bed 6 inches to 2 feet thick provides a widespread marker bed in the Hartville uplift. In well 10, Division II is 204 feet thick and consists mainly of gray to light-gray limestone and dolomite with some shaly and sandy zones and some thin sandstone, siltstone, and anhydrite beds. An incomplete section of Division II in the Moonshine Hills is 138 feet thick and consists of gray cherty limestone and dolomite with some limy and dolomitic siltstone and sandstone beds.

Division I consists of 200 to 300 feet of sandstone, shale, gypsum and anhydrite, limestone and dolomite, and of breccia beds made up of blocks of sandstone and dolomite in a lime cement. The lower half is mainly gray, pink, and red breccia beds, red cherty and dolomitic sandstone, and gray to pink dolomite, with some anhydrite in subsurface sections. The upper half of the unit is predominantly gray, yellow, and red sandstone with a few beds of limestone, anhydrite, and gypsum. The sandstone at the top of Division I is probably equivalent to the Converse sand of drillers which produces oil in the Lance Creek and Little Buck Creek fields. Two-hundred and ninety-eight feet of Division I is penetrated in well 10; Division I is not exposed in the Moonshine Hills.

The Hartville formation was reached in test wells 2, 4,10, and 12 (table 1). The study of Hartville samples from well 10 was made by J. D. Love (Love and others, 1953, section 6; and J. D. Love, written communication, 1946). No oil or gas shows were reported from the formation.

Division VI of the Hartville formation was deposited on a very irregular erosion surface at the top of the Guernsey formation, and Division I is conformably overlain by the Opeche shale.

Love, Henbest, and Denson (1953) have determined the following ages for the divisions of the Hartville formation on the basis of fossil assemblages and stratigraphic position:

	Age
Division VI	Late Mississippian or Early Pennsylvanian.
Divisions V–II	Pennsylvanian.
Division I	Permian (?).

The U.S. Geological Survey now (1961) considers Division I of the Hartville formation to be of Permian age.

PERMIAN SYSTEM

OPECHE SHALE

The Opeche shale is 25 to 90 feet thick and is exposed in the Hartville uplift northwest of the Fort Laramie area, where it was described by Love, Henbest, and Denson (1953). There, the Opeche consists of bright-red silty shale with some shaly yellow to red sandstone near the base, and it contains geodes and lenses of purple, red, and gray chert. The formation was penetrated in wells 2, 4, 10, and 12 (table 1) where it is 60 to 73 feet thick. The Opeche shale is possibly equivalent in part to the lower shaly unit in the Phosphoria formation of central Wyoming (Love, and others, 1953). It is overlain conformably by the Minnekahta limestone.

MINNEKAHTA LIMESTONE

The Minnekahta limestone is 20 to 40 feet thick in the Hartville uplift and adjacent areas, but it thickens to the north. In the Hartville uplift, Love, Henbest, and Denson (1953) report the Minnekahta limestone to consist of hard purple to bluish slabby fine-grained thin-bedded limestone in the lower part and yellow to pink slabby silty limestone in the upper part. Sparse chert and chalcedony nodules and lenses are present. In the Fort Laramie area the Minnekahta limestone was penetrated in wells 2, 4, 10, and 12 (table 1) where it is 21 to 35 feet thick. Abundant but poorly preserved invertebrate fossils from the Minnekahta limestone suggest that it correlates with a part of the lower beds of the Phosphoria formation of central Wyoming (Love, and others, 1953). The Minnekahta limestone is overlain conformably by the Permian gypsum and red shale sequence.

GYPSUM AND RED SHALE SEQUENCE

The Permian gypsum and red shale sequence is commonly placed in the lower part of the Chugwater formation, and includes the Forelle(?) limestone and Glendo shale (Condra and others, 1940) at the base. The sequence is exposed in the Hartville uplift where it is from 230 to 310 feet thick, and it thickens to the northeast (Denson and Botinelly, 1949). In test wells 2, 4, 10, and 12 (table 1), this sequence is 110 to 230 feet thick, and consists of red soft limy and silty shale interbedded with white gypsum and anhydrite.

The Permian gypsum and red shale sequence is conformably overlain by the Chugwater formation. The age for these rocks is based on regional correlations.

Burk and Thomas (1956) have proposed a new name, the Goose Egg formation, for a part of the Permian and Triassic sequence of eastern Wyoming. This new formation includes the Opeche shale. Minnekahta limestone, Permian gypsum and red shale sequence, and lower part of the Chugwater formation of this report.

TRIASSIC SYSTEM

CHUGWATER FORMATION

The Chugwater formation, as used in this report, is the generally nongypsiferous red beds of Triassic age. The nearest exposures are in the Hartville uplift where the formation consists of 150 to 435 feet of red siltstone and shale and fine-grained red, silty sandstone; a few thin gypsum and anhydrite seams are present in the lower part and the upper part is slightly limy (Denson and Botinelly, 1949). A map by Denson and Botinelly (1949) shows that the formation thickens to the southwest. The Chugwater formation is 420 to 600 feet thick in wells 1, 2, 4, 5, 10, and 12 (table 1). The Chugwater formation is unconformably overlain by the Sundance formation. The Triassic age of the Chugwater is based on correlation with fossiliferous sediments in the vicinity of Casper, Wyo. (Denson and Botinelly, 1949).

JURASSIC SYSTEM

SUNDANCE FORMATION

The Sundance formation is exposed in the Hartville uplift where it ranges in thickness from 250 feet to 400 feet, and thin southward. Denson and Botinelly (1949) described three units within the sequence: a basal sandstone 60 to 140 feet thick consisting of light-gray to brick-red, limy, fine- to coarse-grained massive to cross-bedded sandstone; "Lower Sundance" rocks 140 to 220 feet thick consisting of fine-grained, nonglauconitic limy sandstone, with shaly and silty

zones near the base and commonly red in color near the top; and "Upper Sundance" rocks 50 to 120 feet thick consisting of glauconitic green shale and shaly sandstone. The Sundance formation, penetrated in wells 1, 2, 4, 5, 8, 10, and 12 (table 1), is 210 to 289 feet thick in and near the Fort Laramie area and can be divided into a basal unit, 70 to 140 feet thick, consisting of red to pink and tan fine- to coarse-grained friable porous sandstone, and an upper unit, 140 to 170 feet thick, consisting of gray to dark-gray sandy, silty, and limy shale, including about 50 feet of green glauconitic limy, sandy shale at the top.

The basal sandstone as described from wells in the vicinity of the Fort Laramie area is probably equivalent to Denson and Botinelly's (1949) basal sandstone in the Jurassic sequence, the lower part of which they suggest may be equivalent to the Nugget sandstone to the west in Wyoming. A basal sand in the Sundance, which is a prolific oil-producing sandstone in the Lance Creek field, may also correlate with part of this unit.

The upper unit of the Sundance formation in the Fort Laramie area probably represents both "Lower Sundance" and "Upper Sundance" strata as described by Denson and Botinelly (1949) but no attempt was made to separate these two units for this report. Denson and Botinelly (1949) correlate a 30-foot sandstone at the base of the "Upper Sundance" rocks with the "Upper Sundance" oil-producing sand in the Lance Creek field.

Fossils from the middle and upper parts of the basal sandstone in the Jurassic sequence and from "Lower" and "Upper Sundance" rocks (Denson and Botinelly, 1949) establish a Late Jurassic age for the Sundance formation with the possible exception of the lower part of the basal sandstone unit.

The Sundance formation is conformably overlain by the Morrison formation.

MORRISON FORMATION

The Morrison formation, where it is exposed in the Hartville uplift northwest of the Fort Laramie area (Denson and Botinelly, 1949), consists of 130 to 220 feet of variegated claystone, fine-grained fresh-water limestone, and lenticular sandstone. The formation was penetrated in test wells 1, 4, 6–8, 10, and 12 (table 1) where it consists of 77 to 133 feet of gray and green soft limy shale. The Morrison formation is considered to be of Late Jurassic age and is separated from the overlying Cloverly formation by a marked erosional unconformity (Denson and Botinelly, 1949).

CRETACEOUS SYSTEM

LOWER CRETACEOUS ROCKS

CLOVERLY FORMATION

The Cloverly formation is 175 to 320 feet thick and is chiefly sandstone where it is exposed in the Hartville uplift. The lower 50 to 75 feet consists of gray, clean, sparkly, medium-grained, noncalcareous sandstone. A thin shale unit is present in some places near the middle of the Cloverly formation and is gray, black, or pink, very soft, plastic and waxy, and is interbedded with thin sandstone and siltstone. The upper sandstone is more shaly and ferruginous and thinner bedded than the basal sandstone. Where the middle shale unit is not present, the entire Cloverly formation consists of sandstone.

The Cloverly formation was penetrated in test wells 1, 4, 6–10, and 12 (table 1) where it consists of 70 to 100 feet of gray sandstone interbedded with some gray and black shale. The three divisions mentioned above are not clearly distinguishable on the well logs.

