Geology of the Du Noir Area Fremont County Wyoming

By WILLIAM R. KEEFER

SHORTER CONTRIBUTIONS TO GENERAL GEOLOGY

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A detailed study of the geology of a 250-square-mile area in the extreme northwestern part of the Wind River Basin, Wyoming. Prepared in cooperation with the Geological Survey of Wyoming and the Department of Geology of the University of Wyoming as part of a program of the Department of the Interior for development of the Missouri River basin

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GEOLOGY OF THE DU NOIR AREA, FREMONT COUNTY, WYOMING

By William R. Keefer

ABSTRACT

The Du Noir area includes about 250 square miles in the northwestern part of the Wind River Basin, Fremont County, Wyo. It is bounded on the south by the Wind River and Warm Spring Creek, which flow along the northeast flank of the Wind River Range, and on the north by the steep scarps of the southern margin of the Absaroka Range. Rugged mountainous terrain dominates both the southwest and northern portions of the mapped area whereas badland topography and deeply dissected upland surfaces characterize the central part. One of the most prominent physiographic and structural features of the region is the Washakie Range, a belt of folded and faulted rocks of Paleozoic and Mesozoic age, which lies along the southern margin of the Absaroka Range. These highlands, attaining elevations of as much as 10,000 feet, were buried by Tertiary volcanic debris and subsequently partly exhumed as the Wind River Basin was reexcavated by the Wind River and its tributaries.

The sedimentary rocks exposed in the Du Noir area are more than 12,500 feet thick and range in age from Cambrian to Recent. Except for the Silurian, all systems are represented. Precambrian granite and granite gneiss occur both in the Wind River and in the Washakie Ranges.

The Cambrian system is represented by the Flathead sandstone, Gros Ventre formation, and Gallatin limestone. The remaining Paleozoic formations, named in ascending order, are the Bighorn dolomite of Ordovician age, Darby formation of Devonian age, Madison limestone of Mississippian age, Amsden formation and Tensleep sandstone of Pennsylvanian age, and Phosphoria formation of Permian age. With a few exceptions, the thickness and lithologic character of the formations do not vary greatly within the mapped area. Erosional unconformities are present at several horizons, the most conspicuous occurring between the Darwin sandstone member of the Amsden formation and the Madison limestone. This unconformity is considered by the writer to mark the Pennsylvanian-Mississippian boundary in this area.

Mesozoic strata have only limited exposures. Triassic rocks are represented by the Dinwoody and Chugwater formations, Jurassic rocks by the Nugget sandstone, Gypsum Spring formation, "lower Sundance," "upper Sundance," and Morrison formation, and Cretaceous rocks by the Cloverly formation, Thermopolis shale, Mowry shale, Frontier formation, and Cody shale. No consistent basis for subdivision of the Morrison and Cloverly formations, which span the Jurassic-Cretaceous boundary, was found in the area and they have been mapped as a single unit. The Lower Jurassic Nugget sandstone thins markedly from a maximum of about 120 feet to a wedge edge and in places the Gypsum Spring formation rests directly upon the Chugwater formation. The Cody shale has only limited exposures because of overlapping Tertiary rocks and structural complications. Younger Upper Cretaceous rocks, commonly found in adjacent regions, are not present.

Tertiary strata, which cover a large part of the Du Noir area, have been divided into 5 units: the Fort Union(?) formation of Paleocene age, Indian Meadows and Wind River formations of lower Eocene age, Tepee Trail formation of late Eocene age, and Wiggins formation of Oligocene(?) age. Rocks of middle Eocene age have not been confirmed, but they could be present. In some areas the lower Eocene rocks have been mapped as a single unit and designated as Wind River and Indian Meadows formations, undifferentiated. Mountainward facies of the Eocene rocks, consisting mostly of coarse arkose, are present on the northeast flank of the Wind River Range and have been mapped as Eocene rocks, undifferentiated. Conglomerates containing Mesozoic rock fragments along the southwest flank of the Dubois anticlinal complex are believed by the writer to represent the Fort Union formation in this area. The lower Eocene strata are characterized by brightly variegated fine-grained claystones and siltstones and massive conglomerates with Paleozoic and Precambrian rock fragments. A thick drab tuffaceous sandstone unit near the middle of the Wind River formation marks the first appearance of conspicuous amounts of volcanic debris in the Tertiary sequence. Younger beds contain progressively more pyroclastic material, and the upper part of the Tepee Trail formation and the Wiggins formation are predominantly coarse volcanic conglomerates.

Several kinds of Quaternary deposits are distinguished, including glacial moraines, landslide debris, terrace gravels, colluvium, residual basalt debris, travertine, and alluvium. A study of the terraces, seven levels in all, and the glacial deposits indicates a complex glacial and erosional history for the northwestern part of the Wind River Basin.

The Du Noir area includes three major structural divisions, all formed during the Laramide Revolution: the northeast flank of the Wind River Range, an intervening synclinal basin thought to be a northwestern extension of the Wind River Basin, and the Washakie Range on the north. No structural deformation is apparent in the Tertiary volcanic rocks along the southern margin of the Absaroka Range. The trend of the Laramide structural features is approximately N. 45° W. The most intense folding and faulting occurred along the south edge of the Washakie Range and in the northern part of the synclinal basin. Asymmetric anticlinal folds have their steep flanks on the southwest, and, with one exception, the movement of the overriding blocks of thrust or high-angle reverse faults has been relatively southwestward. Large-scale normal faulting is present near the top of Spring Mountain and the adjacent parts of Horse Creek Basin.

The earliest of Laramide folding occurred before the deposition of the Fort Union(?) formation, as evidenced by con-

glomerates which were most probably derived during the initial stages of folding of the Dubois anticlinal complex. The Wind River and Washakie Ranges were folded to mountainous proportions and subsequently deeply eroded before the deposition of the lower Eocene Indian Meadows formation. Both ranges have undergone little deformation since that time. Intense deformation occurred in the center of the synclinal basin, however, during early Eocene time. This deformation was manifested by large-scale thrusting and by renewed folding and faulting of the Dubois anticlinal complex. Erosional unconformities are present at the tops of the Wind River and Tepee Trail formations.

The best opportunities for oil and gas production are in the northern part of the synclinal basin and along the south flank of the Washakie Range where most of the surface rocks are post-Paleozoic and where the greatest amount of folding occurred. One producing well and one dry hole have been drilled on the Dubois anticlinal complex. The producing well yielded 21,741 barrels of 20° API gravity crude oil during the period 1946 through 1953. The anticlinal structures are largely obscured by Tertiary or Quaternary rocks so that a complete appraisal of potential oil traps is not possible from surface data alone. Some areas are deemed favorable for seismic exploration.

Several thin coal beds are present near the base of the Frontier formation and in some zones in the Wind River formation and Eocene rocks, undifferentiated. Surface exposures of coal are of limited extent, and only a few seams are thick enough to be of economic importance. Although small amounts of coal have been mined in the area in the past, no mining operations are being carried on at present. Bentonites, ranging in thickness from a few inches to as much as 14 feet, are common in the Mowry and Frontier formations, but none have been exploited and the quality is not known. There are several abandoned gold placer mines along Warm Spring Creek.

INTRODUCTION

LOCATION AND EXTENT OF THE AREA

The Du Noir area includes about 250 square miles in the northwestern part of the Wind River Basin, Fremont County, Wyo. (fig. 56). The mapped area is bounded on the south by the Wind River and Warm Spring Creek and on the west by the range line between R. 108 and 109 W. The northern edge lies along the southern margin of the Absaroka Range. The eastern boundary is the Wiggins Fork River, except in the southeast corner of the area where mapping was terminated along the range line between R. 105 and 106 W.

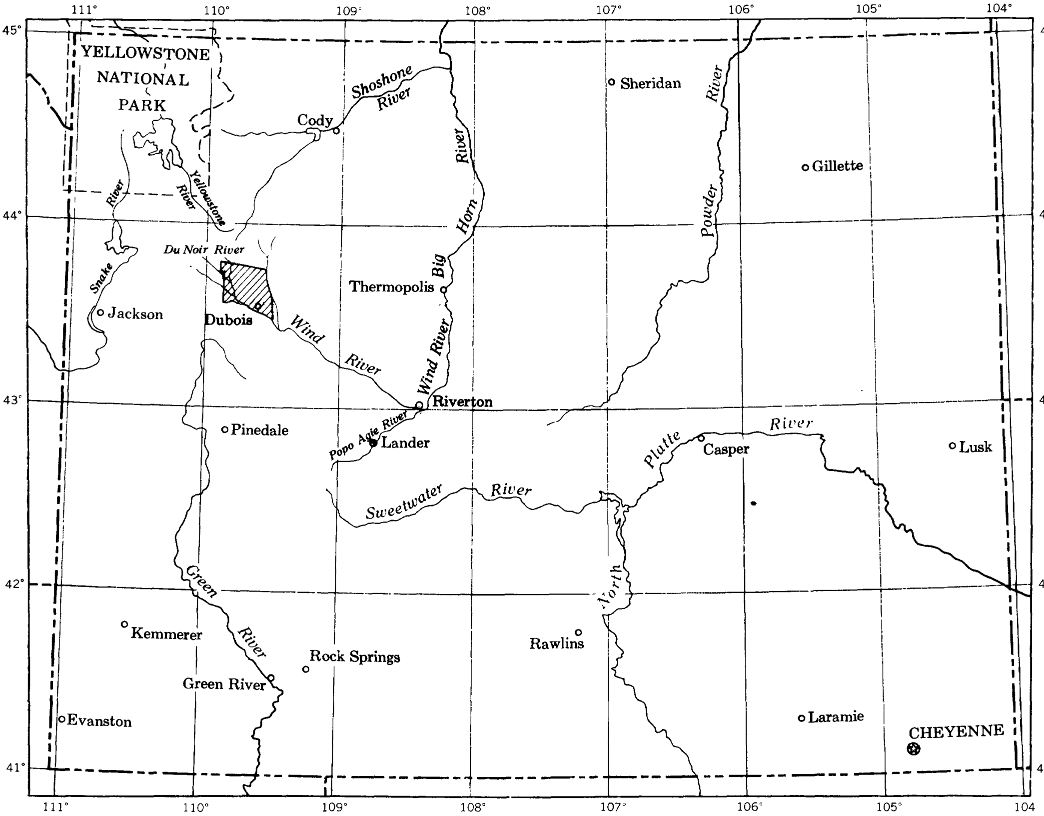


FIGURE 56.—Index map of Wyoming showing location of Du Noir area.

PURPOSE AND SCOPE OF THE REPORT

Geologic investigations in the region were undertaken by the U. S. Geological Survey as part of its program of geologic mapping in the Wind River Basin with the primary objective of evaluating the oil, gas, and coal possibilities of the area. The detailed stratigraphic studies and structure mapping provide useful data in the interpretation of the geologic history of the basin and have a direct bearing on the oil and gas possibilities of the region. In addition, the study of the complex Quaternary deposits and their related physiographic features provide basic data for the interpretation of the glacial and erosional history of much of the western part of the Wind River Basin.

PREVIOUS INVESTIGATIONS AND PUBLICATIONS

Early exploratory investigations in this area and adjoining regions were carried out by various expeditions of the U. S. Army, the work of which resulted in reconnaissance topographic and geologic maps and reports. F. V. Hayden accompanied the expedition in charge of Capt. W. F. Reynolds in 1859 and gave an account of some of the geologic features in the region. T. B. Comstock, who accompanied the expedition of Capt. W. A. Jones in 1873, published a geologic map and brief summary of the general geology of central and northwestern Wyoming. Although maps of the routes followed by this expedition do not show that it visited the upper parts of the valleys of the Du Noir River and Horse Creek, outcrops of Jurassic, Triassic, and Carboniferous rocks are shown on the geologic map as occurring in these areas.

The most significant of the early geologic work in the Du Noir area was that done by O. H. St. John who, in 1877 and 1878, was engaged in reconnaissance geologic investigations of a large part of west-central Wyoming as part of the program of the U. S. Geological and Geographical Survey of the Territories under the direction of F. V. Hayden. St. John (1883, p. 228–270) gives a rather accurate and comprehensive account of the geologic features along the Wind River southeastward from Togwotee Pass through the southern part of the Du Noir area. His report includes discriptions of Tertiary sediments and Quaternary deposits which are present along the river as well as a section of Paleozoic rocks in Warm Spring Canyon. Although only the southern part of the area was visited by St. John, his generalized geologic map covers the entire area. From 1883 to the present no detailed or reconnaissance geologic map of the Du Noir area has been published except the present map (pl. 26) which was published in the Oil and Gas Investigations series as OM 166 (Keefer, 1955).

Eldridge (1894, p. 62) published some coal analyses of samples described as coming from the vicinity of Warm Spring Creek. During the years 1910 to 1913 Blackwelder (1915) carried out regional geologic investigations in west-central Wyoming and described glacial deposits and related features around the mouth of the Du Noir River. Miller (1936) published a section of Cambrian rocks measured along Warm Spring Creek. Love (1939) published a detailed geologic map and comprehensive report of the region which adjoins the Du Noir area on the east. Love's publication contains a complete bibliography of the geologic work that had been done in this part of the Wind River Basin up to that time. Miner and Delo (1943) studied glacial features in the Du Noir valley.

Recent publications include many by the U. S. Geological Survey in its program of geologic mapping and regional stratigraphic studies in the Wind River Basin and adjacent areas to the west along the northwest flank of the Wind River Range and Jackson Hole. The areas covered by recently published geologic maps are shown in figure 57. In addition to these maps there are several Geological Survey Oil and Gas Preliminary charts and other reports primarily concerned with the Mesozoic stratigraphy of the basin. Geological Survey of Wyoming Bulletin 38 (Love, Tourtelot, Johnson, and others, 1947) contains a detailed section of the Mesozoic rocks exposed along Horse Creek, and the writer has freely drawn information from this bulletin for the lithologic descriptions of these formations.

FIELD WORK

The field work on which this report is based was done during the summers of 1951 and 1952 and June 1953. The field mapping was on aerial photographs at a scale of 1:20,000. As no adequate base map was available for the area, one was constructed from aerial photographs by the spider templet (Floore Radial Intersector) system of radial triangulation. A polyconic projection at a scale of 1:31,680 (2 in. = 1 mi.) served as the base on which the control points were plotted, and data were transferred from the aerial photographs to the base map by use of a radial planimetric (Kail) plotter.