Denson and Botinelly (1949) state that, in a general way, the Cloverly formation can be correlated with the Lakota and Fall River formations (Mapel and Gott, 1959) in the Black Hills, except where the middle shale unit is absent; then it is difficult to distinguish the upper sandstone from the lower sandstone. An Early Cretaceous age for the Cloverly formation in the Hartville uplift is based on regional correlations. The formation is conformably overlain by the Thermopolis shale.

THERMOPOLIS SHALE

Thermopolis shale exposures nearest to the Fort Laramie area are about 6 miles south of Glendo in the Hartville uplift. There the Thermopolis shale is divisible into a lower black shale unit 90 to 150 feet thick and an upper sandstone unit, the Muddy sandstone member, 50 to 100 feet thick (Love and others, 1949). The Thermopolis shale was penetrated in test wells 1, 3, 4, and 6–12 (table 1). On the basis of sample and electric logs of these wells, the Thermopolis shale within and near the map area is divided into a lower unit, consisting of 72 to 90 feet of black hard brittle shale, and an upper unit, the Muddy sandstone member, consisting of 37 to 60 feet of gray fine- to medium-grained sandstone. The Muddy sandstone member is an important oil and gas-producing zone throughout Wyoming, and shows of oil and gas were reported from this unit in wells 8 and 12 (table 1).

An Early Cretaceous age for the Thermopolis shale is based on regional correlation (Love and others, 1949). The formation is conformably overlain by the Mowry shale.

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MOWRY SHALE

The Mowry shale is exposed about 6 miles southeast of Glendo in the Hartville uplift where it consists of dark-gray slabby siliceous shale, weathering silvery gray that contains fish scales and thin bentonite beds (Love and others, 1949). Sample and electric logs of test wells 1, 4, and 6–12 (table 1), which penetrate the formation, show that within and near the Fort Laramie area the Mowry is 410 to 455 feet thick. It consists of dark-gray to black siliceous shale containing thin bentonite beds and numerous fish scales. The Mowry shale is the youngest formation of Early Cretaceous age in this region and is conformably overlain by the Frontier formation.

UPPER CRETACEOUS ROCKS

FRONTIER FORMATION

In the Fort Laramie area, the Frontier formation is known only from well data. The nearest outcrops of the formation are about 30 miles to the northwest and southwest, along the east flank of the Laramie Mountains.

The Frontier formation was penetrated in test wells 1, 4, and 6–12 (table 1), where it has an average thickness of about 650 feet. The lower 400 feet consists of gray to dark-gray sandy, calcareous shale. The overlying 50 feet is gray fine-grained very hard sandstone with black shale partings, and comprises one of the Wall Creek sands of drillers. The upper 200 feet consists of gray calcareous shale containing thin partings of bentonite. The Frontier formation is an important oil- and gas-producing zone throughout Wyoming. It is the oldest formation of Late Cretaceous age in this area and is conformably overlain by the Niobrara formation.

NIOBRARA FORMATION

The nearest exposures of the Niobrara formation are along the east flank of the Laramie Mountains, about 30 miles southwest and northwest of the Fort Laramie area. The formation, characterized by gray to light-gray soft calcareous shale with some bentonite, is as much as 210 feet thick in and near the map area (test wells 4 and 6–11, table 1). The Niobrara formation is Late Cretaceous in age and is conformably overlain by the Pierre shale.

PIERRE SHALE

The nearest exposures of Pierre shale are nearly 50 miles north of the Fort Laramie area in Niobrara County. From 265 to 2,020 feet of Pierre shale was penetrated immediately below the Cretaceous-

Tertiary unconformity in test wells 4 and 6–10 (table 1) in and near the Fort Laramie area. Test well 11, drilled about 12 miles southeast of the area, penetrated a complete section of Pierre shale 5,520 feet thick. A sample log from unpublished oil company records of the latter well shows that the formation consists mainly of gray to dark-gray soft sandy shale. A 100-foot unit of medium- to coarse-grained shaly, limy glauconitic sandstone, 2,970 feet below the top of the formation, may be equivalent to the Shannon sandstone member of the Cody shale in central Wyoming. About 2,140 feet below the top of the formation is a 270-foot sandstone bed believed to be in the approximate stratigraphic position of the Mesaverde formation of areas farther west in Wyoming. Thin sandstone beds are present throughout the upper 2,140 feet of the Pierre shale. The formation is of Late Cretaceous age and is conformably overlain by the Fox Hills sandstone.

FOX HILLS SANDSTONE

The nearest exposure of the Fox Hills sandstone is nearly 50 miles north of the Fort Laramie area in Niobrara County. The formation was penetrated in test well 11 (table 1), 12 miles southeast of the Fort Laramie area, where the Fox Hills consists of 190 feet of gray medium-grained "salt and pepper" sandstone and becomes finer grained and more silty near the base. The Fox Hills sandstone is of Late Cretaceous age and is conformably overlain by the Lance formation.

LANCE FORMATION

The nearest exposures of the Lance formation are in Goshen Hole, 6 miles southeast of the Fort Laramie area, where the Lance is 375 or more feet thick (Schlaikjer, 1935, pt. 2, p. 50). In test well 11 (table 1), drilled in Goshen Hole, 1,390 feet of Lance strata was penetrated. The lower 1,100 feet consists of carbonaceous shale, siltstone, and sandstone and the upper 290 feet is a yellow soft crossbedded sandstone containing partings and beds of bentonite, carbonaceous shale, and variegated shale. Several oyster-bearing beds, 5 to 20 feet thick, and numerous ceratopsian dinosaur remains are reported in exposures in Goshen Hole (Schlaikjer, 1935, pt. 2, p. 45–49). The Lance is the youngest formation of Cretaceous age in Goshen Hole, and is unconformably overlain by the White River formation of Oligocene age.

TERTIARY SYSTEM

Descriptions of Tertiary rocks used in the composite stratigraphic section (pl. 3) and in the stratigraphic discussions below have been taken from detailed descriptions of sections in the Fort Laramie and adjacent areas. The provincial age terms "Chadronian," "Orellan,"

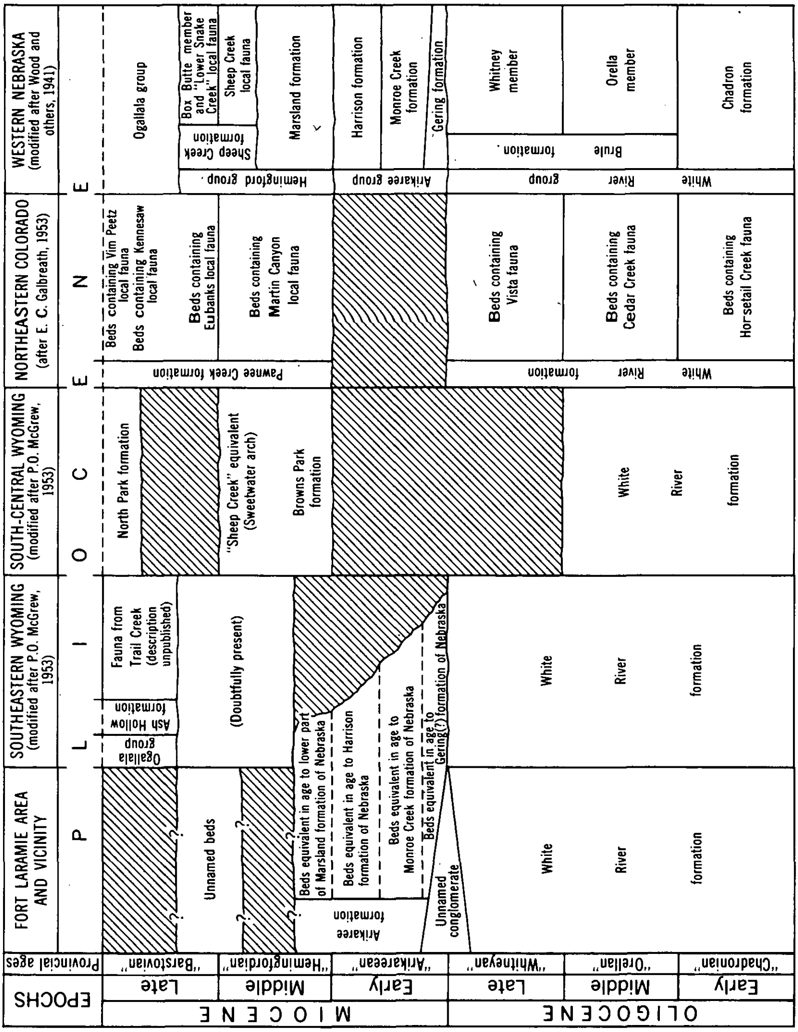

FIGURE 2.—Correlation chart showing age relations of Tertiary rocks.

"Whitneyan," "Arikareean," "Hemingfordian," and "Barstovian" for Tertiary rocks, shown in figure 2, are in general use by vertebrate paleontologists (Wood and others, 1941) and correspond to the following time terminology approved by the U.S. Geological Survey:

Barstovian	late Miocene.
Hemingfordian	middle Miocene.
Arikareean	early Miocene.
Whitneyan	late Oligocene.
Orellan	middle Oligocene.
Chadronian	early Oligocene.

Table 2 is a chart showing the heavy-mineral content of eight samples of Tertiary rocks. These studies were made to determine whether heavy-mineral suites are of value in correlation of Tertiary strata in this region. Data are too incomplete to warrant any definite conclusions, but the table is included to show the general distribution of heavy minerals. All but one of the samples were obtained from the matrices surrounding fossil vertebrate specimens.

OLIGOCENE SERIES

WHITE RIVER FORMATION

The oldest rocks exposed in the Fort Laramie area are of Oligocene age. The Oligocene rocks range in thickness from 370 to 650 feet in Goshen Hole where a complete Oligocene section is exposed, and they are from 506 to 1,050 feet thick in the subsurface. These thicknesses are based on interpretation of sample, drillers', and electric logs of wells drilled in and near the Fort Laramie area (table 1). The variation in thickness of Oligocene rocks is presumably a result of relief on the pre-Oligocene surface, and may also be due in part to late Oligocene-very early Miocene erosion preceding deposition of the overlying unnamed conglomerate sequence.

The entire Oligocene siltstone and claystone sequence in the Fort Laramie area has been mapped as the White River formation for this report. In general, the lower 80 feet of the formation differs lithologically from the upper 290 to 570 feet, but exposures in the lower part are poor and the lithologic change is gradational; thus, the two units are difficult to map separately. The lower 80 feet of the exposed White River formation consists of variegated maroon, gray, green, pink, and white bentonitic claystone interbedded with numerous gray and greenish-gray coarse-grained, conglomeratic, crossbedded channel sandstone beds. The upper 290 to 570 feet of the formation consists of orange-gray limy, sandy, tuffaceous siltstone and silty claystone; a few gray coarse-grained conglomeratic crossbedded channel sandstone beds are present throughout this upper unit but are more abun-

TABLE 2.—*Heavy-mineral distribution in eight dated samples of Tertiary rocks from in and near the Fort Laramie area*

[Analyses by Robert F. Gantnier, U.S. Geol. Survey, Denver, Colo. Samples from all localities except sec. 35, T. 25 N., R. 66 W., are matrix from identified fossils (table 3)]

Locality No. (pl. 1 and table 3)	Location			Formation	Rock type	Age	Mineral (percentage of total heavy mineral fraction)		
	Sec.	Township N.	Range W.				Zircon	Garnet	Tourmaline
13	15	24	65	Arikaree	Sandstone	Early Micoene	18.2	4.7	1.4
8	2	24	65	do	do	do	22.5	3.0	------
16	6	24	64	do	do	do	8.6	3.4	1.1
14	15	26	65	do	do	do	25.5	5.6	4.9
	35	25	66	Unnamed conglomerate.	Conglomerate	Early Miocene or late Oligocene.	17.9	5.0	1.3
20	25	25	64	do	do	Late Oligocene	8.1	5.6	------
29	36	24	64	White River	Siltstone	Early Oligocene (?).	3.8	------	------
26	35	24	64	do	do	Early Oligocene	7.2	2.2	------

Locality No. (pl. 1 and table 3)	Mineral (percentage of total heavy mineral fraction)															
	Rutile	Amphibole	Monazite	Epidote	Augite	Diopside	Muscovite	Sphene	Zoisite	Corundum	Biotite	Hypersthene	Topaz	Opaque	Carbonate	Shards
13	1.4	44.9	-----	2.3	9.8	2.3	1.9	2.3	1.4	-----	4.2	-----	-----	4.2	1.0	----
8	.4	23.8	-----	6.6	5.7	3.9	1.3	3.0	3.5	1.7	1.3	0.4	0.4	22.1	-----	0.4
16	.6	58.3	-----	5.7	7.4	3.4	.6	2.3	2.3	.6	4.0	-----	-----	1.7	-----	----
14	3.7	34.5	3.0	4.1	-----	-----	-----	-----	-----	-----	3.7	-----	.8	13.1	1.1	----
	1.3	36.6	-----	1.8	1.8	2.2	1.8	2.6	.3	.3	3.1	-----	.3	21.0	2.7	----
20	-----	58.4	-----	2.5	3.1	1.2	3.1	4.3	-----	.6	5.6	-----	-----	5.6	1.9	----
29	-----	74.3	-----	.9	8.4	-----	-----	2.8	-----	-----	6.1	2.3	-----	.9	.5	----
26	.9	64.0	-----	1.3	4.5	.9	.9	2.7	.9	-----	9.5	-----	-----	3.2	1.8	----

dant in the lower half, particularly near the base. Thin white tuff beds are locally present throughout the formation. The change from early Oligocene to middle Oligocene faunas is at least 40 feet above the lithologic change, as indicated by a diagnostic fossil rodent of early Oligocene age, *Cylindrodon* (table 3, loc. 26), found in orange-gray siltstone beds about 40 feet above the top of the lower unit of variegated bentonitic claystone.

The White River formation, as used in this report, has been divided into the Chadron and Brule formations by previous workers in the area. Darton and Fisher (Smith, 1903, p. 3) assigned the lower 60 to 200 feet of Oligocene strata in Goshen Hole to the Chadron formation. They recognized that the upper boundary of the Chadron formation was uncertain and arbitrarily placed it at the top of a pink nodular calcareous claystone 14 feet thick. The Chadron formation

was described by them as consisting of maroon, green, and pink claystone with channel deposits of gray and green coarse-grained cross-bedded sandstone, and the overlying Brule formation was described as consisting of as much as 250 feet of pink or flesh-colored massive claystone containing lenses of sandstone and thin volcanic ash beds.

TABLE 3.—*Vertebrate fossils from the Fort Laramie and adjacent areas*

[Unless otherwise noted, identifications of specimens were made by R. W. Wilson, Univ. Kansas and by G. E. Lewis of the U.S. Geol. Survey; specimens are in the U.S. Geol. Survey laboratory, Denver, Colo.]

Locality No. (pl. 1)	Location			Formation	Age	Identification
	Sec.	Township N.	Range W.			
1	35	25	66	Tributary valley alluvium.	Post-Mankato	*Ovis canadensis* Shaw.
2	25	25	66	do	do	*Bison bison* (Linnaeus).
3	6	24	64	do	Mankato or younger.	*Bison* sp.
4 [a]	([b])	([b])	([b])	Quaternary sand and loess or gravel.	Pleistocene	Mammoth tooth. [c]
5	([d])	([d])	([d])	Arikaree	Early middle Miocene.	*Phenacocoelus stouti.* [e]
6 [a]	10	26	66	do	Early to middle Miocene?	*Anchitherium* sp.
7	23	25	65	do	do	*Diceratherium* sp., close to *D. annectens* (Marsh).
8	2	24	65	do	do	*Anchitherium* cf. *A. agatensis* Osborn, *Parahippus tyleri* Loomis, *Merycoides cursor* Douglass, *Blastomeryx* sp. cf. *B.* (*Pseudoblastomeryx*) *falkenbachi* Frick.
9	14	24	66	do	do	*Merycoides* cf. *M. cursor* Douglass.
10	13	24	66	do	Early Miocene	*Merycoides cursor* Douglass geomyids, insectivore (talpid?), lagomorphs (probably ochotonid), Zapodid? cf. *Schaubeumys* or *Plesiosminthus.*
11	31	24	65	do	do	?*Merycoides* sp.
12	22	24	65	Arikaree (Harrison? equivalent).	Early Miocene (possibly late).	Geomyids, Entoptychines?, Mylagaulidae (Promylagaulus?).
13	15	24	65	Arikaree (probably Harrison equivalent).	Early Miocene (probably late).	*Palaeocastor barbouri*?
14	15	26	65	Arikaree	Early Miocene (possibly early).	*Merycoides* cf. *M. cursor* Douglass, *Temnocyon* sp., *Heliscomys*? sp., Entoptychine, ?*Palaeolagus* sp., Mylagaulid or cylindrodont.
15	15	26	65	do	Early Miocene	*Diceratherium* sp.
16	6	24	64	Aikaree (uppermost Gering or lowermost part of Monroe Creek equivalent).	Early Miocene (late early or early middle).	*Diceratherium* sp., cf. *D. annectens* (Marsh), *Cyclopidius lullianus* (Thorpe).
17	5	24	64	Arikaree	Early Miocene	?*Diceratherium* sp.
18 [a]	13	25	64	Arikaree (Monroe Creek equivalent).	Middle early Miocene.	*Mesoreodon megalodon* (Peterson).
19 [a]	35	25	66	Unnamed conglomerate.	Early Miocene (early).	s*Paleocastor montanus* (Scott). [f]
20 [a]	25	25	64	do	Late Oligocene	*Miohippus* cf. *M. meteulophus* Osborn, *Hypisodus* sp., *Leptomeryx* sp.
21 [a]	7	24	63	White River (upper part of Brule equivalent).	do	?*Leptauchenia* sp., ?*Hypertragulus* sp., ?*Leptomeryx* sp., *Palaeolagus*? sp.
22 [a]	25	25	64	do	do	*Leptauchenia* sp.