Most of the General Land Office surveys in the Du Noir area were made in 1891 and 1892. Since that time some resurveys of previously established section lines and additional surveys of areas not covered originally have been made. Most of the section corners are marked by rocks near which have been placed small cairns; some of the more recently established corners are marked by capped iron posts. The north-central portion of the area remains unsurveyed. Many section and quarter corners were located in the field and these formed the basis for the construction of the General

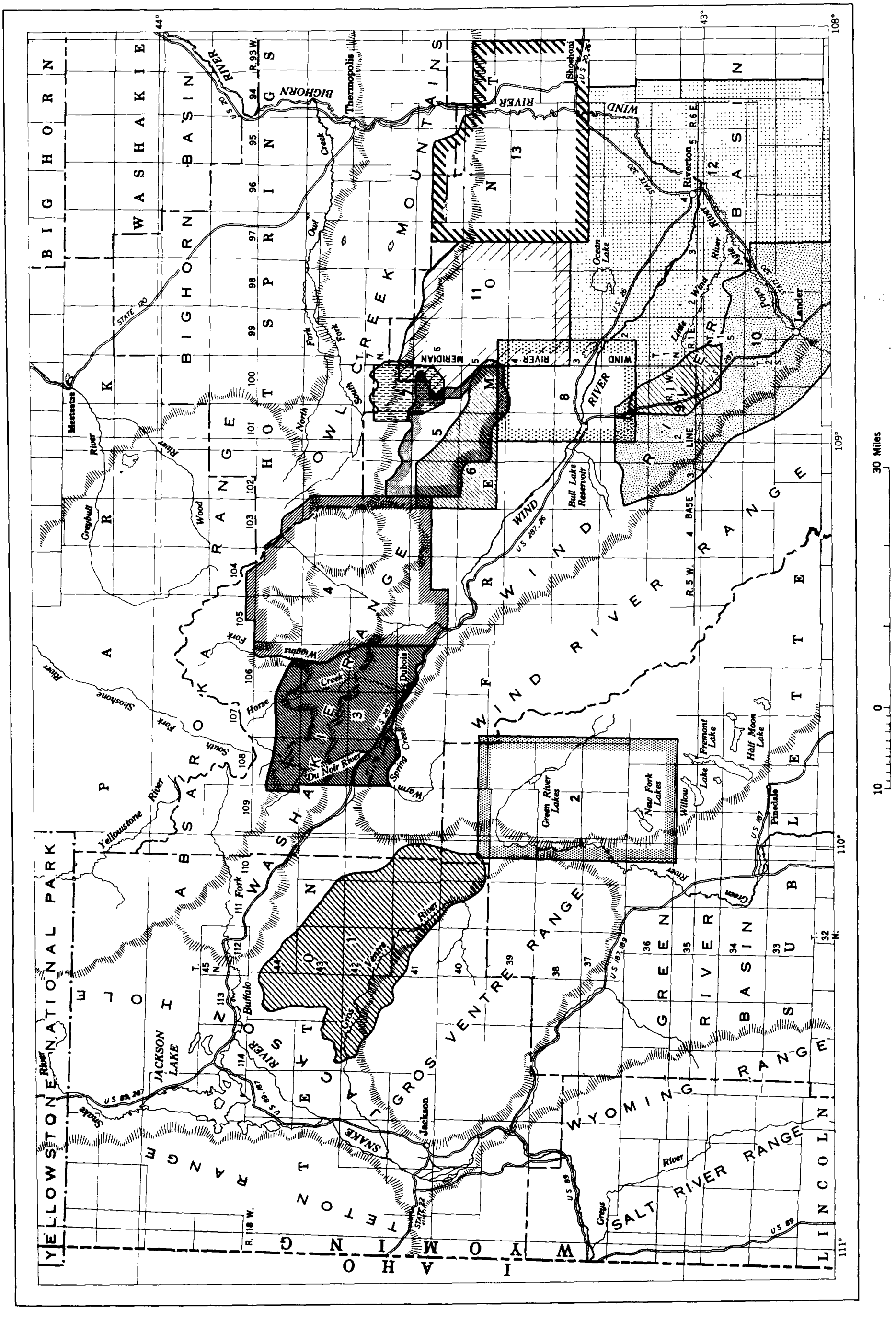


FIGURE 57.—Index map showing major physiographic features and areas of recent geologic mapping in west-central Wyoming.

1. Love, Keefer, Duncan, and others, 1951; 2. Richmond, 1945; 3. Area covered by this report; 4. Love, 1939; 5. Andrews, 1944; 6. Murphy, Privrasky, and Moerlein, 1956; 7. Williams and Sharkey, 1946; 8. Murphy and Roberts, 1954; 9. Sharkey, Zapp, Johnson, and others, 1946; 10. Thompson, Troyer, and others, 1950; 11. Troyer and Keefer, 1955; 12. Thompson and White, 1954; 13. Tourtelot and Thompson, 1948.

Land Office grid on the base map. In areas where no corners were recovered, data from the township plats were used to complete the grid.

The Younts Peak (30-minute) quadrangle, in which the entire Du Noir area is located, was published in 1907. This is the only topographic map of the area. There are both U. S. Coast and Geodetic and U. S. Geological Survey bench marks along the Wind River. Additional lines of Geological Survey bench marks were established along the Union Trail, which is closely approximated by the present Du Noir tie camp road, and along the road that leads northeast out of Dubois to Little Alkali Creek and the Wiggins Fork River. Other bench marks are located sporadically throughout the area, but mostly at remote points not readily accessible for use as control points. Elevations for structure contour data were obtained with aneroid barometer. In some parts of the area lines of elevations were projected many miles from bench marks. The Younts Peak topographic map was used to construct the profiles for the structure sections.

Stratigraphic sections were measured by planetable and alidade, by 100-foot tape and Brunton traverse, and by a combination of the two methods. An aneroid barometer was used to measure the thickness of some of the Tertiary formations.

ACKNOWLEDGMENTS

The writer was assisted in the field during the summer of 1951 by R. J. Burnside and during the summer of 1952 by W. H. Curry, III. The aid of the following U. S. Geological Survey paleontologists is acknowledged: R. W. Brown has collected and studied fossil plants and leaves from the Tertiary rocks of the area from time to time since 1941; J. B. Reeside, Jr., and W. A. Cobban visited the party during the first season and collected Upper Cretaceous invertebrates; M. J. Hough spent a few days collecting vertebrate fossils during both summers; J. E. Smedley and Helen Duncan identified invertebrate fossils from the Madison and Amsden formations; and Josiah Bridge identified collections from the Leigh dolomite member of the Bighorn (Ordovician). Acknowledgment is due C. L. Gazin, of the U. S. National Museum, for his identification of many of the vertebrate collections.

The report was submited to the University of Wyoming as a dissertation in partial fulfillment of the requirements for the degree of doctor of philosophy. The writer wishes to express appreciation to the Director of the Geological Survey for his approval to place the report in open file in advance of its publication for this purpose. The criticisms of Prof. D. L. Blackstone, Jr., and Prof. S. H. Knight, of the department of geology, University of Wyoming, were very helpful.

GEOGRAPHY

SURFACE FEATURES

The Du Noir area lies in the northwestern end of the Wind River Basin, a structural and topographic basin which broadens southward and eastward to form one of the major intermontane basins of Wyoming. Within the mapped area the basin proper is restricted to a northwestward trending synclinal valley only a few miles wide; the southern edge is approximately delineated by the Wind River whereas the northern edge is not well defined and merges with the upland surface that lies along the southern margin of the Absaroka Range.

Regions of rugged mountainous terrain are present south of the Wind River and along the northern part of the mapped area. South of the Wind River the northeast flank of the Wind River Range rises in moderately steep dip slopes through which streams have cut deep canyons. The highest point in the southern part of the area is Warm Spring Mountain with an elevation of 9,500 feet, about 2,300 feet above the adjacent valley floor of the Wind River. Warm Spring Creek, which follows a narrow strike valley along most of its course, has incised a precipitous canyon nearly 1,000 feet deep in its lower reaches.

The Wind River valley, the term herein used to designate only the valley floor upon which the river flows and the adjacent slopes, descends from an elevation of 7,500 feet at the western edge of the mapped area to 6,700 feet at the southeastern edge or at an average rate of about 40 feet per mile. Downstream from the narrow steep-walled canyon at Stony Point the valley is bounded on the north for the most part by broad alluvial plains and on the south by abrupt slopes that descend from terraces that were developed on the northeast flank of the Wind River Range. Upstream from Stony Point the valley is formed by a very broad flat alluvial plain developed at the confluence of the Wind and Du Noir Rivers. Near the western edge of the area the valley of Wind River contains much glacial debris through which the river has cut a narrow channel.

North of the Wind River badlands are developed in nearly flat-lying Tertiary strata. These badlands constitute a zone 4 to 6 miles wide extending from the southeastern corner of the area northwestward to the Du Noir River. The general surface of the badlands rises in elevation northward and, in the central portion of the area, culminates in Ramshorn Peak. The relatively low-lying section along the western edge of the map is characterized by irregular hummocky glaciated topography.

North of a line trending west and northwest from the mouth of Little Alkali Creek to the junction of the East and West Forks of the Du Noir River is an area of rugged mountainous terrain which rises to elevations of 9,500 to 10,000 feet along the base of the steep scarps of the Absaroka Range. This belt of irregular terrain is a zone of folded and faulted Paleozoic and Mesozoic rocks which was buried by volcanic debris and subsequently partly exhumed. The zone extends both northwest and southeast of the mapped area along the southern margin of the Absaroka Range and has been referred to as the Washakie Range by Love (1939) who presented a detailed account of the geologic and geographic features of the range in areas to the southeast and the relationship of this structure to other mountain ranges in the region.

The scarp marking the southern border of the Absaroka Range is a sheer wall of flat-lying Tertiary pyroclastic rocks nearly 1,000 feet high, which dominates the landscape in the extreme northwest corner of the Wind River Basin. The range is a plateau remnant, about 11,500 feet in elevation, which at one time probably extended across the Wind River Basin but has since receded to its present position as the basin was reexcavated by the Wind River. The plateau surface is broken by isolated peaks and rounded hills that reach elevations of 12,000 feet or more. The Continental Divide is located about 3 miles northwest of the northwestern corner of the mapped area. In this general locality, too, is the divide between the drainage basins of the Wind and Shoshone Rivers. Because of active erosion by the major streams the southern margin of the Absaroka Range is very irregular; there are prominent ridges along the interstream divides, such as Du Noir Butte, The Ramshorn, and Elkhorn Ridge, extending several miles southward from the general mass of the range. The most conspicuous of these narrow precipitous ridges is The Ramshorn which culminates in Ramshorn Peak, a sharp angular pinnacle 11,625 feet in elevation, forming the most prominent peak in the entire area.

The Du Noir River, the main tributary of the Wind River within the mapped area, flows through a broad flat-floored valley that is from one-half to three-quarters of a mile wide and approximately 8 miles long. The valley is a striking physiographic feature in an otherwise rugged and irregular terrain. East and West Forks, which join to form the Du Noir River at the upper end of the valley, flow through canyons along most of their courses as do other tributaries to the river. Horse Creek, which enters the Wind River at the town of Dubois, is also characterized for the most part by a broad flat valley in its lower reaches and by canyons toward its headwaters. The Wiggins Fork River, along the northeastern edge of the mapped area, is bounded by precipitous canyons along most of its course.

DRAINAGE AND WATER SUPPLY

The entire area is drained by the Wind River, which heads about 12 miles west of the mapped area in the vicinity of Togwotee Pass, and its tributaries. The main tributaries include the Du Noir River, Warm Spring and Horse Creeks, and the Wiggins Fork River, a tributary of the North Fork which enters the Wind River 3 miles southeast of the area.

The only gaging station of the U. S. Geological Survey on the Wind River within the mapped area is near Stony Point, about 1½ miles downstream from the confluence of the Wind and Du Noir Rivers. The discharge of the Wind River at this point during the water year 1948–49 varied from a minimum of 46 second-feet per day for the period March 26–30 to a maximum of 802 second-feet on June 13, and from a mean of 51.3 second-feet during March to a mean of 543 second-feet during June (U. S. Geol. Survey, 1951, p. 208). The mean annual discharge for the calendar years 1946–48 was 64,443 second-feet.

All the main tributary streams are perennial and head in high mountainous areas where they are charged the year round by melt water. Smaller streams that flow throughout the year include Bench, Crooked, and Long Creeks. Many tributaries of these streams are fed by springs. In the badland areas most of the streams are intermittent and flow only during the spring runoff and after rains. Flash floods are likely to occur in their channels during heavy rainstorms, at which times they become heavily laden with silt from the soft underlying Tertiary strata.

Because much of the area is traversed by perennial streams the need for other water supplies for stock and irrigation is not acute. Water for irrigation is derived mainly by diverting water from the main streams into irrigation ditches which extend along the edges of the valleys. Trail Lake, located in sec. 34, T. 44 N., R. 108 W., is utilized as a reservoir from which water is used to irrigate meadows on the upland surface northeast of the Pickett ranch. Since the mountainous areas contain numerous small streams, springs, and ponds, the water supply for summer grazing generally presents few problems. Much of this water is also excellent for domestic use.

Water for domestic use for the ranches located in the valleys is derived mainly from wells, and in some places from springs. Wells, particularly those located on the valley floors, are generally shallow and bottom in alluvial gravels. Some, however, are deep enough to penetrate the underlying Tertiary sandstone.

CLIMATE AND VEGETATION

The climate of the Du Noir area is semiarid to arid. Records of the U. S. Weather Bureau at Dubois show the average annual precipitation for the period 1907–52 to be 9.29 inches. Nearly half of the precipitation comes during the months of April, May, June, and July. Few data are available for the mountain areas, but the precipitation in those regions is considerably greater as evidenced by the thick growth of trees and other vegetation. The amount of moisture in the valleys is insufficient for agriculture, and farming is successful only where additional water is supplied by irrigation.

The mean annual temperature, compiled from climatic data of Dubois, is 39.7° F for the period 1907–52. Daily and seasonal variations are great. The average length of the growing season is about 88 days; the average date of the last killing frost in the spring is June 11 and the average date of the first killing frost in the autumn is September 7. The average annual snowfall for the period 1906–48 was 39.2 inches at Dubois, but it is considerably greater in the mountains.

The records of the U. S. Weather Bureau at Dubois are given in the table below.

Average monthly and annual precipitation and temperature at Dubois

[Compiled from U. S. Weather Bureau Records; incomplete records for period 1907–52]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Precipitation (inches)	0. 47	0. 41	0. 54	1. 04	1. 38	1. 23	0. 87	0. 83	1. 01	0. 81	0. 37	0. 33	9. 29
Temperature (°F)	20. 9	23. 3	28. 9	38. 2	45. 7	53. 8	60. 3	58. 6	50. 8	42. 0	31. 2	23. 6	39. 7

Because the average annual precipitation is less than 10 inches in the basin, the native vegetation is sparse and consists mainly of grasses and sagebrush. Some willows and pines occur along the streams. The mountain areas, which receive much more moisture, contain thick dense pine forests and plentiful grass, flowers, and other types of vegetation. The principal varieties of grasses are wheat, sedge, fescue, mountain and nodding brome, mountain timothy, big blue grass, juncus, and wild rye. Larkspur, lupine, and species of *Astragalus* are also present. In the mountain areas the forests consist mainly of lodgepole pine, sugar pine, spruce, and Douglas fir. Aspens are also common; cottonwood and dogwood trees are found along streams at lower elevations. Through irrigation, extensive hay meadows have been developed by ranchers along the main valleys. Besides the raising of hay, mainly alfalfa, brome, and meadow fescue for winterfeed, small grains, such as oats, barley, and intermediate wheat, are also cultivated.

TRANSPORTATION AND SETTLEMENT

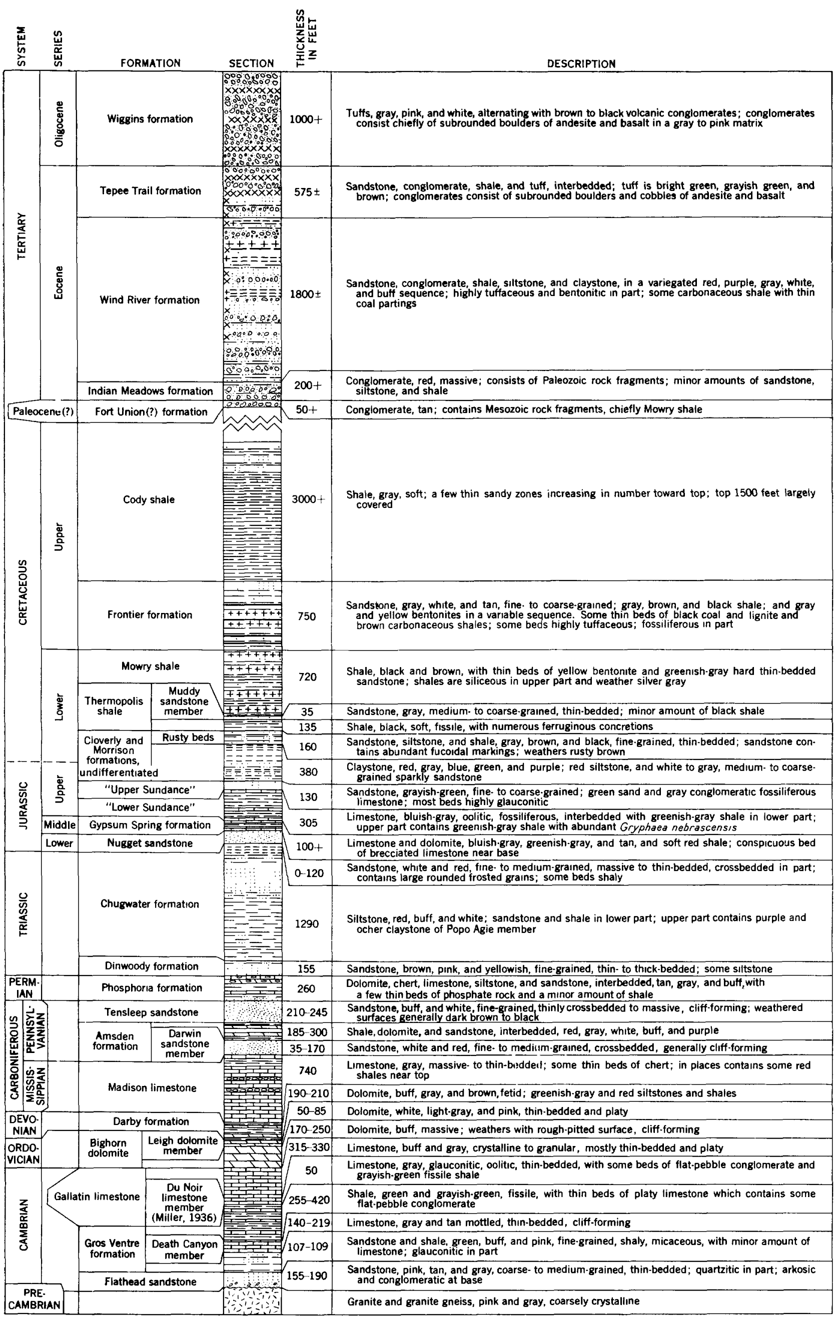
Dubois, the only town in the area, has a population of 279 according to the 1950 census. It is on U. S. Highway 287 which parallels the Wind River through the southern part of the area. The highway affords the best avenue of travel into the area. The nearest railroads are at Lander and Riverton, Wyo., both about 80 miles to the southeast.