See footnotes at end of tables.

TABLE 3.—*Vertebrate fossils from the Fort Laramie and adjacent areas*—Con.

Locality No. (pl. 1)	Location			Formation	Age	Identification
	Sec.	Township N.	Range W.			
23 [a]	18	23	65	White River	Oligocene	*Palaeolagus* sp., *Mesohippus?* sp.
24	13	24	65	White River (Brule equivalent).	Middle or late Oligocene.	*Eporeodon* sp.
25	21	24	64	White River (lower part of Brule equivalent).	Middle Oligocene	*Mesohippus* cf. *M. trigonostylus* Osborn, *Eporeodon* sp.
26	35	24	64	White River (Chadron equivalent).	Early Oligocene	*Merycoidodont* gen. and sp. indet., *Cylindrodon* sp. (not *fontis*, possibly new.)
27	35	24	64	White River	do	*Palaeolagus* sp., *Cylindrodon?* sp.
28 [a]	35	24	64	do	do	*Palaeolagus* sp.
29 [a]	36	24	64	do	do	Lagomorph, probably *Palaeolagus* sp.

[a] Located outside the boundaries of the map area.
[b] East of Wheatland.
[c] Univ. Wyoming collection No. 1442.
[d] 2 miles south of Guernsey, Wyo.
[e] Identified by C. B. Schultz and C. H. Falkenback; Frick collections (Schultz and Falkenback, 1950 p. 109).
[f] Identified by T. M. Stout, Univ. Nebraska; Univ. Wyoming collection No. 1036 (L. W. McGrew, 1953 p. 65–67).

Schlaikjer (1935, no. 2, p. 102) included the lower 80 feet of Oligocene strata in Goshen Hole in the Chadron formation. He, too, recognized that the upper contact of his Chadron formation was not distinct in many localities in Goshen Hole and placed it at the base of the pink sandy claystone beds, including in the Chadron only the variegated green, maroon, and light-gray bentonitic claystone beds. Schlaikjer's Brule formation consisted of as much as 430 feet of pinkish flesh-colored relatively hard claystone including numerous lenses of cherty limestone, thick channel sandstone and conglomerate beds, and many beds of nearly pure volcanic ash.

Because the lithologic change between the lower and upper units of the White River formation is gradational and difficult to map, and because the change from early to middle Oligocene faunas occurs above the lithologic change, the writer has placed the entire sequence of rocks of Oligocene age in the White River formation.

The White River formation in the Fort Laramie area was penetrated in all the wells that are listed in table 1 except well 11. No oil or gas was reported from the formation in this area, but sandstone beds at or near the base have produced small amounts of oil and gas in the Shawnee field. This field is on the northwest flank of the Hartville uplift about 35 miles northwest of the Fort Laramie area.

The formation lies with angular unconformity on the eroded surface of folded rocks of Precambrian through Cretaceous age (pl. 2). No rocks of Paleocene or Eocene age are present in the area. Verte-

brate fossils collected from many horizons within the White River formation indicate that it includes rocks of early through late Oligocene age (table 3, loc. 23–29).

OLIGOCENE AND MIOCENE SERIES, UNDIVIDED

UNNAMED CONGLOMERATE SEQUENCE

A conglomerate sequence, 50 to 60 feet thick, is present above the White River formation and below the Arikaree formation along the northwest rim of Goshen Hole north of Cherry Creek. Fossil remains of a horse, *Miohippus* sp., and two primitive pecorans, *Hypisodus* sp. and *Leptomeryx* sp., collected from near the top of the conglomerate, indicate that it is of late Oligocene age (table 3, loc. 20). Another conglomerate sequence, 60 to more than 100 feet thick, is present in the northwestern part of the map area and occupies the same stratigraphic position, but a fossil beaver jaw collected from near the top of this conglomerate was identified by T. M. Stout (written communication, 1953) as "*Paleocastor montanus* (Scott), the supposed Gering [basal Miocene] form" (table 3, loc. 19). Lithologically the two conglomerate sequences are very similar; however, the conglomerate along the rim of Goshen Hole is interbedded with layers of orange-gray siltstone similar to the upper part of the White River formation, whereas the matrix and finer grained layers in the conglomerate in the northwestern part of the area are generally similar to sediments in the overlying Arikaree formation. Locally, however, the lower part of the conglomerate in the northwestern part of the area also contains layers of orange-gray siltstone similar to those in the White River formation. Because the only fossil collected from the conglomerate in the northwestern part of the Fort Laramie area was from near the top, it is possible that the lower sediments may contain equivalents of the late Oligocene conglomerate and that the two conglomerates represent a period of continuous channel deposition from the latest Oligocene into the earliest Miocene. The two conglomerate sequences have the same symbol on the geologic map.

The unnamed conglomerate sequence ranges in thickness from 50 to about 150 feet in outcrops, and as much as 340 feet of conglomerate was penetrated in well 10 (table 1) just west of the map area.

The lithology of the conglomerate sequence is variable. A typical section is exposed along the southeast rim of the Laramie River valley in T. 25 N., Rs. 65 and 66 W. There, the lower 50 feet consists of gray loosely to well-cemented crossbedded to massive conglomerate. Constituents of this lower conglomerate are largely unsorted, rounded to subrounded coarse-grained sand, pebbles, cobbles, and boulders; the

boulders are as much as a foot in diameter. Rock types of the constituents include granite, gneiss, quartzite, and schist derived from Precambrian rocks, and quartzite, limestone, dolomite, and siltstone derived from the Guernsey and Hartville formations. The matrix of the conglomerate is fine-grained sand and silt which are generally cemented with calcium carbonate.

The upper 50 to 100 feet of the conglomerate sequence consists of gray fine- to medium-grained conglomeratic sandstone interbedded with lenses and layers of conglomerate similar to the conglomerate in the lower unit. Hard dark-gray "pipy" (Schultz, 1941) limy sandstone concretions are present throughout this upper part. At some localities the upper part of the conglomerate sequence is predominantly gray massive fine- to medium-grained sandstone containing only scattered pebbles.

Locally, the conglomerate layers are interbedded with lenses and layers of orange-gray siltstone similar to and possibly derived from the upper part of the White River formation. These siltstone layers commonly contain sporadic pebbles, cobbles, and boulders of Precambrian and Hartville rocks similar to those found in the conglomerate beds proper. At a few localities the calcareous matrix is red stained, which imparts a light brick-red color to the conglomerate. The most extensive exposure of this red conglomerate is in the west-central part of the Fort Laramie area. West of the area, a similar reddish conglomerate is present near exposures of rocks of Precambrian age and the Guernsey and Hartville formations, and it interfingers laterally with the typical gray conglomerate sequence. The red conglomerate therefore is believed to represent a near-source facies, deriving its red color from the red shale and siltstone of the Hartville formation, Permian gypsum and red shale sequence, and the Chugwater formation. In general, the red facies is more loosely cemented than the gray, and consequently, weathers into boulder-strewn rounded hills instead of the cliffs and ledges which are the characteristic erosional forms of the gray facies.

The contact between the conglomerate and the underlying White River formation is generally well defined, but the conglomerate grades upward into the massive soft gray sandstone of the Arikaree formation. Where the conglomerate is absent, the Arikaree formation rests directly on the White River formation.

MIOCENE SERIES

ARIKAREE FORMATION

The Arikaree formation is widely exposed in the Fort Laramie area, and, as used in this report, includes rocks equivalent in age to the

Gering(?), Monroe Creek, Harrison, and the lower part of the Marsland formations of Nebraska (Schultz, 1938), as shown in table 2. Because of faulting, a single complete section of the formation is not exposed in the map area, but on the basis of known faunal horizons the total thickness of the Arikaree is estimated to be at least 700 feet. The formation consists mainly of soft gray tuffaceous sandstone containing numerous pipy limy sandstone concretions and white siliceous tubular structures believed to be root casts. The pipy concretions are elongate structures ranging from less than an inch to more than 2 feet in diameter and from a few inches to more than 8 feet in length. They are oriented with the long axis parallel to the bedding plane and generally with a northeast trend. The limy concretions in the Arikaree formation are thought by Schultz (1941) to be the result of calcite precipitation from ground water flowing through the sands.

The Arikaree formation is a light-gray to orange-gray massive medium- to fine-grained sandstone as much as 700 feet thick that can be divided into three rather distinct lithologic units. The lower unit is 200 to 300 feet thick and consists mainly of orange-gray, massive, medium- to fine-grained loosely-cemented sandstone which weathers into vertical cliffs and columnar-type badlands. The predominantly orange-gray color of these beds is probably due in part to a high clay content of the matrix. Hard gray pipy limy sandstone concretions are present in irregularly spaced layers throughout the unit, either as individual "pipes" or fused into concretionary ledges. Small hard nodular limy sandstone concretions 3 to 4 inches in diameter occur locally in the lower part of the unit. In some areas, crystalline calcite has formed authigenically around sand grains, resulting in calcite sand crystals. Some of these crystals are as much as three-fourths of an inch in diameter and 2 inches in length. Hard white siliceous root casts are present throughout the unit, but locally are more abundant near the top. This lower unit also includes a few thin tuff beds, ranging from a few inches to 3 feet in thickness.

The unit described above is approximately equivalent in age to the Gering(?) and Monroe Creek formations in Nebraska. This age designation is based partly on stratigraphic position and partly on fossil oreodonts, which are extinct piglike ruminants; the fossils were collected from two localities near the base of the lower unit of the Arikaree. The oreodonts were identified by G. E. Lewis as *Cyclopidius lullianus* (Thorpe) (table 3, loc. 16), indicating a stratigraphic position equivalent to the uppermost part of the Gering or lowermost part of the Monroe Creek formation, and *Mesoreodon megaladon* (Peterson) (table 3, loc. 18), indicating a stratigraphic position equivalent to the Monroe Creek formation.

The middle unit of the Arikaree formation is about 200 feet thick and consists of light-gray fine- to medium-grained limy tuffaceous sandstone and fresh-water limestone. These strata differ from the beds below in that they are generally lighter gray, less massive, and contain more carbonate and more white siliceous root casts. Pipy limy sandstone concretions are common throughout this middle unit, but the soft sandstone layers between the concretionary ledges are thinner than those in the underlying unit, and the bedding is accentuated on a weathered surface by numerous resistant limy sandstone and fresh-water limestone layers. In many places the limestone contains chert nodules. A few coarse-grained sandstone and conglomerate channel deposits are present locally. Because of the more pronounced stratification and the numerous hard calcareous layers, this unit weathers to a broad undulating surface in contrast to the steep columnar-type badlands common in the underlying and overlying strata. The undulating surface of this middle unit forms the high plain on the divide between the Laramie River and Goshen Hole.

On the basis of general lithologic characteristics, stratigraphic position, and the fossil rodent burrow, *Daemonelix*, the middle unit of the Arikaree formation is considered late early Miocene and equivalent to the Harrison formation of Nebraska.

The upper unit of the Arikaree formation, which is exposed in the northwest corner of the map area, is about 200 feet thick and consists of fine- to medium-grained soft massive orange-gray sandstone. Hard limy pipy sandstone concretions similar to those in the underlying units of the formation are also common in the upper unit. Small limy spherical concretions covered with irregular, partly formed calcite sand crystals also are common. Many of the spheres are fused, forming clusters and ledges. Siliceous root casts are more abundant than in either of the underlying units, and in places are so abundant that layers several feet thick are almost completely composed of a complex network of siliceous tubes; where exposed, these layers weather to a very hard rough surface. Thin claystone and tuff beds are locally interbedded with the sandstone. The orange-gray color of this unit probably is due in part to a high clay content of the matrix. The thick soft sandstone beds between the calcareous concretionary ledges weather into vertical cliffs and columnar-type badlands.

On the basis of a fossil oreodont, *Phenacocoelus stouti* (table 3, loc. 5) which was collected and described by Schultz and Falkenbach (1950, p. 109), at least part of the upper unit of the Arikaree is of early middle Miocene age and is equivalent to the lower part of the Marsland formation of Nebraska.

The Arikaree formation in and near the report area is overlain by deposits of later Miocene and Quaternary age.

DEPOSITS OF POST-EARLY MIOCENE AND PRE-PLIOCENE AGE

Granite and gneiss boulders 3 to 4 feet in diameter rest on the Arikaree formation in secs. 20 and 29, T. 26 N., R. 65 W. These boulders are similar to those in a conglomerate that, according to Bretz and Horberg (1952, p. 483), overlies the White River and Arikaree formations in northern Platte County, Wyo., and which crops out along a sinuous line extending from T. 28 N., R. 70 W., southeastward into T. 26 N., R. 66 W. Bretz and Horberg (1952, p. 483) suggested a probable Pliocene age for this large boulder conglomerate because of its position on eroded Oligocene and Miocene rocks. Conglomerate and coarse sandstone similar to the finer constituents of the large boulder conglomerate are present at the same stratigraphic position just west of the Fort Laramie area in T. 26 N., R. 66 W. Vertebrate fossils from this unit strongly suggest a post-early Miocene and pre-Pliocene age for these deposits, although more evidence will be necessary before positive dating is possible. The boulders in the Fort Laramie area are believed to have weathered out of such a conglomerate. Because of their sporadic distribution, the boulders are not differentiated on the geologic map.

PLIOCENE(?)

No rocks of Pliocene age have been observed in the Fort Laramie area. Waterworn fragments of Pliocene(?) horse teeth have been found in gravels on top of Spoon Butte and other hills in T. 27 N., R. 60 W. (P. O. McGrew, oral communication, 1956), which suggest that Pliocene deposits were present in the general area but have since been eroded.

QUATERNARY SYSTEM

Surficial deposits of several different types overlie the Oligocene and Miocene strata in much of the Fort Laramie area. They range in age from Pleistocene to Recent and in thickness from a thin veneer to as much as 80 feet.

HIGH-LEVEL GRAVEL

A thin veneer of lag gravel composed mainly of quartz and chert pebbles rests on the Arikaree formation on the divide between Deer and Cherry Creeks. The source of this gravel is unknown; the deposit is believed to be too far from the mountains to be a pediment veneer. It is conceivable that this gravel weathered out of an upper Miocene, Pliocene, or Pleistocene deposit that may once have overlain these lower Miocene beds. The high-level gravel is too thin to be mapped as a separate unit and is not differentiated on plate 1.

TERRACE DEPOSITS

Terrace gravels are as much as 20 feet thick along the Laramie and North Platte Rivers in the northern part of the area. Although they are not separately mapped, at least three stages of downcutting by streams, probably during Pleistocene time, are represented in these deposits. The gravel fragments are well rounded and waterworn and are composed chiefly of quartzite and some schist, granite, gneiss, and chert cobbles. Terrace deposits on the North Platte River also contain pebbles of iron ore apparently derived from the Seminoe Mountains in east-central Wyoming (J. D. Love, oral communication, 1955). Most of the gravel on the Laramie River terraces was probably derived from the Laramie Mountains, whereas the gravel on the North Platte River terraces was probably derived from the Sweetwater arch in south-central Wyoming, the Hartville uplift, and the Laramie Mountains.

Fragments of fossil horse teeth from gravel deposits 800 feet above river level, on Casebier Hill, 6 miles north of the Fort Laramie area, and 300 feet above river level in sec. 17, T. 25 N., R. 66 W. 3 miles west of the Fort Laramie area, indicate a Pleistocene age. A fossil mammoth tooth in the University of Wyoming collections reportedly came from "the high hill" east of Wheatland (table 3, loc. 4). It is not known whether the fossil was obtained from the sand and loess or from the gravel deposits at that locality, but, as there are extensive gravel deposits in the hills east of Wheatland, it is probable that the mammoth tooth came from the gravels.

SAND AND LOESS DEPOSITS

Fine-grained sand and loess cover the rocks of Oligocene and Miocene age throughout much of the Fort Laramie area. Soils on broad, relatively flat surfaces, such as the bottom of Goshen Hole and the surface of the High Plains, are formed from these deposits. The sand and loess mantle may be as much as 20 feet thick, but more commonly it is thin, and the cut of a plow will often turn up bedrock. No fossils were found in the deposits, but, because they overlie terrace gravel on some surfaces, they are considered to be, for the most part, Recent in age.

TRIBUTARY VALLEY ALLUVIUM

Tributary valley alluvium consisting of fine-grained sand, silt, and gravel is now being actively dissected by tributaries of the North Platte and Laramie Rivers. Unstratified silt, sand, and talus debris cover the slopes below some of the steep escarpments of Oligocene and Miocene rocks along the southeast rim of the Laramie River valley. They are also mapped as tributary valley alluvium.

An alluvial-type deposit 80 feet thick is exposed in a railroad cut in sec. 12, T. 26 N., R. 65 W. (fig. 3). The sequence, from bottom to top, is 50 feet of poorly exposed gray fine-grained sand and silt, 10 feet of gray fine-grained tuffaceous loosely cemented sandstone, 5 feet of orange-gray clay, 10 feet of coarse granitic pebble conglomerate in an orange-gray fine-grained sand matrix, and 5 feet of gray medium-grained sandstone containing hematitic root casts. No fossils were found in the sequence, but it underlies as much as 20 feet of Pleistocene terrace gravel and is, therefore, of earlier Pleistocene age than the terrace gravel or of pre-Pleistocene age.