Improved roads extend along the main valleys and lead to ranches in those areas. A graded road extends southward from U. S. Highway 287 to the former site of the Du Noir tie camp on Warm Spring Creek. Only the roads that lie at lower elevations are suitable for year-round travel; roads at higher elevations are commonly blocked by snow during the winter months.

The principal occupations of residents of the region are ranching and lumbering. Ranch headquarters are usually along the main streams where irrigation water and bottom land are available for the raising of hay. Summer grazing areas are on Federal land in the mountains. Several ranches maintain permanent camps as bases for summer activities in the mountains. Because of the proximity to extensive unsettled mountainous areas and the accompanying big-game hunting and fishing, the operation of guest-ranches has become an important occupation. The extensive forests in the northern part of the mapped area and along Warm Spring Creek have been the site of logging operations for many years. This industry accounted for much of the early settlement of the region. The lumber has been used largely for railroad ties. Because of the necessity of good roads for heavy logging equipment many remote localities have been made accessible for automotive travel.

STRATIGRAPHY

The sedimentary rocks exposed in the Du Noir area aggregate more than 12,500 feet of strata, ranging in age from Cambrian to Recent. Except for the Silurian, all systems are represented. Precambrian rocks are exposed in both the southwestern and northeastern parts of the area. The lithologic character and thickness of the formations are shown in figure 58 and their distribution on plate 26. Locations of measured sections that are referred to in the stratigraphic discussions are found in figure 59.



SYSTEM	SERIES	FORMATION	MEMBER	THICKNESS IN FEET	DESCRIPTION
TERTIARY	Oligocene	Wiggins formation		1000+	Tuffs, gray, pink, and white, alternating with brown to black volcanic conglomerates; conglomerates consist chiefly of subrounded boulders of andesite and basalt in a gray to pink matrix
	Eocene	Tepee Trail formation		575±	Sandstone, conglomerate, shale, and tuff, interbedded; tuff is bright green, grayish green, and brown; conglomerates consist of subrounded boulders and cobbles of andesite and basalt
		Wind River formation		1800±	Sandstone, conglomerate, shale, siltstone, and claystone, in a variegated red, purple, gray, white, and buff sequence; highly tuffaceous and bentonitic in part; some carbonaceous shale with thin coal partings
		Indian Meadows formation		200+	Conglomerate, red, massive; consists of Paleozoic rock fragments; minor amounts of sandstone, siltstone, and shale
	Paleocene(?)	Fort Union(?) formation		50+	Conglomerate, tan; contains Mesozoic rock fragments, chiefly Mowry shale
CRETACEOUS	Upper	Cody shale		3000+	Shale, gray, soft; a few thin sandy zones increasing in number toward top; top 1500 feet largely covered
		Frontier formation		750	Sandstone, gray, white, and tan, fine- to coarse-grained; gray, brown, and black shale; and gray and yellow bentonites in a variable sequence. Some thin beds of black coal and lignite and brown carbonaceous shales; some beds highly tuffaceous; fossiliferous in part
	Lower	Mowry shale		720	Shale, black and brown, with thin beds of yellow bentonite and greenish-gray hard thin-bedded sandstone; shales are siliceous in upper part and weather silver gray
		Thermopolis shale	Muddy sandstone member	35	Sandstone, gray, medium- to coarse-grained, thin-bedded; minor amount of black shale
				135	Shale, black, soft, fissile, with numerous ferruginous concretions
		Cloverly and Morrison formations, undifferentiated	Rusty beds	160	Sandstone, siltstone, and shale, gray, brown, and black, fine-grained, thin-bedded; sandstone contains abundant fucoidal markings; weathers rusty brown
JURASSIC	Upper			380	Claystone, red, gray, blue, green, and purple; red siltstone, and white to gray, medium- to coarse-grained sparkly sandstone
		"Upper Sundance"		130	Sandstone, grayish-green, fine- to coarse-grained; green sand and gray conglomeratic fossiliferous limestone; most beds highly glauconitic
		"Lower Sundance"		305	Limestone, bluish-gray, oolitic, fossiliferous, interbedded with greenish-gray shale in lower part; upper part contains greenish-gray shale with abundant *Gryphaea nebrascensis*
	Middle	Gypsum Spring formation		100+	Limestone and dolomite, bluish-gray, greenish-gray, and tan, and soft red shale; conspicuous bed of brecciated limestone near base
	Lower	Nugget sandstone		0–120	Sandstone, white and red, fine- to medium-grained, massive to thin-bedded, crossbedded in part; contains large rounded frosted grains; some beds shaly
TRIASSIC		Chugwater formation		1290	Siltstone, red, buff, and white; sandstone and shale in lower part; upper part contains purple and ocher claystone of Popo Agie member
		Dinwoody formation		155	Sandstone, brown, pink, and yellowish, fine-grained, thin- to thick-bedded; some siltstone
PERMIAN		Phosphoria formation		260	Dolomite, chert, limestone, siltstone, and sandstone, interbedded, tan, gray, and buff, with a few thin beds of phosphate rock and a minor amount of shale
CARBONIFEROUS	PENNSYLVANIAN	Tensleep sandstone		210–245	Sandstone, buff, and white, fine-grained, thinly crossbedded to massive, cliff-forming; weathered surfaces generally dark brown to black
		Amsden formation		185–300	Shale, dolomite, and sandstone, interbedded, red, gray, white, buff, and purple
			Darwin sandstone member	35–170	Sandstone, white and red, fine- to medium-grained, crossbedded, generally cliff-forming
	MISSISSIPPIAN	Madison limestone		740	Limestone, gray, massive- to thin-bedded; some thin beds of chert; in places contains some red shales near top
DEVONIAN		Darby formation		190–210	Dolomite, buff, gray, and brown, fetid; greenish-gray and red siltstones and shales
ORDOVICIAN		Bighorn dolomite	Leigh dolomite member	50–85	Dolomite, white, light-gray, and pink, thin-bedded and platy
				170–250	Dolomite, buff, massive; weathers with rough-pitted surface, cliff-forming
CAMBRIAN		Gallatin limestone		315–330	Limestone, buff and gray, crystalline to granular, mostly thin-bedded and platy
			Du Noir limestone member (Miller, 1936)	50	Limestone, gray, glauconitic, oolitic, thin-bedded, with some beds of flat-pebble conglomerate and grayish-green fissile shale
		Gros Ventre formation		255–420	Shale, green and grayish-green, fissile, with thin beds of platy limestone which contains some flat-pebble conglomerate
			Death Canyon member	140–219	Limestone, gray and tan mottled, thin-bedded, cliff-forming
				107–109	Sandstone and shale, green, buff, and pink, fine-grained, shaly, micaceous, with minor amount of limestone; glauconitic in part
		Flathead sandstone		155–190	Sandstone, pink, tan, and gray, coarse- to medium-grained, thin-bedded; quartzitic in part; arkosic and conglomeratic at base
PRE-CAMBRIAN					Granite and granite gneiss, pink and gray, coarsely crystalline

FIGURE 58.—Generalized columnar section of rocks in the Du Noir area.

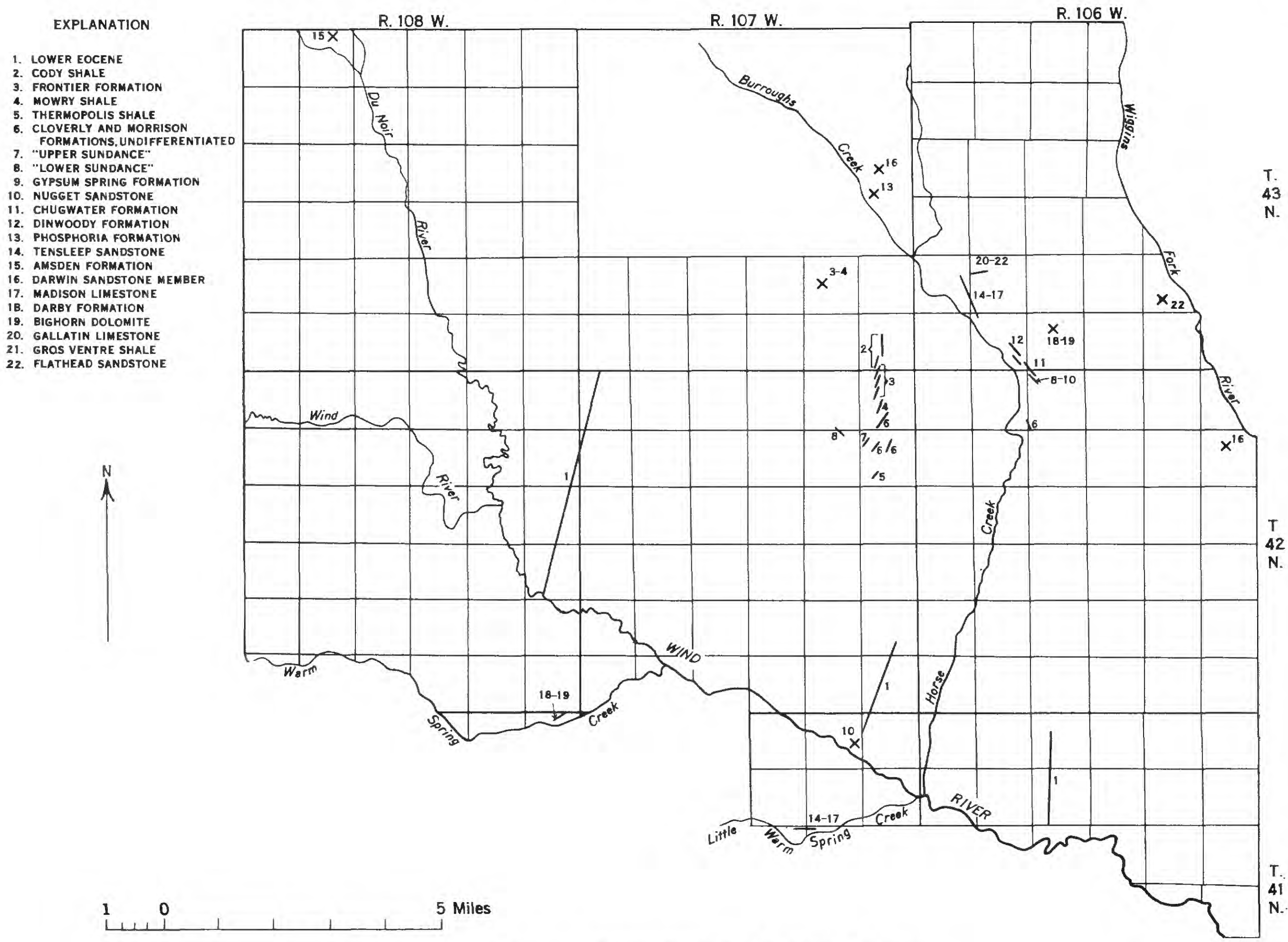


FIGURE 59.—Index map showing location of measured sections.

Complete sections of rocks of Paleozoic age are exposed on the northeast flank of the Wind River Range and at the western end of Spring Mountain. These two sections, which lie only about 10 miles apart, are excellent tie points for correlation and study of the Paleozoic sequence because the outcrop belts diverge basinward along the Owl Creek Mountains on the north and the Wind River Range on the west. Rocks of Mesozoic age are well exposed along Horse Creek and Little Horse Creek; some of the older Mesozoic formations are exposed along the Wind River near Dubois. These occurrences constitute the northwesternmost exposures of Mesozoic rocks in the Wind River Basin and therefore offer the best opportunities for correlation with similar stratigraphic units in regions to the west. Inasmuch as a detailed study of the Mesozoic rocks had been made by the Geological Survey in the Horse Creek area (Love, Tourtelot, Johnson, and others, 1947), the writer has freely drawn from this information for the stratigraphic discussions of those formations. Tertiary strata, which form an uninterrupted sequence about 5,000 feet thick in the central part of the mapped area, cover a large part of the area. A variety of Quaternary deposits, including glacial moraines, landslides, terrace gravels, and alluvium, have been differentiated.

PRECAMBRIAN ROCKS

Precambrian rocks crop out along Warm Spring Mountain and in many places in the northeast part of the mapped area where they form the core of a large anticlinal structure. Detailed studies of the Precambrian rocks were not attempted. Gray and pink coarsely crystalline granite and granite gneiss are the predominant rock types. They consist mainly of quartz, feldspar, and mica. Many of the rocks are schistose; they contain an abundance of biotite and appreciable amounts of pink garnet. Some of the gneissic granites are cut by thin pegmatite dikes and quartz veins.

The unconformity between Precambrian and Cambrian rocks is not readily observed as the contact is commonly obscured by talus from the overlying Flathead sandstone cliffs and by dense forest cover in many parts of the area. It is thought that the contact is relatively even and that local relief along the contact is not pronounced, although the thickness of the Flathead sandstone varies about 50 feet within the area. Regionally, however, the thickness of the Flathead sandstone varies greatly, and this variation is thought by Miller (1936, p. 118) to reflect the relief of the Precambrian peneplain. In some places, where the contact is not sharp, the coarse Flathead arkose beds grade downward through a weathered zone into unweathered granite.

CAMBRIAN SYSTEM

FLATHEAD SANDSTONE

The name Flathead formation was originally proposed by Peale (1893, p. 20–22) from exposures in southwestern Montana to include a basal quartzite or sandstone, termed the Flathead quartzite, and an upper green shale sequence designated the Flathead shales. In the Gros Ventre Range, Blackwelder (1918, p. 417) included the shales in the lower part of the Gros Ventre formation and restricted the term Flathead to the basal sandstone. The Flathead sandstone (Flathead quartzite of many writers) is now generally accepted in this restricted sense and has been recognized over wide areas in western and central Wyoming. In the Wind River Canyon, Miller (1936, p. 124) included both the Flathead sandstone and the Gros Ventre formation in the Depass formation, because there the contact between the two was found to be gradational. Tourtelot and Thompson (1948) however, separated the two formations in that area and present a brief summary of the problems involved in the Cambrian nomenclature. The name Depass has not been generally accepted in central Wyoming.

The Flathead sandstone crops out along Warm Spring Creek and in many places along the margins of Horse Creek Basin and upper Horse Creek valley, where it characteristically forms resistant cliffs above the Precambrian slopes. The thickness of the formation ranges from about 150 to 190 feet. The variation in thickness, which has no uniform trend, is probably due to the relief on the Precambrian peneplain developed before the deposition of Flathead sandstone. The formation consists of pink, reddish-brown, tan, and gray fine- to coarse-grained thin-bedded sandstone. The sandstone is quartzitic for the most part, and many of the beds are thinly laminated with purplish and reddish-brown layers alternating with gray and tan layers. The basal beds are commonly conglomeratic and arkosic with angular fragments of quartz, feldspar, and mica. Some granite pebbles as much as 1 inch in diameter are present. The upper beds are generally softer and shaly. Glauconite and hematite are present in some places. Dip slopes developed on the top of the Flathead sandstone are characteristically partly covered by a rubble of large sandstone blocks which have slid down the slopes; many such slopes are devoid of all vegetation except grass and are conspicuous in an otherwise heavily forested area (fig. 60).