Charcoal layers were observed several feet below the top of alluvial deposits in Cottonwood and Little Cottonwood Draws, Cherry Creek valley, and Eagles Nest Canyon. Remains of *Bison* sp. in the charcoal layers in Cherry Creek valley (table 3, loc. 3) indicate that the deposits are latest Pleistocene or younger in age. The skull of a mountain sheep, *Ovis canadensis* Shaw, was collected from alluvial deposits in Little Cottonwood Draw (table 3, loc. 1). This species lived from Yarmouth (second interglacial stage of the Pleistocene to Recent times (Schultz and others, 1951, table 1).

Most of the tributary valley alluvium in the Fort Laramie area is Recent in age.

FIGURE 3.—Valley fill (Qta) of sand, silt, and gravel of probable Pleistocene age, deposited against an 80-foot cliff of sandstone in Arikaree formation (Ta), and overlain by about 20 feet of gravel (Qg) of probable Pleistocene age. View looking at north side of railroad cut in sec. 12, T. 26 N., R. 64 W.

FLOOD-PLAIN DEPOSITS

Sand, silt, and gravel of various thicknesses form the flood plains of the North Platte and Laramie Rivers. The finer grained constituents of the flood-plain alluvium are, for the most part, locally derived from weathered rocks of Oligocene and Miocene age. The gravel probably was reworked in part from conglomerate beds of Oligocene and Miocene age, and in part derived from the mountain ranges through which the streams flow. The deposits are Recent, and the flood plains are still receiving sediments, particularly from tributaries at times of heavy rains and flash floods.

STRUCTURE

The Fort Laramie area (fig. 4) is on the northwest margin of the Julesburg basin, a large synclinal area which was downwarped in pre-Oligocene time and which occupies parts of southeastern Wyoming, southwestern Nebraska, northwestern Kansas, and northeastern Colorado. North of the area is the Hartville uplift, an elongate northeastward-trending relatively low anticlinal fold about 45 miles long and 15 miles wide (Denson and Botinelly, 1949). Pre-Tertiary rocks exposed in the uplift range from Precambrian to Early Cretaceous in age; these rocks are unconformably overlain by rocks of Oligocene and Miocene age.

In secs. 22 and 28, T. 25 N., R. 66 W., west of the Fort Laramie area, there are a few isolated exposures of rocks on the southeast limb of another pre-Oligocene anticline, which also has a northeasterly trend. There the Precambrian rocks and the Guernsey and Hartville formations are exposed and are overlapped unconformably by Oligocene and Miocene strata. The low hills formed by the rocks of Paleozoic and Precambrian age have been called the Moonshine Hills by the writer.[1] A series of subsurface anticlines and synclines are believed to lie parallel to, and northeast, southwest, and southeast of the axis of the Moonshine Hills anticline. Two of these folds have been referred to as the Wheatland and Grayrocks anticlines by oil companies that have drilled wells in the general area (table 1).

The most conspicuous structural feature west of the Fort Laramie area is the uplift of the Laramie Mountains, an elongate fold about 130 miles long in southeast Wyoming. This mountain range, which is asymmetrical with a steeper east flank, has a general north trend throughout most of its length in Wyoming, but the north end trends northwesterly. The Deadhead basin anticline[2] branches off the

[1] McGrew, L. W., 1953, The geology of the Grayrocks area, Platte and Goshen Counties, Wyoming: Wyoming Univ., unpublished M.A. thesis, p. 39.

[2] Lynn, J. R., 1947, The geology of the north margin of the Richeau Hills, Platte County, Wyoming: Wyoming Univ., unpublished M.S. thesis.

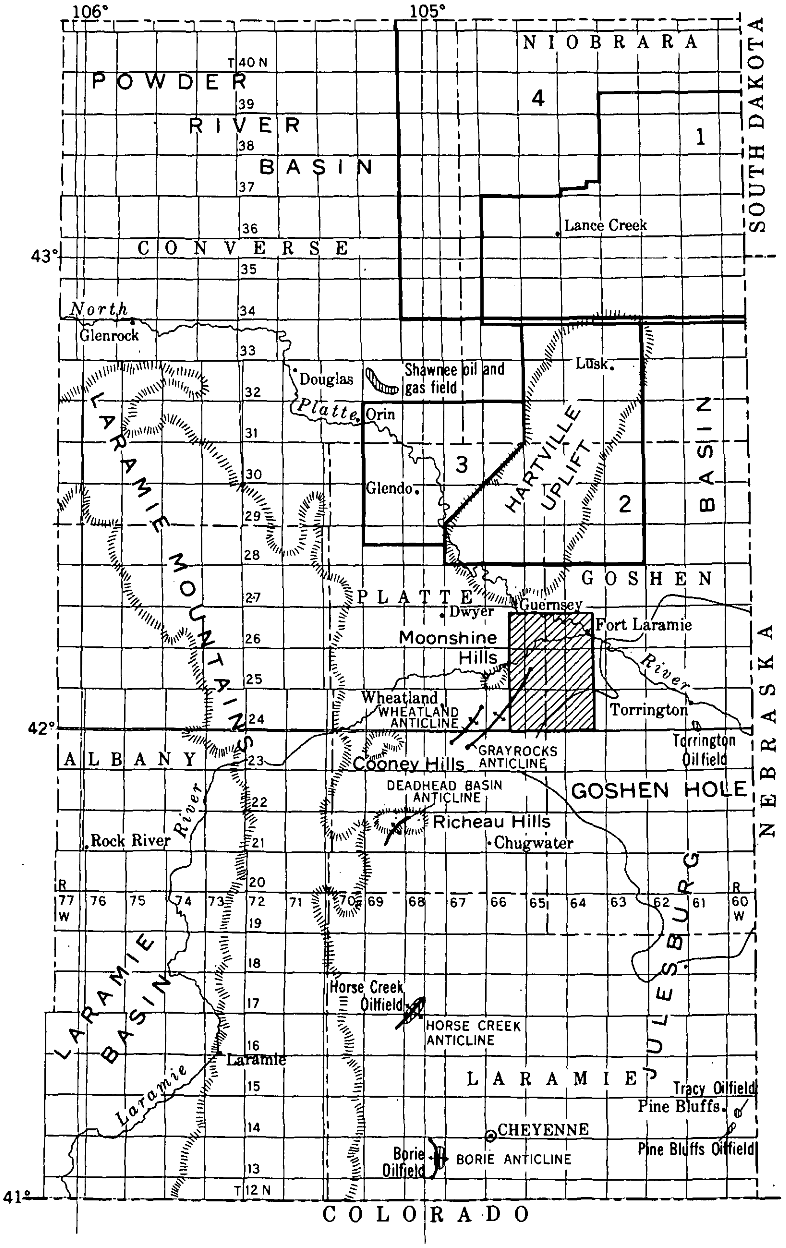

FIGURE 4.—Map of southeastern Wyoming showing the structural setting of the Fort Laramie area (cross-hatched) and its relation to areas of other U.S. Geological Survey geologic maps. 1, Kramer and Dobbin (1943); 2, Denson and Botinelly (1949); 3, Love, Denson, and Botinelly (1949); and 4, Dobbin and others (1957).

Laramie Mountains and extends northeastward through T. 21 N., Rs. 68 and 69 W. This anticline is probably a part of the same system of pre-Oligocene folds as the Hartville uplift and the Moonshine Hills anticline. The Richeau Hills, which lie southwest of the Fort Laramie area, are erosional remnants of this uplift.

To the east and south, and lying partly within the Fort Laramie area, is Goshen Hole, a broad erosional basin believed to be a breached domal uplift of post-Miocene age (Schlaikjer, 1935, no. 4, p. 121). Regional dip of Tertiary rocks in the Fort Laramie area is to the northeast about 50 feet per mile. This dip is presumably a result of the Goshen Hole doming and the upwarping associated with the Whalen-Wheatland fault systems (cross section, pl. 1).

A series of post-middle Miocene normal faults are the most conspicuous structural features within the Fort Laramie area. These faults trend northeasterly through the area and have been grouped into two main systems, the Whalen and the Wheatland fault systems.[3]

FAULTS

The Whalen fault was named by Schlaikjer (1935, no. 4, p. 121), who mapped a 10-mile segment of the fault southwestward from the North Platte River escarpment. Schlaikjer reported that the fault extends 10 to 15 miles northeast of the North Platte River. Hares and Cook (1937, p. 77–78) cited the faults in the Fort Laramie area as part of the evidence for their "Rocky Revolution," and Cook (1951, p. 88) later described the faults as a system extending from the Laramie Mountains northeastward past Wheatland and Fort Laramie into Nebraska.