FIGURE 60.—Flathead sandstone (€f) and Gros Ventre formation (€gv) along Warm Spring Creek in SW¼ sec. 30, T. 42 N., R. 108 W. Dip slope of Flathead sandstone in foreground. Death Canyon member of Gros Ventre in distance.

Miller (1936), who made a paleontologic and stratigraphic study of the Cambrian rocks in northwestern Wyoming, concluded on paleontologic evidence that the Flathead sandstone is largely, if not wholly, Middle Cambrian in age. The contact between the Flathead sandstone and the overlying Gros Ventre formation is marked by a change from quartzitic and, in part, shaly sandstone below to soft micaceous shaly sandstone above. The lithologic change is not pronounced, however, and in places it is gradational. The contact is also marked by a topographic change from cliffs below to weathered slopes above.

GROS VENTRE FORMATION

The Gros Ventre formation was named by Blackwelder (1918) from exposures on Doubletop Peak in the Gros Ventre Range, approximately 25 miles southwest of the mapped area. The sequence probably includes the lateral equavalents of the Flathead shales and the lower part of the Gallatin formation of Peale (1893, p. 20–25). At the type section the Gros Ventre formation is 769 feet thick; it can be divided into three distinctive lithologic units: a lower shale unit, a middle limestone unit called the Death Canyon member by Miller (1936), and a thick upper shale and limestone unit. These units are readily distinguishable throughout the mapped area. The formation crops out along Warm Spring Creek and in many places in the northeastern part of the area. Outcrops of the shale units commonly are grass-covered slopes and good exposures are rare; in contrast the Death Canyon member forms vertical cliffs and constitutes one of the most conspicuous units in the Cambrian sequence of this region (fig. 60).

Because of poor exposures no detailed measured section of the Gros Ventre formation was obtained in the mapped area. A generalized section was measured on the northwest end of Spring Mountain, where it is 503 feet thick. The section on Warm Spring Creek in the extreme southwestern corner of the area is 747 feet thick (Miller, 1936, p. 132). In areas to the east Love (1939, p. 15) reported thicknesses ranging from 550 to 700 feet.

The lower unit has a uniform thickness of about 110 feet throughout the mapped area. It consists of greenish-gray, tan, and pink shaly micaceous very fine grained sandstone that is highly glauconitic in most places. The basal part contains some beds similar to those in the upper part of the Flathead sandstone so that the contact in places in gradational. The Death Canyon member, which ranges in thickness from 140 to 219 feet, is characterized by gray thin-bedded crystalline cliff-forming limestone that is commonly mottled tan by the inclusion of granular tan irregular masses.

The upper unit is 421 feet thick on Warm Spring Creek (Miller, 1936, p. 132) and only 254 feet at the Spring Mountain locality. The sequence is composed mostly of soft greenish-gray micaceous shale with varying amounts of thin-bedded gray limestone that increase in abundance toward the top. The limestone commonly contains beds of flat-pebble conglomerate. Best exposures of the shale can be seen in the road cuts along the switchbacks that descend into Warm Spring Canyon southwest of the Harrison ranch.

No fossils were found in the formation by the writer, but a few trilobites and brachiopods have been reported from the Warm Spring Creek section (Miller, 1936, p. 132) and adjoining areas to the east (Love, 1939, p. 16). The fauna indicates a Middle Cambrian age, which agrees with that assigned by Blackwelder (1918) to the type section.

The contact between the Gros Ventre formation and the overlying Gallatin limestone is marked by a sharp topographic break and by a change from predominantly shaly rocks below to predominantly limestone above. Wherever the contact was observed it appeared to be conformable, but the variation in thickness of the upper shale unit may be indicative of a disconformity between the two formations. A disconformity was noted by Miller (1936, p. 122) in the Teton Range and by Blackwelder (1918) at the type section in the Gros Ventre Range. Inasmuch as the Death Canyon member also thins considerably northeastward from Warm Spring Creek the thinning of both of the upper units may be due largely to nondeposition.

GALLATIN LIMESTONE

The Gallatin limestone, the youngest Cambrian formation in the area, was named and described by Peale (1893, p. 22–23) from exposures in southwestern Montana. At the type section it originally included in its lower part limestone and shale of Middle Cambrian age, which probably constitute the upper part of the Gros Ventre formation as that formation was defined by Blackwelder (1918), and limestone of Late Cambrian age in its upper part. Inasmuch as the Gallatin limestone, in its restricted sense, contains only strata of Late Cambrian age and is therefore not completely representative of the type Gallatin as originally defined, Deiss (1938, p. 1104) applied the term Boysen formation for the Upper Cambrian rocks in Wind River Canyon. That name, although extended into the Gros Ventre Range by Foster (1947, p. 1547), has not gained wide acceptance.

The Gallatin limestone is a resistant sequence that forms conspicuous cliffs above the shale slopes of the Gros Ventre formation. In Warm Spring Canyon it constitutes the lowermost series of ledges in the precipitous canyon wall (fig. 61). The formation is also well exposed in the northeastern portion of the area. On Warm Spring Creek it is 365 feet thick. The Du Noir member, which forms the basal unit, was named by Miller (1936, p. 125); the type section is about 2 miles west of the Du Noir tie camp, in the southwest corner of the area.

In Warm Spring Canyon the Du Noir limestone member (Miller, 1936) is an easily recognizable 48-foot cliff-forming unit of gray thin-bedded highly glauconitic and oolitic limestone with some flat-pebble conglomerates. The overlying unit, which is 54 feet thick and generally poorly exposed because of talus

FIGURE 61.—Gallatin limestone (€g) and Bighorn dolomite (Ob) on north side of Warm Spring Canyon, N½ sec. 1, T. 41 N., R. 108 W. Gros Ventre formation (€gv) in foreground.

cover, consists mainly of soft greenish-gray shale and a minor amount of thin-bedded gray limestone. The uppermost sequence which forms the main mass of the formation is a hard resistant series of gray thin-bedded to massive limestones. Some of the exposed surfaces weather with a rough-pitted surface similar to the overlying Bighorn dolomite. The upper part of the unit is commonly mottled with tan small irregular granular limestone masses. The formation in many places contains caverns filled with red earthy deposits which, where exposed on the sides of cliffs, contribute much red staining to the outcrops. Because of this, the outcrops, when viewed from a distance, appear to contain a large amount of red material. The caverns may have been developed and filled during short periods of erosion in Late Cambrian time and as such may represent local disconformities within the formation. On the contrary they may have been formed and filled at a much later date.

Section of Gallatin limestone measured on north wall of Warm Spring Canyon in sec. 1, T. 41 N., R. 108 W.

	Feet
Bighorn dolomite.	
Gallatin limestone:	
Limestone, white to gray and tan mottled, thin-bedded glauconitic(?): sporadic brachiopod fragments	49
Limestone, gray, thin-bedded: cherty at top; abundant trilobite fragments at top	36
Limestone, gray to buff, massive to thin-bedded; cavernous with caverns containing red earthy material which stains cliff red	97
Limestone, gray, thin-bedded; conglomeratic in part with granule-size fragments of glauconite(?)	81
Largely covered interval; underlain mostly by soft greenish-gray shale and gray limestone	54
Du Noir limestone member of Miller, 1936: Limestone, gray, thin-bedded, highly glauconitic, oolitic; some flat-pebble conglomerates; sporadic brachiopod fragments at top: forms cliff	48
	365
Gros Ventre formation.	

Only unidentifiable trilobite and brachiopod fragments were found in the Gal'‑tin limestone. However, in his studies of the Cambri‑n sequence of this region Miller (1936, p. 140–141) collected fossils from many faunal zones in the Gallatin limestone and correlated them with zones in the type St. Croixan (Upper Cambrian) of the upper Mississippi Valley.

The contact between the Gallatin limestone and the overlying Bighorn dolomite is not sharp in the section measured in Warm Spring Canyon, but is marked only by a gradual change from gray limestone below to buff granular limestone and dolomite above. The contact is also difficult to determine in the cliff faces along the canyon. In many places throughout the area, however, a sharp topographic change delineates the contact as the more easily eroded thin-bedded limestone forms slopes beneath the very resistant massive Bighorn dolomite. Love (1939, p. 19) states that the Bighorn dolomite rests with slight disconformity on the Gallatin limestone. In some areas Miller (1936) found an erosional disconformity at the top of the Cambrian; in others the contact appeared to be conformable. Miller (1936, p. 131) noted 100 feet of beds at the top of the Gallatin limestone on Warm Spring Mountain that were absent about 3 miles to the west. Since the Gallatin limestone is Upper Cambrian and the lower part of the Bighorn dolomite is believed to be of Middle or Late Ordovician age (Thomas, 1948, p. 80), this break represents considerable time.

ORDOVICIAN SYSTEM

BIGHORN DOLOMITE

Along the flank of the Wind River Range the Bighorn dolomite, which was named and described by Darton (1904, p. 394–396) from exposures in the Bighorn Mountains, is divisible into three lithologic units: a basal lenticular sandstone called the Lander sandstone member by A. K. Miller (1930, p. 196), an unnamed middle massive dolomite member, and an upper thin-bedded dolomite member called the Leigh dolomite member by Blackwelder (1918). Within the mapped area only the upper two dolomite members are believed to be present, although, owing to its lenticular nature and thinness, the Lander sandstone member may be present in areas where the basal part of the formation is concealed. A 1-foot bed of coarse-grained sandstone at the base of the Bighorn dolomite was observed by the writer along Torrey Creek near the Trail Lake ranch, about 5 miles south of the Fish ranch. Love (1939, p. 18) reported the Lander sandstone member to be present in several places in areas to the east, with thicknesses averaging about 7 feet.

The Bighorn dolomite forms massive cliffs throughout most of its area of outcrop (fig. 61). It is 254 feet thick in Warm Spring Canyon and 296 feet on top of Spring Mountain in the N½ sec. 33, T. 43 N., R. 106 W. The lower massive member ranges from 170 to 250 feet in thickness; it is composed of buff very resistent massive granular dolomite which weathers with a characteristic rough-pitted surface. The lower part of the member is quite limy and commonly more gray in color, but it still retains it granular texture. The Leigh dolomite member at the top, 47 to 84 feet thick, consists of gray to pink platy dense porcelaneous dolomite, the lower part of which weathers chalky white and constitutes a conspicuous unit that generally forms reentrants along the cliff faces. The upper part of the member is similar to the massive dolomite in the lower part of the formation. The variation in thickness of both members is most probably due to the unconformities at the top and bottom of the formation.

Section of Bighorn dolomite measured on north wall of Warm Spring Canyon in sec. 1, T. 41 N., R. 108 W.

	Feet
Darby formation.	
Bighorn dolomite:	
Leigh dolomite member:	
Dolomite, light-buff and pink, granular to crystalline, thin-bedded; upper part earthy and contains layers of calcite crystals as much as 1 in. thick and cavities as much as 1 ft in diameter filled with calcite crystals; upper part brecciated	38
Dolomite, gray and pink, massive, crystalline, dense	9
Dolomite, white and light-gray, pinkish at top, weathers chalky white, dense, porcelainlike, thin-bedded; contains brachiopods and molds of small gastropods	34
Dolomite, mottled pink and white; contains cavities filled with calcite crystals	3
	84
Lower part of Bighorn dolomite:	
Dolomite, buff, massive, granular, sugary, fetid in part; contains geodes as much as 1 in. across filled with calcite crystals; weathers with characteristic rough-pitted surface	101
Limestone, or dolomite, buff, granular; in beds 1 to 4 ft thick, blocky, sugary texture in part; some surfaces contain characteristic pitted weathering; crinoid stems 15 ft below top	69
	170
Total thickness Bighorn dolomite	254
Gallatin limestone.	

The problems involved in the age and correlation of the Bighorn dolomite, which have long been controversial, have been summarized by Thomas (1952, p. 35; 1948, p. 83) and Love (1939, p. 20). Until 1930 the lower part of the formation was thought to be Middle Ordovician (Trenton) in age and the upper part to be late Late Ordovician (Richmond) in age. A. K. Miller (1930, 1932) found in the Lander sandstone member near Lander, Wyo., a large fauna, chiefly cephalopods, which consisted of both Mohawkian and Richmond species. He (Miller, 1932, p. 203, 209) concluded that the appearance of Richmond fossils was sufficient to fix the age of the lower part of the formation as very Late Ordovician. More recent investigations of North American Ordovician cephalopods by Flower (1946, 1952) have shown that Bighorn-type forms occur in New York and Ontario in beds of definite late Trenton age. Thomas (1952, p. 35) summarizes: "The Bighorn may be correlated with certainty with strata of similar age through wide areas in northern North America, but the determination of the age of these units in terms of standard Ordovician time remains a problem."

A few horn corals were the only fossils observed in the massive dolomite member within the mapped area, but the Leigh dolomite member contains crinoid stems, small brachiopods, gastropods, and ostracodes. A collection obtained from the Leigh dolomite member along the Wiggins Fork River in SE¼ sec. 3, T. 43 N., R. 106 W., contained an abundance of crinoid stems and small poorly preserved brachiopods tentatively identified as *Catazyga?* sp. Josiah Bridge stated (memorandum to W. R. Keefer, June 12, 1953) that species of *Catazyga* are common in both uppermost Ordovician and lowermost Silurian horizons, but that no exact stratigraphic determination could be made because specific identification was impossible. He further stated, however, that the material is similar lithologically to collections made by R. K. Hose in the Bighorn Mountains, which are Late Ordovician in age. Thus it seems that at least the upper part of the Bighorn dolomite is Late Ordovician in age.

There is an erosional unconformity, marked by earthy beds with layers and cavities filled with calcite crystals, at the top of the Bighorn dolomite. In Warm Spring Canyon the contact appears to have as much as 20 feet of relief locally and at one place in the canyon wall a large mass of breccia was observed at the upper contact which is thought to be a sinkhole deposit that was developed in the Bighorn beds before the deposition of the Darby formation. The contact is also marked by a conspicuous topographic break.

DEVONIAN SYSTEM

DARBY FORMATION

The Darby formation was named by Blackwelder (1918) from exposures on the west slope of the Teton Range and includes all the strata of Devonian age in that area. The formation has been traced eastward into the Gros Ventre and Wind River Ranges and Owl Creek Mountains. At most places in the mapped area the Darby formation is poorly exposed, commonly forming topographic saddles or benches between the resistant beds of the overlying Madison limestone and the underlying Bighorn dolomite. However, along the north side of Warm Spring Canyon it is well exposed and constitutes a very distinctive unit. Most of the formation is also well exposed in a large excavation just south of the Horse Creek road in the SW¼ sec. 19, T. 43 N., R. 106 W., where material was removed for surfacing roads in the vicinity. Other exposures were observed in the core of the Du Noir anticline along the East Fork of the Du Noir River and at the eastern end of Spring Mountain in Wiggins Fork Canyon.

The formation is 193 feet thick in Warm Spring Canyon and 209 feet thick on Spring Mountain. It consists mainly of buff, gray, and brown dolomites and greenish-gray and red siltstone and shale. The most characteristic beds of the sequence are the dark-brown hard fetid dolomites which are readily distinguished from the Bighorn dolomite and the Madison limestone, although some of the lower limestones of the Madison limestone are superficially similar. On Spring Mountain it contains some thin beds of red, tan, and gray fine-grained soft porous thin-bedded sandstone. Near the top of the formation in Warm Spring Canyon is a white to pink granular limestone bed containing an abundance of limy oolites and large frosted sand grains. Also at this locality, about 35 feet above the base, are lenses of coarse-grained sandstone and granule conglomerate containing fragments of limestone in a limy matrix; these appear to be of local extent only and probably indicate local disconformities within the formation. The base of the Darby formation is very irregular, because of the erosional unconformity on the top of the Bighorn dolomite.

Section of Darby formation measured on north wall of Warm Spring Canyon in sec. 1, T. 41 N., R. 108 W.

	Feet
Madison limestone.	
Darby formation:	
Poorly exposed; underlain mostly by interbedded shale, siltstone, and limestone; varicolored white, pink, brown, gray, greenish gray, and red	59
Limestone and dolomite interbedded, white and pink; geodes at base	10
Siltstone, mottled red and green, shaly, sandy in part, slightly dolomitic	5
Limestone, mottled pink and white, thin-bedded and slabby; extremely granular and appears oolitic in part with fine grains of calcite and large frosted sand grains	4
Dolomite, dark-gray, brown, and pink, crystalline, massive to thin-bedded, hard, fetid; minor amount of green and red siltstone	18
Siltstone, red and greenish-gray, shaly	1
Dolomite, brown, granular to crystalline, massive to thin-bedded, fetid	24
Siltstone, greenish-gray and red, thin-bedded; minor amount of red shale and hard brown dolomite; poorly exposed	31
Dolomite or limestone, buff, gray, and brown, granular to crystalline, platy, hard; rings when struck	2
Dolomite, light-gray, dense, hackly and splintery; locally contains lenses of coarse sandstone and granule conglomerate with fragments of calcite in a limy matrix	4
Dolomite, light-gray and brown, finely granular, thin-bedded, hard, ledgy; upper 3 ft fetid and contains geodes as much as 4 in. across filled with calcite crystals	15
Dolomite, dark-gray to dark-brown, crystalline, massive to thick-bedded, fetid	12
Dolomite, buff and green, shaly in part, soft, sandy	2
Dolomite, brown, thin-bedded; base very irregular	6
	193
Bighorn dolomite.	

No fossils were found in the Darby formation of the mapped area and few have been found in adjacent regions. Recent studies of Devonian rocks near the north end of the Bighorn Mountains, north-central Wyoming, have been made by Blackstone and McGrew (1954). There the sequence is characterized by a basal conglomeratic channel deposit containing Lower Devonian fossils and an upper 250-foot unit of dolomite, limestone, and siltstone with frosted sand grains containing fossils of Middle to Late Devonian age. Blackstone and McGrew (1954) correlated the lower channel deposit with the Beartooth Butte formation (Dorf, 1934) and the upper part with the Jefferson limestone and Three Forks shale of northwestern Wyoming. Correlation of the Darby formation at the northwest end of the Wind River Range with the Devonian sequence at the north end of the Bighorn Mountains is uncertain; the Darby formation may be equivalent to only the upper part of the Devonian section in the latter region. In western Wyoming the formation is considered to be Late Devonian in age and is correlated with the upper part of the Jefferson limestone of Idaho (Cooper and others, 1942).

The contact between the Darby formation and the overlying Madison limestone is marked by a sharp topographic break and by a change from red shale and siltstone and brown dolomite below to predominantly gray crystalline limestone above. No evidence of an unconformity between the two formations was seen in the mapped area, but Love (1939, p. 22) noticed a sharp erosional unconformity in Wiggins Fork Canyon. Blackwelder (1918) reported at least local erosional unconformities at the type section in the Teton Range to the west.

CARBONIFEROUS SYSTEMS

MISSISSIPPIAN SYSTEM

MADISON LIMESTONE

The Madison limestone forms extensive outcrops along the northeast flank of the Wind River Range, on Spring Mountain, and on the high ridge north of the Horse Creek Ranger Station. It also forms the bulk of rocks exposed in the Du Noir anticline in the northwestern part of the area. The formation is 740 feet thick on the west end of Spring Mountain near the Livingston ranch, but the thickness is probably variable because of a pronounced unconformity at the top. There is a regional thickening westward, however, and in the Gros Ventre Range the limestones of Mississippian age total 930 feet in thickness (Love, Keefer, Duncan, and others, 1951).

No detailed section of the Madison limestone was measured, but the lithologic character is quite uniform throughout. It consists mainly of resistant bluish-gray to gray massive to thin-bedded crystalline limestone. The limestone is commonly mottled tan because of inclusions of tan granular material similar to those in both the Gallatin limestone and the Death Canyon member of the Gros Ventre formation. At most localities the basal part of the formation contains thin beds of buff granular dolomitic limestone similar to some of the strata in the upper part of the Darby formation. The lower beds also contain masses of breccia consisting of angular limestone fragments in a red earthy matrix. Weathering and erosion of these cause conspicuous red staining on many outcrops. Massive to bedded chert layers as much as 15 feet thick are present at several localities on the northeast flank of the Wind River Range. Caverns are commonly developed in the limestone, especially in the more granular beds. In some places near or at the top of the Madison limestone, a zone, estimated to be 100 feet thick, of red shale and thin-bedded tan to yellowish dolomite and limestone, resembles beds in the upper part of the Amsden formation. About 2 miles north of the Horse Creek Ranger Station this zone is overlain by about 20 feet of limestone similar to the Madison. The sequence was not observed along the northeast flank of the Wind River Range, but it is thought to be present in places in the northwestern part of the Du Noir area.

The Madison limestone, named by Peale (1893, p. 32) from the Madison Range in north-central Montana, is considered to be of early Mississippian age (Weller and others, 1948). Evidence indicates, however, that the formation, as it is defined in this report, also includes strata of later Mississippian age which probably are equivalent to some parts of the middle and upper Mississippian Brazer limestone of northeastern Utah, southeastern Idaho, and western Wyoming (Williams and Yolton, 1945). A late Mississippian fauna from the upper part of the Madison limestone along Bull Lake Creek, about 40 miles southeast of the Du Noir area, was described by Branson and Greger (1918) and, because of both faunal and lithologic distinction, these strata were subsequently named the Sacajawea formation (Branson, 1937). Love (1939) also reported late Mississippian fossils from this sequence.

The following collection, identified by J. E. Smedley, was obtained about 100 feet below the top of the Madison limestone at the Spring Mountain locality: *Spirifer striatus* var. *madisonensis* (of Girty, 1899), *Spirifer* sp. undet., aff. *S. missouriensis* Swallow, *Spirifer* cf. *S. increbescens* Hall, *Spirifer* sp., *Composita* sp. undet. Smedley concludes (1954, written communication) that the absence of *Spirifer centronatus* Winchell, particularly from a fauna composed largely of Spirifers, is rather unusual and that it may represent a facies of the Madison that is a little younger than the typical Madison limestone. The collection also contained crinoid columnals, fenestellid bryozoans, and corals. Although the specimens were too fragmentary and poorly preserved for specific determination, Helen Duncan (1954, written communcation) concludes that the coral faunule is not one that would be considered typical Madison, at least not typical of the lower part of the formation where the characteristic Madison fauna is best developed.

Thus it seems likely that Mississippian strata younger than true Madison are present in this region, but not enough lithologic and faunal data are available to warrant separation of the sequence into two formations in the Du Noir area. The term Sacajawea formation (Branson, 1937) has not gained wide acceptance.

One of the most pronounced erosional unconformities in the Paleozoic sequence of this region occurs between the Madison limestone and the overlying Darwin sandstone member of the Amsden formation. The Darwin sandstone member was apparently deposited on a karst topography developed on the top of the Madison limestone that may have as much as 135 feet of relief (fig. 62) in a distance of 3 miles. Many dip slopes formed on the top of the limestone had cracks and joints filled with red sandstone in areas where the main mass of the Darwin sandstone member has been stripped away by erosion.

PENNSYLVANIAN SYSTEM

AMSDEN FORMATION

The Amsden formation was named and described by Darton (1904, p. 396–397) from exposures in the Bighorn Mountains and included the strata lying between the Madison limestone and the massive crossbedded Tensleep sandstone. In the Du Noir area two distinct lithologic units, the Darwin sandstone member at the base and an upper predominantly shale and dolomite sequence, are readily recognized. Except for the Darwin sandstone member, which forms cliffs in most places, the formation is generally poorly exposed because of the weak nature of most of the strata and of the talus cover from the overlying Tensleep sandstone cliffs. The upper part of the formation characteristically produces red and yellowish soils which are generally sufficient for recognition of the sequence.

The formation is 291 feet thick near the Livingston ranch in the SW¼ sec. 29, T. 43 N., R. 106 W., and 309 feet thick along Esmond Creek near its junction with the West Fork of the Du Noir River in the NE¼ sec. 5, T. 43 N., R. 108 W. At these two localities the exposures are poor and detailed descriptions could not be obtained. A detailed section was measured on the north side of Little Warm Spring Creek, which lies outside the mapped area about 2 miles southwest of Dubois in the NE¼ sec. 15, T. 41 N., R. 107 W. Here the formation is 356 feet thick.

Section of Amsden formation measured on the north side of Little Warm Spring Creek in secs. 14 and 15, T. 41 N., R. 107 W., about 2 miles southwest of Dubois.

Tensleep sandstone.

Amsden formation:	Feet
Dolomite, gray to pink, fine-grained; 6 in. of gray chert at top	2
Shale, grayish-green; some thin partings of dolomite	2
Sandstone, buff, brown, and gray, hard, quartzitic	2
Dolomite, brown, granular	2
Shale, green	1
Sandstone, buff, fine-grained, thick-bedded, hard, limy; sporadic black chert grains	5
Dolomite, brown to tan, thin-bedded; some dark chert layers and nodules; upper 1 ft mostly quartz which appears to have replaced the dolomite	4
Shale, gray-green, fissile	2
Dolomite, brown and gray, platy to blocky	4
Sandstone, gray to white, very fine grained, limy; very hard and quartzitic in part	4
Dolomite, brown, blocky	1
Shale, green	1
Sandstone, gray to white, very fine grained, limy, friable to quartzitic, slight disconformity at base	2
Dolomite, brown to gray, thin-bedded to massive, dense	4
Sandstone, gray and brown, hard, quartzitic; thin beds of green shale at top and 2 ft below top	4
Shale, gray, fissile	1
Breccia; mostly limy sandstone with green shale pellets in lower 6 in.; angular fragments of sandstone and cherty limestone as much as 2 in. across in upper part	3
Limestone, gray and buff, hard, crystalline; many calcite veinlets	3
Shale, pale-green and maroon, fissile	2
Sandstone, white and light-red, very fine grained, thin-bedded; geodes as much as 1 ft in diameter filled with calcite crystals present near the top; local disconformity 3 ft above the base overlain by 1 ft of red sandstone that contains crossbedded laminae of white coarse sand grains	7
Dolomite, pink to red, fine-grained, irregularly bedded; thin bed of green fissile shale at top	2
Shale, red, blocky to fissile	1
Dolomite, white, granular, hard	2
Shale, purple, some tan laminae, fissile; some thin beds of purple dolomite	11
Dolomite, purplish-red and green, thin-bedded, sandy in part	4
Dolomite, variegated red, brown, reddish-brown, gray, and greenish-gray, in beds as much as 3 ft thick, cherty near base; crinoid columnals 3 ft below top	7
Siltstone, gray to green	1
Shale, tan, red, and green, fissile in part; silty in part	1
Dolomite, brown, reddish-brown, and buff, sublithographic, massive to thin-bedded and shaly, cherty in lower 3 ft; some beds ring when struck	7
Poorly exposed; underlain mostly by greenish-gray fissile shale	3
Dolomite, gray to reddish, massive to thin-bedded, dense, hard, slightly limonitic; some thin beds of green shale in middle	18
Poorly exposed; sporadic outcrops of hard dolomite, yellow silty shale, and green fissile shale	20
Dolomite, light-brown, buff, and pink, thin-bedded to shaly	2
Shale, green and grayish-green, fissile; minor amount of dolomite	1
Sandstone, white, very fine grained, irregularly bedded, moderately soft and porous	2
Dolomite, buff to brown, massive to irregularly bedded, dense, hard; masses of black chert as much as 1 ft in diameter occur locally at the base; thin bed of white clean sandstone 4 ft above base	9
Dolomite, buff and pink, dense, massive, hard; contains vugs as much as 1½ in. across filled with calcite crystals; some calcite veinlets	5
Covered. Lateral exposures indicate that unit is mostly underlain by soft red shale	34
Darwin sandstone member: Sandstone, red in basal 10 ft, white and reddish in remainder; weathers gray for the most part, fine- to medium-grained, massively to thinly crossbedded, moderately porous and friable, soft to hard, limy, limonitic in part; some green grains; some pink grains that may be feldspar; grains mostly rounded; forms conspicuous cliff; base very irregular and disconformable on Madison limestone	170
	356

Madison limstone.

The Darwin sandstone member at the base of the formation was named by Blackwelder (1918) from exposures on Darwin Peak in the Gros Ventre Range, about 25 miles southwest of the mapped area. The average thickness throughout west-central Wyoming is about 75 feet. Throughout a large part of the Du Noir area the unit forms one of the most prominent sandstones in the Paleozoic sequence. The sandstone is red, gray, and white, fine to medium grained, commonly crossbedded to massive, and moderately porous and friable. Most of the grains are rounded and consist of quartz with a minor amount of pink and green grains, some of which are feldspars. In gross aspect the Darwin sandstone member is strikingly similar to the overlying Tensleep sandstone. It varies considerably in thickness, from 29 feet on the east end of Spring Mountain, N½ sec. 12, T. 42 N., R. 106 W., to 170 feet at the Little Warm Spring Creek locality (fig. 62). Within the mapped area this thickness variation has no uniform trend (fig. 62), except for a slight regional thinning toward the southeastern part of the Wind River Range. The very irregular erosion surface that was developed on top of the Madison limestone before the deposition of the Darwin sandstone member is thought to account for the extremely localized character of this variation.

The upper part of the Amsden formation is a variable sequence of dolomite, shale, quartzitic sandstone, and limestone, ranging in thickness from 186 to about 300 feet. Most common colors are red, green, and buff.

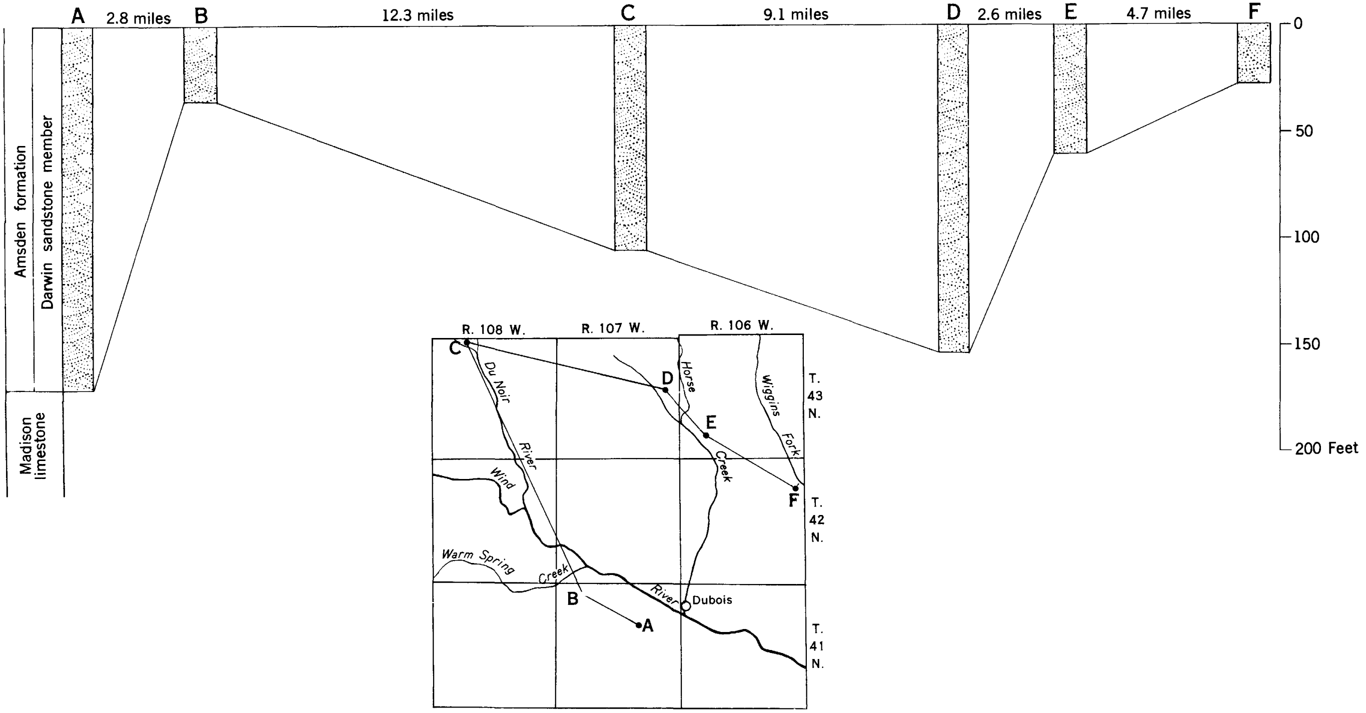


FIGURE 62.—Diagram showing thickness variation of Darwin sandstone member of the Amsden formation.