The writer has mapped about 24 miles of the Whalen fault and also the minor faults which parallel it to the southeast, and has called them collectively the Whalen fault system. About 18 miles of this fault system are shown on Plate 1.

Faults in the Whalen normal fault system generally strike N. 45° E. The plane of the main fault dips from 74° to 77° SE. Dips of the minor fault planes range from 63° to 70°, and the direction of dip may be either southeast or northwest. One fault in secs. 26 and 34, T. 26 N., R. 65 W., dips to the northwest and, together with the main fault, defines a small graben about 2 miles long and ⅛ mile wide.

Along the main fault in sec. 18, T. 26 N., R. 64 W., the White River formation and the unnamed conglomerate sequence are faulted against the middle unit of the Arikaree formation (fig. 5). Stratigraphic displacement along the main fault in this area is about 600 feet and

[3] McGrew, L. W., 1953, The geology of the Grayrocks area, Platte and Goshen Counties, Wyoming: Wyoming Univ., unpublished M.A. thesis, p. 36.

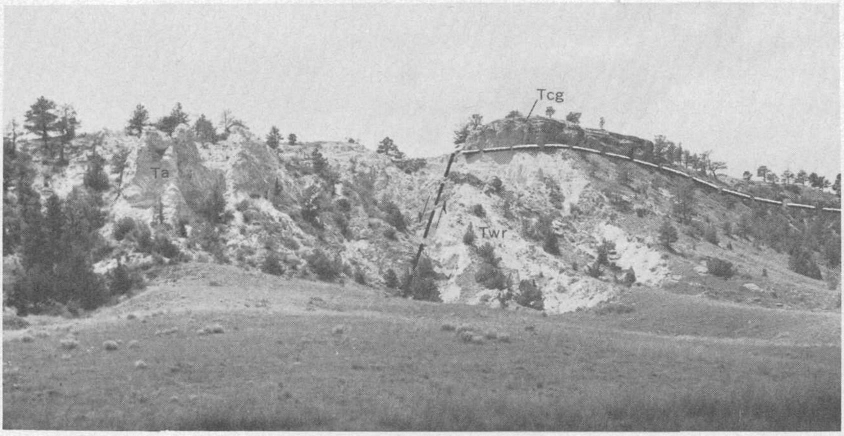

FIGURE 5.—The Whalen fault in the North Platte River escarpment, sec. 18, T. 26 N., R. 64 W. White River formation (Twr) and unnamed conglomerate sequence (Tcg) on right are in fault contact with Arikaree formation (Ta) on left. Looking south.

the movement is chiefly dip slip. Displacement decreases to the southwest and is 20 feet or less in sec. 35, T. 25 N., R. 66 W. Displacement along the subsidiary faults is small, only a few feet in some places, but because of lithologic similarity of the beds on both sides of the fracture, offset cannot be detected at many localities. On the aerial photographs some lines roughly parallel the known faults, but could not be specifically identified on the ground. These lines have been plotted on the geologic map (pl. 1) as possible faults or fractures.

Northwest of the Whalen fault system is another series of parallel normal faults which is termed the Wheatland fault system.[4] Dips of the fault planes in this system range from 56° to 73° and are generally to the northwest.

The area of the accompanying geologic map (pl. 1) includes about 8 miles of the northeast end of the Wheatland fault system. The faults are somewhat obscured by surficial deposits, particularly to the northeast, but are known to extend into the North Platte River escarpment in secs. 9 and 16, T. 26 N., R. 65 W. No evidence of these faults was found on the north side of the North Platte River. Because of poor exposures, the stratigraphic displacement along the faults in the Wheatland fault system is not known. Displacement is believed to be small in the Fort Laramie area, but to increase southwestward. In T. 24 N., R. 67 W., west of the area, drag dips of 30° to 40° NW. were observed in beds cut by the Wheatland fault system, and a minimum stratigraphic displacement of 650 feet was estimated.[5]

[4] McGrew, L. W., op. cit., p. 43.
[5] McGrew, L. W., op. cit., p. 45.

The Wheatland fault system extends southwest of the Fort Laramie area for more than 30 miles (Love and others, 1955) and may possibly continue into the Laramie Mountains near the Richeau Hills where similar faulting was suggested by Lynn.[6]

The fault block between the Whalen and Wheatland fault systems is a large horst 1½ miles to slightly more than 3 miles wide and at least 15 miles long. Surface rocks cut by the faults are, for the most part, Oligocene and Miocene in age; west of the area, however, rocks of Precambrian and Paleozoic age are faulted into contact with rocks of Oligocene and Miocene age.

FOLDS

Folding in rocks of Tertiary age in the Fort Laramie area is largely of a regional type. The doming of the Goshen Hole area and the arching across the Whalen-Wheatland fault systems (cross section, pl. 1) are examples of such regional folding. A shallow syncline with a northeastward-trending trough line about 2 miles long is present in secs. 22 and 28, T. 26 N., R. 65 W. Structural incompetence of the slightly indurated sediments of Tertiary age apparently caused these rocks to succumb to faulting rather than to acute folding when deformational stresses were applied in the region.

TERTIARY AND QUATERNARY GEOLOGIC HISTORY

TERTIARY HISTORY

After the withdrawal of the sea during the Late Cretaceous, the Rocky Mountain geosyncline was extensively folded and faulted during the Laramide orogeny. Love (1954a) suggested that the folding, which produced the Laramie Mountains, Hartville uplift, Moonshine Hills, and the subsurface folds which may exist to the east and southeast in this region, reached its maximum development at the close of earliest Eocene time.

After the orogeny, the region was extensively eroded, and Oligocene and younger sediments were deposited. No Paleocene or Eocene sediments are known in the region southeast of the Hartville uplift in Wyoming; however, these rocks may have been deposited and subsequently eroded prior to the deposition of the White River formation of Oligocene age.

At the beginning of the Oligocene, regional uplift rejuvenated the old streams and developed new ones that cut many deep channels into the pre-Oligocene surface. Claystone, sandy claystone, coarse-grained sandstone, and conglomerate of early early Oligocene age were deposited in these channels.

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[6] Lynn, J. R., 1947, The geology of the north margin of the Richeau Hills, Platte County, Wyoming: Wyoming Univ., unpublished M.S. thesis.

The remainder of early Oligocene time was characterized by widespread fluviatile deposition of thick fine-grained pyroclastic debris over broad flood plains. Intermittent channel cutting and filling also continued. The channels have a general east-west trend and the direction of flow of the streams was toward the east.

During middle and late Oligocene time deposition of fine-grained pyroclastic material continued on the broad flood plains, building up a thick succession of tuffaceous siltstone and claystone and some volcanic ash. Channel cutting and filling continued to a lesser degree throughout middle and late Oligocene time.

Volcanism in the Absaroka area of northwestern Wyoming has been cited (Love, 1952, p. 19) as a possible source for a large part of the fine-grained deposits of Oligocene age. The channel deposits of nonvolcanic material of Oligocene age probably were derived from the Laramie Mountains and associated positive areas to the west.

During latest Oligocene and earliest Miocene time, streams which were once more rejuvenated owing to regional uplift cut conspicuous channels in rocks of Oligocene age, and these channels became filled with conglomerate and conglomeratic sandstone.

During the middle and late parts of early Miocene time and the early part of middle Miocene time, fluvial deposition similar to that during the Oligocene prevailed. These Miocene sediments of the Arikaree formation are predominantly fine- to medium-grained tuffaceous sandstone, rather than the siltstone and claystone characteristic of the Oligocene sediments. Volcanos continued to be an important source of sediment during early Miocene and early middle Miocene time. Channel cutting and filling continued, but to a lesser degree than during the Oligocene. The conglomeratic channel deposits were derived largely from nearby rocks of Precambrian and Paleozoic age, but some channel deposits are almost entirely sand, sandstone pebbles, and concretions that were reworked from parts of the Arikaree formation deposited earlier.

The limy standstone concretions in the Arikaree formation were formed shortly after deposition of the sand, and probably were precipitated from ground water percolating through the sand (Schultz, 1941, p. 71–74). The dissolved calcium carbonate in the ground water probably was leached from limestone of Paleozoic age in positive areas to the north and west.

Rocks of late middle Miocene and late Miocene age are not known in the Fort Laramie area. Channel deposits of post-early Miocene and pre-Pliocene age are present northwest of the area, and upper Miocene rocks are present in southeastern Wyoming north of Cheyenne. The entire Miocene is represented by sediments in western

Nebraska. This distribution suggests that deposition was taking place in the region throughout the Miocene. Subsequent erosion, however, has removed any upper middle Miocene and upper Miocene rocks that may have been in the Fort Laramie area as well as most of these rocks from adjacent areas in eastern Wyoming. Sediments laid down during late middle Miocene and late Miocene time in the areas of outcrop are predominantly channel-fill deposits which indicate periodic rejuvenation of the streams.