Overlying the Darwin sandstone member in most places is a sequence of poorly exposed red shale, averaging about 40 feet in thickness, which forms a conspicuous red zone along the weathered slopes. Hematite-nodule beds are commonly present in the red shale. Thin sandstone beds occur mostly in the upper part of the formation and are typically fine grained, hard, and quartzitic. The dolomite and limestone are massive to thin bedded and generally cherty. Shale is soft and fissile to blocky. Local inconspicuous disconformities occur within the sequence. The formation is only sparsely fossiliferous; crinoid stems and small brachiopods, *Composita* sp., were the only fossils observed.

For many years the age of the lower part of the Amsden formation and the position of the Mississippian-Pennsylvanian boundary have been the subjects of discussion in this and adjacent areas. Branson and Greger (1918) described a Ste. Genevieve fauna from red ferruginous shale and purple limestone about 60 feet above the base of what they believed was the Amsden formation near Lander, Wyo. Because the section was poorly exposed near Lander they cited the Bull Lake section (Sacajawea formation, Branson, 1937) of gray limestone containing a Ste. Genevieve fauna, as a lateral equivalent. This sequence is overlain by the Darwin sandstone member at the Bull Lake locality, but at the Lander locality the Darwin is very poorly developed or entirely absent and cannot be recognized with certainty. Morey (1935, p. 474) studied the ostracodes from the same beds of the Lander section in which Branson and Greger (1918) collected their fauna and confirmed the Ste. Genevieve age. From more recent studies (Shaw and Bell, 1955) it is now apparent that two faunal sequences, one of Mississippian age and one of Pennsylvanian age, occur in red strata overlying typical Madison limestone in the Lander area. The older fauna is like that of the Sacajawea formation at Bull Lake. C. C. Branson (1937, p. 651–652) assigned a few feet of limestone lying above the Sacajawea formation and below the Darwin sandstone member to the lower Amsden formation (fig. 63) of possible Chester age. The whole of the Amsden formation as it is defined in this report he then referred to as the Upper Amsden formation. In subsequent papers C. C. Branson (1939, p. 1209–1211) and Branson and Branson (1941, p. 132) abandoned the name Amsden formation and included both the Amsden formation and Tensleep sandstone, as defined in the present report, in the Tensleep formation (fig. 63).

In the northwestern part of the Wind River Basin the Amsden formation is now generally restricted to those strata which lie between the base of the Darwin sandstone member and the base of the overlying Tensleep sandstone. No fossils have been reported from the Darwin sandstone member, but several localities have yielded faunas from beds lying above the Darwin. Burk (1954) concludes, after studying many of these faunas from the region, that the Amsden formation, as thus defined, should be referred to the Pennsylvanian. Scott (1948, p. 38) also places the entire formation in the Pennsylvanian on both faunal and physical evidence. Inasmuch as the most pronounced erosional unconformity within the Carboniferous sequence in the Du Noir area lies at the base of the Darwin sandstone, it seems most likely that the Mississippian-Pennsylvanian boundary falls at this horizon.

The boundary between the Darwin sandstone member and the upper part of the Amsden formation is rarely well exposed, and no evidence of a physical break was observed where the contact was mapped. At some localities shaly beds have been reported in the upper part of the Darwin, suggesting that the boundary is gradational. The contact between the Amsden formation and the overlying Tensleep sandstone is also ill defined and is gradational in adjacent areas (Love, Keefer, Duncan, and others, 1951; Scott, 1948). The gradational nature of this boundary, as well as the one at the top of the Darwin sandstone, probably accounts for the conspicuous thickness variation of the upper part of the Amsden formation. Within the mapped area the upper boundary of the Amsden formation is generally obscured by talus, but it is well exposed on Little Warm Spring Creek and shows a conspicuous change from thin-bedded dolomite, shale, and sandstone below to massive sandstone above. No physical break in sedimentation is in evidence. The boundary is also marked by a conspicuous topographic change from weathered slopes below to nearly vertical cliffs above.

TENSLEEP SANDSTONE

The Tensleep sandstone was defined by Darton (1904, p. 397) as the thick sandstone overlying the Amsden formation in the Bighorn Mountains. It is well exposed at many localities in the mapped area and forms massive cliffs throughout most of its area of outcrop. The formation is 213 feet thick at the Little Warm Spring Creek locality, but it thickens to 245 feet near the Livingston ranch on the west end of Spring Mountain. It consists of buff, cream-colored, and white, fine-grained moderately friable and porous crossbedded sandstone. Some beds are hard and slightly quartzitic. Thin irregular beds of chert are present. Many of the outcrops weather brown and rusty brown and, viewed from a distance, some cliffs appear to be nearly black. Coarse talus generally accumulates at the base of the cliffs and obscures the lower part of the formation as well as much of the underlying Amsden formation.

The Tensleep sandstone is generally unfossiliferous. However, a few fossil fragments, chiefly brachiopods, were found in the lower 1 foot of the formation on Little

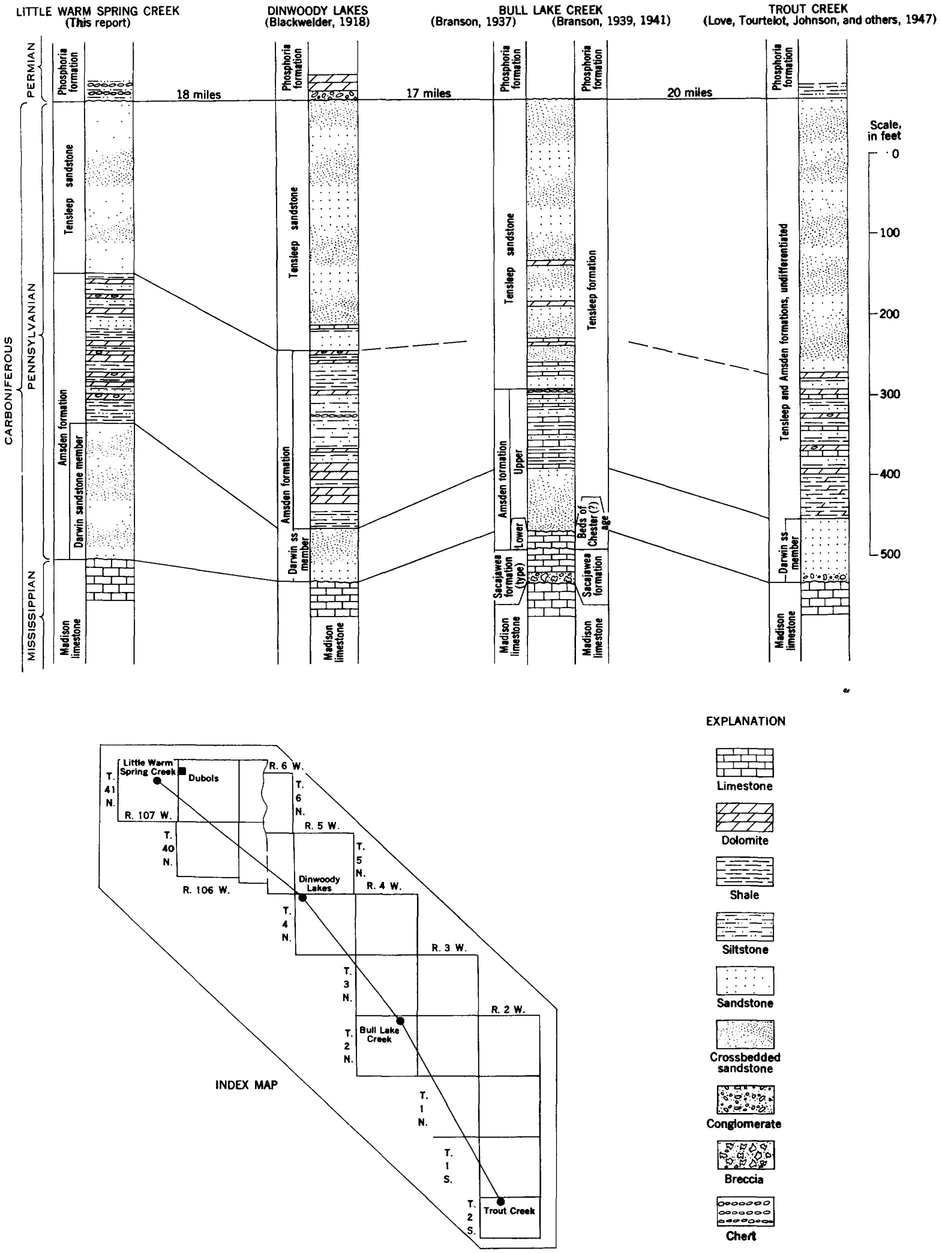


FIGURE 63.—Correlation of Carboniferous strata from Dubois southeast along flank of Wind River Range, Wyo.

Warm Spring Creek. Fusulinids have been found in the formation in other areas and indicate a Pennsylvanian age (Thomas, 1948, p. 88).

The boundary between the Tensleep sandstone and the overlying Phosphoria formation is marked by only a slight erosional unconformity, although regionally this break is quite pronounced. Blackwelder (1911, written communication) reported as much as 37 feet of the Tensleep sandstone locally cut out by pre-Phosphoria erosion in the vicinity of Dinwoody Lakes, approximately 12 miles southeast of the Du Noir area. Within the mapped area the basal beds of the Phosphoria formation are conglomeratic and are overlain by a distinctive series of interbedded chert, limestone, and siltstone which contrast sharply with the massive to coarsely bedded Tensleep sandstone. The contact is best exposed in the cliff at Stony Point.

PERMIAN SYSTEM

PHOSPHORIA FORMATION

Originally the term Embar formation, proposed by Darton (1906, p. 35) for exposures on the north flank of the Owl Creek Mountains, was used to include all strata occurring between the Tensleep sandstone and the Chugwater formation. In 1912 Richards and Mansfield (1912, p. 683–689) applied the name Phosphoria formation to include the lower part of these strata in southeastern Idaho and the name has since been used for the lower part of the Embar formation in central and western Wyoming. Blackwelder (1918) proposed the term Dinwoody formation for the upper part of the Embar formation in Dinwoody Canyon approximately 12 miles southeast of the mapped area. These names are now in general usage in this region. The Phosphoria formation produces oil and gas in many areas in Wyoming and constitutes the producing horizon in the Sinclair-Wyoming Oil Co. Dubois Unit Well 1 on the Dubois anticline.

The Phosphoria formation crops out along the Wind River Range, around the Du Noir anticline, on the west end of Spring Mountain, and along the east side of Burroughs Creek. The best exposures are found along Burroughs Creek about a mile north of the Horse Creek Ranger Station. At this locality the strata on the west side of a thrust fault are overturned and dip eastward into the hill at an angle of about 40°. The formation here is 261 feet thick.

The Phosphoria formation consists chiefly of interbedded dolomite, chert, limestone, siltstone, and sandstone with a few thin beds of phosphate rock. A minor amount of shale is present. The color is predominantly tan, gray, and buff. The more phosphatic beds are dark gray to brown and black. The basal bed, about 5 to 15 feet thick, is commonly conglomeratic with angular fragments as much as one-half inch in diameter of white and gray siltstone, sandstone, and crystalline quartz, and black rounded chert pebbles and granules. At Stony Point the basal beds contain some pebbles as large as 2 inches in diameter. The matrix of the conglomerate varies from a dense pink and gray sandy limestone to a tan and pink coarse-grained sandstone with an abundance of dark grains. The conglomerate is distinctive and thus forms a valuable criterion for determining the base of the formation. Chert occurs in thin beds and as tubular twisted masses in thick-bedded limestone and dolomite; these latter beds form very predominant units and are the most characteristic lithologic feature of the formation. A bed of black oolitic phosphate rock, 1.2 feet thick, is present about 160 feet above the base; and other beds from 160 to 200 feet above the base are phosphatic to some extent Many fossils are also phosphatic.

Section of the Phosphoria formation measured on the east side of Burroughs Creek, SW¼ sec. 13, T. 43 N., R. 107 W. (unsurveyed)

Dinwoody formation.	
Phosphoria formation:	*Feet*
Dolomite, tan, massive; contains geodes as much as 3 in. across filled with calcite crystals; forms ledge	4
Sandstone, gray to tan, very fine grained, limy; geodes	4
Dolomite or limestone, tan, granular, massive to thin-bedded, cherty in part; geodes	9
Limestone, gray and tan, massive to thin-bedded, cherty, silty; geodes in part; abundant bryozoans and brachiopods	22
Shale, gray, soft	1
Limestone, gray, tan, and black, platy, fossiliferous	3
Limestone and chert interbedded, dark-gray to black, phosphatic(?)	10
Limestone, dark-grayish-brown, irregularly bedded, highly fossiliferous	4
Limestone and chert, dark-gray, brown, and black, massive; phosphatic(?) in part; chert occurs as tubular twisted masses	8
Siltstone, dark-brown and black, massive, limy	4
Limestone and chert, dark-gray and brown; contains characteristic tubular twisted masses	6
Dolomite and chert, dark-gray, irregularly bedded	20
Phosphate rock, black, oolitic, slightly limy	1
Sandstone, tan to brown, very fine grained; abundant large brachiopods	5
Siltstone, gray and buff, massive to thin-bedded, limy, highly fossiliferous	23
Limestone, dark-gray to black, hard, dense, fossiliferous	2
Limestone and siltstone interbedded, tan, thin-bedded	6
Limestone, tan, thin-bedded, crystalline, hard, cherty; fossiliferous	8
Dolomite, white to cream-colored, thin-bedded, cherty in part	10
Chert, white and pink	1
Siltstone, tan, shaly at base, cherty at top	9

Phosphoria formation—Continued	Feet
Dolomite, tan and pink, cherty	2
Siltstone, tan, shaly, highly limy	11
Siltstone, tan and pink, massive to thin-bedded, sandy, limy, cherty; geodes in part; fossiliferous	6
Sandstone, pink, very fine grained, massive, soft, porous, friable	2
Chert, white, dark-gray, and black	1
Siltstone, pink, slightly limy	1
Sandstone, white, uniformly very fine grained, massive; nearly a pure quartz sandstone	16
Chert, gray, irregularly bedded	2
Siltstone, limestone, and chert interbedded, pink and gray, brecciated in part	3
Siltstone, pink, highly limy; some thin beds of chert	19
Chert, white and bluish-gray, irregularly bedded; some limy layers	9
Siltstone, pink and gray, cherty, porous	2
Chert, white and bluish-gray; some limy layers	3
Siltstone, pink to brown, sandy, slightly limy; contains some red grains	4
Limestone and siltstone interbedded, pink, tan, and gray, slabby, thin-bedded; basal beds contain limy pebbles and are quite conglomeratic	14
	261
Tensleep sandstone.	

The Phosphoria formation is abundantly fossiliferous with a predominance of brachiopods and bryozoans. Beds consisting almost entirely of large specimens of a single fossil species occur locally. Most notable are bellerophon gastropods and productid brachiopods, both of which are as much as 3 inches in width. *Orbiculoidea* fragments are common near the base. Shark teeth are also present at some localities. The fauna was not collected extensively or studied for this report, but in most respects it resembles the fauna collected from adjacent areas and to which a middle Permian age is generally assigned. The exact time span of the formation, however, has not been determined because the faunal assemblage is a provincial one and is not well represented in the classic Permian section of west Texas (Thomas, 1948, p. 90).

The contact between the Phosphoria formation and the overlying Dinwoody formation, which marks the boundary between the Paleozoic and Mesozoic eras, appears to be conformable throughout the mapped area. Regionally, however, the Dinwoody formation overlaps the Phosphoria formation progressively from west to east (Newell and Kummel, 1942, p. 945). Lithologically, the boundary is marked by a change from hard ledgy cherty limestone and dolomite below to thin-bedded gray siltstone and sandstone above.

TRIASSIC SYSTEM

DINWOODY FORMATION

The Dinwoody formation is rarely well exposed and crops out only along Horse Creek north of the EA ranch and at some places along Burroughs Creek. A section was measured in the SE¼ sec. 32, T. 43 N., R. 106 W., approximately 1½ miles north of the EA ranch by Love, Tourtelot, Johnson, and others (1947, p. 10). At this locality the formation is 154 feet thick and is characterized by yellowish, pink, tan, and brown thin-bedded very fine grained sandstone and siltstone. The beds are commonly dolomitic and limy, and some are shaly. An examination of cores and samples from the Stanolind Oil and Gas Co. Dubois Well 2 on the Dubois anticline shows the formation to contain much grayish-green shale with an abundance of cubic pyrite crystals. The sequence is easily weathered and consequently forms soil-covered slopes in most places.

Section of Dinwoody formation in sec. 32, T. 43 N., R. 106 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 10]

	Feet
Chugwater formation.	
Dinwoody formation:	
Sandstone, brown, very limy, thick to thin-bedded, ripple-marked; fine rounded grains; upper 20 ft is a slabby siltstone containing *Lingula*	66
Sandstone, brown, fine-grained, very limy, thin-bedded, slabby, hard to soft, containing *Lingula*	58
Covered interval. Probably all fine-grained sandstone	8
Sandstone, pink, fine-grained, slabby	15
Sandstone, pink, coarse-grained, very limy; subangular grains; numerous calcite vugs	5
Sandstone, yellowish, very fine grained, limy, slabby, brecciated	2
	154
Phosphoria formation.	

The Dinwoody formation contains an abundance of *Lingula* and poorly preserved pelecypods. Newell and Kummel (1942, p. 942–945) who made a regional stratigraphic and faunal study of the Lower Triassic rocks in western Wyoming and southeastern Idaho, recognized two faunal zones in the formation, a lower *Lingula* zone and an upper *Claraia* zone with molds of several kinds of pelecypods of which species of *Claraia* are the most distinctive. The formation is considered to be Early Triassic in age.

The contact between the Dinwoody formation and the overlying Chugwater formation is commonly marked by a change from grayish-green and tan dolomitic siltstone below to red nondolomitic siltstone and shale above. The contact, however, is gradational and at some localities it has been found that the color change is independent of the bedding. Love, Johnson, Nace, and others (1945), following a regional study of the two formations in the Wind River Basin, state that strata both above and below the contact are commonly superficially similar in appearance and lithologic character, but that the beds above are generally softer, less dolomitic, and more shaly.

CHUGWATER FORMATION

The Chugwater formation includes the thick and prominent series of redbeds which lies between the Dinwoody formation and the Nugget sandstone. It is one of the most easily recognized units of the sedimentary succession in this part of Wyoming because of its thickness and bright red color. The name, proposed by Darton (1904, p. 397) and applied by him to all the redbeds between the Tensleep sandstone and the Sundance formation from the Bighorn Mountains southward to Colorado, has undergone extensive redefinition. The original description of the Chugwater formation included strata that were later separated off as the Embar formation by Darton (1906, p. 35) in the Owl Creek and Bighorn Mountains and which in turn were further subdivided, as previously discussed, into the Phosphoria and Dinwoody formations. Love (1939, p. 42) included in the Chugwater formation all the strata lying between the Dinwoody formation and the Sundance formation, but he has since (Love, Johnson, Nace, and others, 1945) restricted its usage to those beds lying below the Nugget sandstone and above the Dinwoody formation.

Throughout most of the southern and western parts of the Wind River Basin the Chugwater formation, ranging in thickness from 1,000 to 1,250 feet, is divisible into three distinctive members (Love, Johnson, Nace, and others, 1945): the Red Peak, the Alcova limestone, and the Popo Agie members. These divisions can be distinguished and mapped as separate units only where the Alcova limestone member is present. This member does not occur in the northwestern part of the Wind River Basin, including the Du Noir area, but it has been recognized as far west as Lower Slide Lake on the Gros Ventre River (Love, Keefer, Duncan, and others, 1951). In the area of this report and adjacent areas to the east there is locally formed between the Popo Agie and Red Peak members, a 200- to 300-foot unit of sandstone that was named the Crow Mountan sandstone member by Love (1939, p. 44). Much interest has centered on the latter unit since the recent discovery of oil in it by the Skelly Oil Co. Tribal 1 well, SWSWSW sec. 36, T. 6 N., R. 3 W. (Wind River meridian), at Northwest Sheldon anticline, approximately 24 miles east of the Du Noir area.

Within the mapped area a section of the Chugwater formation was measured (Love, Tourtelot, Johnson, and others, 1947, p. 9–10) along the east side of Horse Creek about 1 mile north of the EA ranch. At this locality it is, for the most part, well exposed and aggregates a thickness of 1,293 feet. The lower 766 feet constitutes the Red Peak member, which is characterized by bright-red shaly siltstone and a very minor amount of sandstone. The overlying 300 feet, which is the Crow Mountain member, consists chiefly of buff and orange, shaly and silty in part, massive to slabby fine-grained sandstone. The upper 227 feet constitutes the Popo Agie member, which is a variable sequence of ocher-colored claystone, red, green, and purple shale and siltstone, and limestone pellet conglomerate. Many of the beds contain conspicuous amounts of pinhead-sized growths of white analcite. The presence of analcite (also called analcime) in the Popo Agie member has recently been recognized (Keller, 1952, p. 70–82) as a distinctive sedimentary feature of these strata, and it is thought to be a valuable aid in regional correlation. The lower part of the Popo Agie member is not well exposed along Horse Creek, but it forms conspicuous outcrops on the south side of the Wind River at Dubois and at many places along U. S. Highway 287 southeast of Dubois.

Section of Chugwater formation in secs. 32 and 33, T. 43 N., R. 106 W. and sec. 4, T. 42 N., R. 106 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 9–10]

	Feet
Nugget sandstone.	
Chugwater formation:	
Popo Agie member:	
Shale, red and green, soft, limy	1
Claystone, ocher, soft, silty, blocky	82
Covered interval	144
Crow Mountain sandstone member:	
Sandstone; buff in upper part; red and silty in lower part; numerous shaly beds near top	300
Red Peak member:	
Siltstone, red, soft to hard; numerous red shale partings	292
Sandstone, white, fine-grained, soft, clean; rounded grains; forms prominent white zone marker bed	6
Siltstone, red, hard to soft; numerous red shale partings; a few thin white siltstones in upper 70 ft	246
Siltstone, red, shaly; locally gray and red in lower 20 ft; increasingly silty near top; partly covered	222
	1,293
Dinwoody formation.	

The precise age and correlation of the various members of the Chugwater formation in central Wyoming with Triassic rocks in other areas are still in doubt. The Red Peak member, though devoid of fossils, overlies the Dinwoody formation of known Early Triassic age and is correlated by Newell and Kummel (1942, p. 949) with the Woodside formation of western Wyoming and southeastern Idaho which is overlain by the Lower Triassic thick marine Thaynes limestone in those regions. The Red Peak member probably also contains equivalents of at least a part of the Thaynes limestone. Present evidence thus indicates that the lower part of the Chugwater formation is Early Triassic in age. Both marine vertebrates and invertebrates are sparsely present in the Alcova limestone member, but there is no general agreement regarding the age of the fauna, which has variously been ascribed to the Early, Middle, and Late Triassic. Love, Johnson, Nace, and others (1945) state that the fauna has little present significance, but that it is more like known Early Triassic assemblages. They further conclude that, since there is no significant physical evidence at the base or at the top of the Alcova to indicate whether it is more closely associated with the beds above or below, it seems better to assign it arbitrarily to the Lower Triassic. Newell and Kummel (1942, p. 949) correlate both the Alcova limestone and the Crow Mountain member with the Thaynes limestone, thus considering those two units to be Early Triassic in age. Marine reptiles and a few pelecypods and plant remains have been collected from the Popo Agie member. The vertebrates have been assigned to the Middle Triassic by some investigators and to the Late Triassic by others. Colbert, who collected vertebrate fossils from the Popo Agie member southeast of Dubois in 1953, believes that the member is of Late Triassic age (written communication to J. F. Murphy, 1953).

The contact between the Chugwater formation and the overlying Nugget sandstone is marked by a sharp lithologic change from red and green shale and ocher-colored claystone below to gray and orange sandstone above. There is a regional unconformity between the two formations, but it is not readily apparent in localized exposures. In some parts of the mapped area the Nugget sandstone is absent and the Chugwater formation is overlain directly by the Gypsum Spring formation.

JURASSIC SYSTEM

NUGGET SANDSTONE

According to present definition in the western part of the Wind River Basin and adjacent regions the Nugget sandstone occupies the stratigraphic position between the Popo Agie member of the Chugwater formation and the Gypsum Spring formation. Its original definition in southwestern Wyoming (Veatch, 1907, p. 56) included all the strata lying between the Thaynes limestone (Lower Triassic) and the Twin Creek limestone (Middle and Upper Jurassic). In the type area near Nugget, Wyo., the formation included a lower red shale member and an upper sandstone member considered to be wholly or in part of Triassic age. The lower red shale unit, possibly the stratigraphic equivalent of the Popo Agie member, was designated the Ankareh shale and the Nugget sandstone was restricted to the upper sandstone unit by Boutwell (1912, p. 58) in the Park City mining district, Utah. The Nugget sandstone was used in this restricted sense by Mansfield (1927, p. 96) in southeastern Idaho.

The Nugget sandstone is present throughout the central and western parts of the Wind River Basin. At some localities in the southern part of the basin where the overlying Gypsum Spring formation is not present it is difficult to determine whether the basal sandstone of the Jurassic system is the Nugget sandstone or a sandstone in the basal part of the "lower Sundance." In adjacent areas to the east of the Du Noir area, where the Nugget sandstone is very poorly developed or entirely absent, its stratigraphic interval was included in the Chugwater formation by Love (1939, p. 43). The name Wyopo formation was applied by Branson and Branson (1941, p. 136) to the Nugget strata near Lander, Wyo., but that term has not been generally accepted.

Within the mapped area the Nugget sandstone ranges in thickness from a wedge edge to at least 120 feet, reaching its greatest development in exposures near Dubois (fig. 64). The formation has a marked north-

FIGURE 64.—Outcrop of Nugget sandstone (Jn) west of Dubois in E½ sec. 2, T. 41 N., R. 107 W. (T̄Rc, Chugwater formation).

ward thinning from Dubois, being 65 feet thick in the Sinclair-Wyoming Oil Co. Dubois well 1, only 31 feet (Love, Tourtelot, Johnson, and others, 1947, p. 9) along Horse Creek about 1 mile north of the EA ranch, and entirely absent about one-half mile northwest of the Horse Creek Ranger Station. The sandstone is gray, white, and orange, fine to medium grained, massively crossbedded to thin bedded and slabby. Large rounded frosted grains are common. A few green shaly beds are present. Where the unit is thick, it forms conspicuous cliffs above the red and ocher-colored slopes of the Chugwater formation.

Section of Nugget sandstone in sec. 4, T. 42 N., R. 106 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 9]

Gypsum Spring formation.

Nugget sandstone:	Feet
Sandstone, red, massive to thin-bedded, fine- to medium-grained	15
Sandstone, red, massive, fine- to medium-grained; rounded frosted grains; a few green shale fragments near top	5
Sandstone, white, fine-grained, rounded grains, thin-bedded, limy	11
	31

Chugwater formation.

The Nugget sandstone is unfossiliferous, and in the past it has been assigned to both the Triassic and Jurassic systems. It is now considered to be Early Jurassic in age (Imlay, 1950, table 1).

The contact between the Nugget sandstone and the overlying Gypsum Spring formation is marked by a sharp lithologic change from sandstone below to red shale and dolomitic limestone above. Evidence of an unconformity, other than the sharp lithologic change, was not observed in the mapped area. Present data, however, indicate that the northward thinning and disappearance of the Nugget sandstone is caused largely by a regional unconformity between the Nugget sandstone and the overlying Gypsum Spring formation. Love (1948, p. 101) states:

> Studies of electric log data from the northwestern part of the Wind River Basin indicate that successively older beds are cut out from south to north by the unconformity at the top of the Nugget sandstone and that the lowest bed forms the wedge edge along the northern margin of the basin.

Regionally the thinning of the Nugget sandstone is very gradual, but in areas immediately adjacent to the wedge edge the thinning is abnormally abrupt, as is demonstrated in the Du Noir locality and also in the area between the Gros Ventre River and Ditch Creek in Jackson Hole (Love, Keefer, Duncan, and others, 1951). The position of the wedge edge indicates gentle uplift of the region along the northern margin of the Wind River Basin and in the area extending westward from Togwotee Pass to Ditch Creek and erosion before the deposition of the Gypsum Spring formation.

GYPSUM SPRING FORMATION

The Gypsum Spring formation was named and described by Love (1939, p. 45) from exposures on Red Creek, about 15 miles east of the mapped area, and was originally designated the topmost member of the Chugwater formation. Following recognition of its Middle Jurassic age and more detailed stratigraphic studies the unit was later classed as a formation (Love, Tourtelot, Johnson, and others, 1945). In the Du Noir area the Gypsum Spring formation crops out in the vicinity of Dubois, along Horse Creek north of the EA ranch, and at one locality northwest of the Horse Creek Ranger Station.

A detailed section was measured in the NW¼NW¼ sec. 4, T. 42 N., R. 106 W., along the east side of Horse Creek where the formation is 109 feet thick (Love, Tourtelot, Johnson, and others, 1947, p. 9). In the Sinclair-Wyoming Oil Co. Dubois Unit well 1 it is 140 feet thick. The Gypsum Spring formation is a variable sequence of thin-bedded red shale and gray to gray-green dolomitic limestone and dolomite. The limestone and dolomite are commonly dense and very finely crystalline and form ledges in otherwise smooth soft shale slopes. The most prominent bed in surface outcrop is a 20-foot earthy limestone breccia near the base. In the Sinclair well on the Dubois anticline the formation contains anhydrite throughout but most abundantly near the base, and the thickness is correspondingly greater.

Section of Gypsum Spring formation in sec. 4, T. 42 N., R. 106 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 9]

"Lower Sundance."

Gypsum Spring formation:	Feet
Limestone, earthy; obscure fossil fragments	1
Shale, red	1
Limestone, green, silty, soft; poorly exposed	2
Limestone, green to tan, dolomitic, moderately fossiliferous	2
Shale, red, with thin green siltstone 2 ft above base	10
Dolomite, white to grayish-green, slabby, moderately pure	6
Shale, red, soft; silty in lower 2 ft	10
Limestone, bluish-gray, brecciated; locally dolomitic and slabby in upper part; probably a residual breccia from which gypsum has been leached	2
Shale, red, soft, with thin green shale at top	14
Interval covered. Apparently mostly red shale	34
Limestone breccia, dolomitic, with cavities filled with gypsum crystals. Apparently this is a residual breccia resulting from leaching out of the main gypsum bed in the Gypsum Spring formation. Thickness maps indicate that probably at least 100 ft of gypsum has been leached out of this section, most of it probably from this unit	19
Shale, red, fine-grained; dolomite nodules near top; a thin purple shale at top	8
	109+

Nugget sandstone.

At the type section on Red Creek the basal part of the Gypsum Spring formation contains a massive cliff-forming gypsum sequence, 127 feet thick, and a minor amount of red shale and limestone, but no limestone breccia. The occurrence of evaporites at the base of the formation is sporadic in surface outcrops, but regional studies in the western part of the Wind River Basin (Love, Tourtelot, Johnson, and others, 1945) indicate that the conspicuous anhydrite sequence is consistently present in the subsurface. Because of the subsurface persistence of the calcium sulfate beds, their general absence in surface outcrops is believed by the writer to be due mainly to near-surface leaching by water. No studies were made to determine the physical or chemical means by which the leaching may have occurred. In areas where the gypsum is not present in surface exposures its stratigraphic position is generally occupied by a resistant brecciated limestone sequence which is thought to be the residuum after the leaching of the gypsum. The total thickness of the formation at these outcrops is considerably reduced from the expected thickness in the area. Burma and Anderson (1939), from studies of the formation near Lander, Wyo., attempted to relate the amount of gypsum remaining to diastrophism and concluded that in areas of intense deformation the Gypsum Spring formation was likely to contain less gypsum because of the flowage of the gypsum into areas of relatively little deformation. Love, Tourtelot, Johnson, and others (1945), however, report that there is little evidence of flowage of gypsum even where it has been subjected to intense deformation.

A few fossil fragments are present in some of the limestone beds of the Gypsum Spring formation on Horse Creek. In some areas it is abundantly fossiliferous with a varied fauna of Middle Jurassic age. The formation has been traced westward into Jackson Hole (Love, Keefer, Duncan, and others, 1951) and is correlated with the redbed sequence in the lower part of the Twin Creek formation in western Wyoming and southeastern Idaho. It is not present in the southern part of the Wind River Basin.