A period of extensive block faulting followed the deposition of middle Miocene rocks in eastern Wyoming and resulted in the Whalen and Wheatland fault systems. The youngest rocks known to be cut by these faults are of early middle Miocene age. Surface traces of the faults roughly parallel the trends of the buried pre-Tertiary folds, which suggest that the position of the post-middle Miocene faults was controlled by pre-existing folds and fractures in the older rocks.

Evidence indicates that limited deposition took place in eastern Wyoming during the Pliocene, although no rocks of Pliocene age are known in the Fort Laramie area.

QUATERNARY HISTORY

Periodic uplift apparently continued during the Pleistocene, particulary in the mountain regions, forming several erosional levels or terraces. Terrace gravels are as much as 20 feet thick on dissected remnants of these terraces in the Fort Laramie area. Fine-grained sand and silt deposits in old stream channels and some of the high-level sand and loess deposits may also represent local deposition during the Pleistocene; however, the Pleistocene in the Fort Laramie area was generally a time of erosion. In Nebraska, thick deposits of fine-grained sand and loess were laid down during this same time interval.

Dissection of thick deposits of valley alluvium of probable Recent age suggests that the streams in the Fort Laramie area have been periodically rejuvenated during Recent time.

ECONOMIC POSSIBILITIES

OIL AND GAS

The discovery in 1955 of oil in the Torrington field, about 15 miles southeast of the Fort Laramie area (fig. 4), renewed interest in the petroleum possibilities in eastern Wyoming. Production in the Torrington field is from a Lower Cretaceous sandstone called the J sand by oil company geologists. Farther south, in the southeast corner of Wyoming, the Pine Bluffs and Tracy fields also produce oil from the J sand. The entrapment of oil in each of these fields

is believed to be the result of updip permeability pinchouts on small anticlinal folds, similar to the type of accumulation in the extensively developed western Nebraska oil fields (Finch and others, 1956). The Nebraska fields produce from both the J sand and the stratigraphically higher D sand, also named by oil company geologists, but to date the D sand has not been productive in Wyoming. The D sand has been penetrated in many of the test wells drilled along the southeastern margin of Wyoming, and shows of oil were reported from that zone in the Lakota Petroleum Albert 1 well in sec. 11, T. 23 N., R. 62 W. The precise stratigraphic relations of the D and J sands to the Lower Cretaceous units on the west and north sides of the Julesburg basin have not been established.

Other stratigraphic traps for oil and gas may exist in the thick series of rocks of Cretaceous age east of the Fort Laramie area. Shows of oil and gas were reported from a sandstone about 2,100 feet above the base of the Pierre shale in the Kingwood Oil Co. Smith 1 well in sec. 6, T. 20 N., R. 60 W., south of the Torrington field. It is not known whether these shows are related to a lensing sandstone or an anticlinal fold, or a combination of both.

Wells drilled in or near the Fort Laramie area are listed in table 1. Wells 1–4 and well 12 were drilled within the area. Wells 5–10 were drilled to the west just outside the area, and well 11 was drilled about 11 miles to the southeast. None of these wells have been productive, but a show of oil was reported from the Cloverly formation in well 6; shows of oil and gas from the Muddy sandstone member of the Thermopolis shale and a show of gas from the Morrison formation were reported in well 8; and a show of oil was reported from the Muddy sandstone member in well 12. Further subsurface investigation is necessary before the oil and gas possibilities of the so-called Grayrocks and Wheatland structures and of other possibly related folds can be fully evaluated. Subsurface anticlines are proved to be oil-bearing structures in the Horse Creek and Borie fields (fig. 4) on the west margin of the Julesburg basin south of the Fort Laramie area. Oil in both of these fields is produced from the Muddy sandstone member of the Thermopolis shale, and in the Horse Creek field some is also derived from the Cloverly formation.

Faults are possible traps for oil and gas in this region. The late Tertiary normal faults in the Fort Laramie area probably cut pre-Oligocene rocks in the subsurface; these faults may represent late Tertiary movement along preexisting faults which have their greatest displacement in pre-Oligocene rocks. The oil and gas in the basal sandstone beds of the White River formation in the Shawnee field in Converse County (fig. 4) presumably migrated upward from older

strata, possibly the Tensleep sandstone or Madison limestone, along fractures and were trapped in sandstone beds in the White River formation (Ball and Espach, 1948, p. 233).

SAND AND GRAVEL

Unconsolidated Pleistocene terrace gravel deposits as much as 20 feet thick are distributed along the North Platte and Laramie Rivers in the northern part of the map area and have been quarried at several localities. The main component of the gravel is quartzite, although schist, gneiss, granite, and chert are also present. The gravel is unsorted and contains material ranging in size from fine sand to large boulders; the bulk of the material, however, consists of cobbles 2 to 4 inches in diameter. A large quarry is located just north of the town of Fort Laramie in sec. 14, T. 26 N., R. 64 W. The gravel from this deposit is used in highway and railroad construction and as riprap for maintenance of the Interstate Canal. A large volume of gravel has been removed from this site, but a substantial reserve remains. Gravel is quarried on a small scale from the Pleistocene terrace deposits in sec. 36, T. 26 N., R. 66 W., and sec. 30, T. 26 N., R. 64 W., and is used locally for road surfacing material. The latter deposit probably was the source of riprap for the Fort Laramie Canal. Many other small pits in the area indicate that the gravel was used by ranchers for road surfacing and concrete aggregate. Extensive unexploited gravel deposits exist throughout the northern part of the Fort Laramie area.

URANIUM

During 1955, nine water samples were collected from springs and wells issuing from Tertiary rocks in or near the Fort Laramie area, and one sample was collected from a stream. Eight of these were from springs and wells in the Arikaree formation and two were in the White River formation. Uranium analyses of these samples are listed in table 4. Those from springs and wells in the Arikaree formation average 15.1 ppb (parts per billion) uranium and those from the White River formation average 20 ppb. The stream sample contained 3 ppb uranium. Denson and others (1956, p. 673) stated that most ground water contains less than 2 ppb uranium, but sampling in the southern part of the Powder River Basin northwest of the Fort Laramie area indicated that water from rocks of Oligocene and Miocene age in that area contains an average of 46 ppb uranium (Denson and others, 1956, p. 674). One water sample collected from Hawk Springs in the White River formation about 20 miles southeast of the Fort Laramie area in Goshen Hole contained 118 ppb uranium (Love, oral communication, 1957).

At two localities, rocks having abnormally high radioactivity were sampled, and the samples were submitted for chemical analysis. A sample of limestone from the SE¼ sec. 34, T. 24 N., R. 66 W., from the middle part of the Arikaree formation, contained 0.010 percent uranium oxide (U_3O_8); a sample of conglomerate from the lower part of the White River formation in Goshen Hole, about 2 miles south of the Fort Laramie area, contained 0.004 percent uranium oxide.

TABLE 4.—*Uranium analyses of 10 water samples from the Fort Laramie area and vicinity*

[Analyses by R. P. Cox and Mary Finch, U.S. Geol. Survey, Denver, Colo.]

Location				Laboratory No.	Source	Formation	Uranium (parts per billion)	pH
County	Sec.	Township N.	Range W.					
Goshen	19	24	64	234094	Well	White River (upper part).	[a] 11	7.5
Do	1	24	65	234096	Stream	Arikaree (upper part)	[a] 3	8.1
Do	15	24	65	234093	Well	Arikaree (middle part)	[a] 7	8.0
Do	30	25	63	234095	do	White River (upper part).	29	7.7
Do	4	26	64	234090	do	Arikaree (upper part)	28	7.7
Do	15	26	64	234091	do	Arikaree(?) (middle part).	[a] 29	7.7
Platte	12	23	66	234092	do	Arikaree (middle part)	22	7.7
Do	10	24	66	234089	Spring	Arikaree (lower part)	6	7.6
Do	25	25	66	234087	do	do	[a] 6	7.9
Do	35	25	66	234088	do	do	[a] 8	7.9

[a] Shown on plate 1.

Miocene rocks contain uranium minerals in several other areas in southern Wyoming. In the Miller Hill area, an algal limestone layer in the Browns Park formation, which is approximately equivalent in age to the upper part of the Arikaree formation (table 1), locally contains as much as 0.15 percent uranium (Love, 1953, p. 7). In the Poison basin area, the same formation contains as much as 3 percent uranium in secondary uranium minerals distributed erratically through crossbedded sandstone overlying the basal conglomerate (Prichard and Chisholm, 1955, p. 127). In the Saratoga area, the Browns Park contains uranium minerals along fractures in sandstone, carbonaceous shale, and white chalcedonic limestone (Love, 1954b, p. 179). In the Hanna Basin and the Saratoga area, the North Park formation of late Miocene age (table 2) contains uranium minerals in sandstone and claystone (Love, 1954b, p. 179; 1955, p. 209–210).

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