At the type section of the Gypsum Spring formation the basal bed of the overlying "lower Sundance" is conglomeratic, with an abundance of limestone fragments and chert pebbles, and the contact is consequently easily recognized. The conglomeratic beds are not present in the Du Noir area, however, and the contact is more difficult to determine. Regionally the contact is described (Love, Tourtelot, Johnson, and others, 1945) as being between "very finely crystalline slabby limestone, earthy gray weathered-looking dolomites, red shales, or gypsums below and oolitic fossiliferous limestones with chert pebbles, or gray fossiliferous marls above." The contact in the Du Noir area generally falls in a variable sequence of thin-bedded limestone and shale; it is placed at the base of the lowest highly fossiliferous oolitic limestone in the sequence, below which the shales are generally red and the overlying shales are gray and gray green.

"LOWER SUNDANCE"

The Sundance formation was named and defined by Darton (1899, p. 383–386) from exposures near the town of Sundance in the Black Hills. Since that time the formation, which included the rocks between the Spearfish formation (Triassic redbeds) and the Morrison formation, has undergone extensive redefinition in that area. Imlay (1947) separated the sequence into the Nugget sandstone(?), Gypsum Spring formation, and Sundance formation, and differentiated five members within the Sundance formation. The name has been accepted widely throughout the State of Wyoming. In the northwestern part of the Wind River Basin it is applied to the sequence of rocks overlying the Gypsum Spring formation and underlying the Morrison and Cloverly formations, undifferentiated. In this region the Sundance strata are provincially divided into two sequences, "lower Sundance," and "upper Sundance" (Love, Tourtelot, Johnson, and others, 1945). Peterson (1954, p. 465 ff.) has proposed that the Sundance formation in the Powder River Basin be raised to group rank and that the two units of formational rank within the Sundance be called Rierdon and Swift formations.

A section of the "lower Sundance" was obtained in the NW¼NW¼ sec. 4, T. 42 N., R. 106 W., along the east side of Horse Creek north of the EA ranch (Love, Tourtelot, Johnson, and others, 1947, p. 9). The lower part is exposed also in the hill which rises abruptly on the north edge of Dubois and at a few places northwest of the Horse Creek Ranger Station, whereas the upper part is exposed on the west end of the Dubois anticlinal complex in the vicinity of the Sinclair-Wyoming Oil Co. Dubois Unit well 1. At the Horse Creek locality, where parts of the formation are poorly exposed, it is 305 feet thick. The lower part is characterized by an alternating succession of hard gray and bluish-gray oolitic limestone, and soft green and gray, locally red, shale and siltstone. The upper 250 feet is a gray-green soft fissile nonglauconitic shale sequence containing specimens of *Gryphaea nebrascensis* that weather out in abundance on the slopes. This prominent shale zone can be recognized over wide areas in west-central Wyoming. The limestone of the "lower Sundance" is coarsely crystalline in contrast to the finely crystalline carbonates of the Gypsum Spring formation.

Section of "lower Sundance" in sec. 4, T. 42 N., R. 106 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 9]

"Upper Sundance."	
"Lower Sundance":	*Feet*
Shale, gray-green, sandy in upper 10 ft; contains abundant *Gryphaea nebrascensis* and *Pentacrinus* sp	95
Covered interval	180
Limestone, bluish-gray, hard, very oolitic, fossiliferous	8
Shale, greenish to red, limy	1

"Lower Sundance"—Continued	*Feet*
Limestone, gray, hard, fine-grained	2
Siltstone, green to gray, limy at top	3
Limestone, bluish-gray, hard, oolitic, fossiliferous	2
Shale, green, laminated	2
Limestone, bluish-gray, very oolitic, very fossiliferous	2
Partly covered interval; probably limestone in lower 4 ft and green shale in upper 2 ft	6
Limestone, bluish-gray, oolitic, hard; highly fossiliferous, containing *Pentacrinus* sp. and bryozoans	4
	305

Gypsum Spring formation.

The "lower Sundance" contains abundant fossils of Late Jurassic age, and it is correlated with the upper part of the Twin Creek limestone and the Preuss sandstone of southeastern Idaho (Imlay, 1947, table 1). The contact between the "lower" and "upper" Sundance is placed at the base of the lowermost glauconitic bed in the sequence, commonly a coarse-grained conglomeratic limestone.

"UPPER SUNDANCE"

The "upper Sundance" is the glauconitic upper part of the Sundance strata in the Wind River Basin. In the mapped area it crops out on the Dubois anticline and in the vicinity of the EA ranch. A detailed section of the formation was measured and described on the west side of Little Horse Creek opposite the Sinclair-Wyoming Oil Co. Dubois Unit well 1, NE¼ sec. 11, T. 42 N., R. 107 W., where it is 130 feet thick (Love, Tourtelot, Johnson, and others, 1947, p. 8). The formation consists chiefly of green to gray-green fine- to coarse-grained slabby and thin-bedded highly glauconitic sandstone and greensand. The lower 30 feet contains some 3- to 5-foot beds of ledgy gray conglomeratic limestone with pebbles as much as one-half inch in diameter and abundant coarse sand grains. The limestones are in part highly fossiliferous and some may be classed as coquinas. The sandstone and greensand are moderately soft, porous, and friable, depending on the amount of calcareous cement present. The formation is ledgy and the soft sandstone weathers to slopes.

Section of "upper Sundance" in sec. 11, T. 42 N., R. 107 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 8]

Morrison formation.

"Upper Sundance":	*Feet*
Sandstone, grayish-green, limy, medium-grained, soft to hard, slabby, with some pink grains and a moderate amount of emerald-green glauconite in rounded grains	20
Sandstone, grayish-green, very limy, hard, coarse-grained, glauconitic. Upper 2 ft is a sandy limestone with sporadic small limestone pebbles	10
Sandstone or greensand, green, coarse-grained, highly glauconitic; abundant dark-greenish-gray shale in upper part	10
Sandstone, grayish-green, glauconitic, coarse-grained, slabby	2
Greensand, green, medium-grained; a thin sandy limestone 40 ft above base	57
Limestone, gray, hard, glauconitic, highly fossiliferous	4
Greensand, green, fine-grained, limy	5
Limestone, gray, very conglomeratic and fossiliferous. Pebbles as much as one-half inch across in upper part	3
Greensand, green; very glauconitic in upper half; shaly near base; partly covered	14
Limestone, gray, very conglomeratic; some pink and pale-green rounded grains; slightly oolitic near top	5
	130

"Lower Sundance".

The "upper Sundance" is of Late Jurassic age. The contact between it and the overlying Morrison and Cloverly sequence is marked by a change from glauconitic sediments below to nonglauconitic beds above. The overlying Morrison and Cloverly rocks have some commonly red strata in contrast to the gray-green colors below.

JURASSIC AND CRETACEOUS SYSTEMS

UPPER JURASSIC AND LOWER CRETACEOUS SERIES

MORRISON AND CLOVERLY FORMATIONS, UNDIFFERENTIATED

The Morrison formation was first named and defined by Eldridge (Emmons, Cross, and Eldridge, 1896, p. 60–62) from exposures near the town of Morrison, Colo. The name had already been used by Cross (1894, p. 2). The formation included a series of green, drab, or gray marls, sandstone, and limestone with abundant dinosaur remains and was overlain disconformably by the basal conglomeratic bed of the Dakota sandstone (Cretaceous) and underlain disconformably by a "brown and pink sandstone closing the Trias." The type section has been revised at various times, most recently by Waldschmidt and Leroy (1944) who divided the sequence into several units and included the brown and pink sandstone mentioned above as the basal sandstone of the Morrison. This sandstone may possibly contain some equivalents of the Sundance formation. The name Morrison has gained wide acceptance throughout a large part of Wyoming and the Rocky Mountains.

The Cloverly formation was first described by Darton (1904, p. 398–399) from Cloverly, a former post office on the east side of the Bighorn Basin, Wyo., to include a basal, locally conglomeratic sandstone and an upper shale sequence. Darton correlated the basal sandstone with the Lakota sandstone and the overlying shale with the Fuson shale of the Black Hills. Later Darton (1906, p. 50) referred to the Cloverly formation as being representative of the Dakota sandstone.

Regional studies of the Morrison and Cloverly formations have been made in the Wind River Basin (Love, Thompson, Johnson, and others, 1945) but no consistent basis for subdivision was found. Conglomeratic beds, some of which are probably equivalent to the basal beds of the Cloverly formation as it is defined in other regions, occur locally within the sequence. Where they are present at the base, the conglomerates provide a mappable contact in some areas in the basin, but in other areas, including the Du Noir area, where they are not present, the two formations are mapped together as a single unit. Throughout the basin, however, a quartz crystal sandstone zone occurs 100 to 200 feet above the top of the "upper Sundance" and may mark the base of the Cloverly formation. More data are needed, however, before the actual relationships of the Morrison and Cloverly sequences in this region are known.

In the Du Noir area the Morrison and Cloverly formations, undifferentiated, are underlain by the "upper Sundance" and overlain by the Thermopolis shale. A composite section of the sequence was measured on the Dubois anticline and in the vicinity of the EA ranch, the total thickness being 539 feet (Love, Tourtelot, Johnson, and others, 1947, p. 7–8). It can be divided into three slightly distinctive lithologic units. The lower 186 feet is characterized by variegated red, purple, gray, blue, and green claystone, shale, and siltstone, interbedded with gray to white silty fine- to coarse-grained lenticular sandstone that locally becomes yellowish buff because of the presence of ferruginous material. The conspicuous claystone beds commonly contain layers of hard limestone nodules. Highly polished pebbles as much as 2 inches in diameter, chiefly of chert, occur throughout and are thought by some geologists to be gastroliths. A few dinosaur bones were observed. The overlying 193 feet is also characterized chiefly by variegated claystone and gray to white sandstone, but the sandstone is sparkly and clean. The basal sandstone of this sequence is locally conglomeratic. The upper 60 feet of claystone in the middle unit is sometimes referred to as the "lilac zone" because of its distinctive color. Because of the predominance of soft plastic claystone in both the lower and middle units they are readily susceptible to landsliding and many local slumps have occurred in them, particularly on the Dubois anticline and in the vicinity of the EA ranch.

Composite section of Morrison and Cloverly formations, undifferentiated, in secs. 1 and 12, T. 42 N., R. 107 W., and sec. 4, T. 42 N., R. 106 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 7–8]

	Feet
Thermopolis shale.	
Morrison and Cloverly formations, undifferentiated:	
Rusty beds member of Cloverly formation:	
Sandstone, gray, weathering rusty brown, fine-grained, hard, thin-bedded, highly fucoidal; interbedded with thin black shale. At a point 35 ft above the base there are 6 ft of black laminated shale overlain by 6 in. of sandstone, then 6 ft of black laminated shale	57
Siltstone, black, hard, shaly from 5 to 8 ft above base; minor amounts of interbedded sandstones	20
Sandstone, gray, weathering rusty; thin-bedded in lower part; slightly shaly near top	10
Shale, brown to black; thin interbedded sandstone and siltstone	10
Sandstone, gray, weathering brown, fine-grained, hard, thick-bedded	5
Partly covered interval. Some exposures of sandstone, gray, weathering rusty, thin-bedded, fine-grained, highly fucoidal; interbedded with minor amounts of dark gray shale	30
Covered interval	28
Lower part of Morrison and Cloverly formations, undifferentiated:	
Claystone, variegated, gray, light red, with lilac zone in upper 60 ft. Partly covered	155
Sandstone, gray, medium-grained, sparkly, clean; numerous pink minerals	10
Claystone, variegated, gray, red, and purple; largely covered	20
Sandstone, gray, coarse-grained, sparkly, clean; numerous pink minerals. A quarter of a mile east along strike this unit contains chert pebble conglomerates	8
Claystone, red and purple, lavender in upper 3 ft	16
Sandstone, dark-gray, with prominent yellowish layers, soft, silty and clayey; contains numerous polished pebbles	6
Shale, dark-gray, laminated; a thin sandstone in middle	4
Sandstone, white, medium-grained, limy; sparse pink grains	1
Siltstone and sandstone, grayish-green to dark-gray, shaly, hard; contains dinosaur bones	13
Sandstone, gray, lenticular; contains variegated claystone lenses and dinosaur bones. Sandstone is soft in lower part, hard in upper part	24
Claystone, red, blocky; numerous sandstone lenses, more abundant near top	7
Sandstone, greenish-gray, lenticular, fine-grained, variegated claystone lenses	11
Claystone, variegated red, blue, green, and gray, silty; contains numerous thin hard sandstone lenses, layers of limestone nodules, and a few polished pebbles	92
Sandstone, greenish-gray; very lenticular; limy, medium- to coarse-grained	4
Claystone, red, sandy, hard	3
Siltstone, red, hard, with some claystone and sandstone near top	5
	539
"Upper Sundance."	

The upper 160 feet, commonly referred to as the rusty beds member of the Cloverly formation, offers sharp contrast to the underlying units and was consequently mapped as an individual unit. It is comprised of resistant gray, olive-drab, brown, and black fine-grained thin-bedded to platy sandstone and siltstone interbedded with a minor amount of black fissile shale. Bedding surfaces have abundant fucoidal markings. The basal bed is commonly a gray and white massive to slabby hard sandstone 5 to 10 feet in thickness which forms a conspicuous ledge. The name Rusty beds was originated by Washburne (1908, p. 350) to apply to the lowermost bed of the Colorado formation in the Bighorn Basin and refers to the distinctive rusty-brown weathering color of most of the outcrops. The relationship between the rusty beds (Washburne, 1908) in the Bighorn Basin to the rusty beds in the Wind River Basin is not adequately known.

The Morrison and Cloverly formations are continental in origin; the former is Late Jurassic and the latter Early Cretaceous in age. In central Wyoming the sequence locally contains abundant fresh-water mollusks, ostracodes, and charaphyte oogonia in addition to dinosaur remains. The Morrison formation has yielded dinosaurs of Late Jurassic age, most notably from Como Bluff in southeastern Wyoming. Fresh-water mollusks of Early Cretaceous age have been found in both the rusty beds and the variegated claystone zone directly beneath the rusty beds at some localities in the Wind River Basin (Love, Thompson, Johnson, and others, 1945) and from fresh-water limestones in the variegated beds, mentioned above, on Bacon Ridge to the west (Love, Keefer, Duncan, and others, 1951). In the western part of the Wind River Basin microfossils, ostracodes and charaphyte oogonia, have proved to be the most useful criteria for distinguishing Upper Jurassic from Lower Cretaceous beds (Peck, 1937, 1941; Peck and Reker, 1948). Peck (written communication to J. F. Murphy, 1953) has identified microfossils from red zones just above the top of the "upper Sundance" on the Dubois anticline as being Late Jurassic in age.

The contact between the rusty beds and the overlying Thermopolis shale is rarely well exposed. It is marked by a change from olive-drab and gray-green thin-bedded sandstone interbedded with a minor amount of black shale below to predominantly black laminated shale above. The lower part of the Thermopolis shale, however, may in places contain thin stringers of sandstone similar to that in the rusty beds. The contact is commonly also marked by a conspicuous topographic change from ledges below to weathered slopes above.

CRETACEOUS SYSTEM

THERMOPOLIS SHALE

The Thermopolis shale was named and described by Lupton (1916, p. 168) from exposures in the Bighorn Basin near Thermopolis, Wyo., where it is about 700 feet thick and consists predominantly of shale and a number of lenticular sandstone beds, the most persistent being the Muddy sandstone occurring from 210 to 330 feet above the base. The shale is underlain by the Cloverly formation (Greybull sandstone member) and overlain by the Mowry shale. In the Du Noir area and throughout much of the Wind River Basin the Thermopolis shale consists of three members: a lower black shale member, a middle sandstone member referred to as the Muddy sandstone member, and an upper black shale member. The contact between the upper black shale member and the overlying Mowry shale is everywhere difficult to determine because of lithologic similarities, gradational nature, and generally poor exposures. For these reasons the upper member is combined with the Mowry shale for stratigraphic discussion and geologic mapping purposes; it will not be treated in this report as a part of the Thermopolis shale even though it is correlative with the upper part of the formation at the type section. The Muddy sandstone member was mapped as a separate unit.

Within the mapped area the Thermopolis shale crops out on the complexly folded southwest flank of the Dubois anticlinal complex and forms limited exposures in the vicinity of the EA ranch and just east of the Stanolind Oil and Gas Co. Dubois Unit well 2. A composite section was measured on the flanks of the Dubois anticline (Love, Tourtelot, Johnson, and others, 1947, p. 7). The lower black shale member is 136 feet thick; it consists of black soft laminated shales with numerous ferruginous and dahllite concretions. The concretions, where exposed, readily weather to small angular fragments which are scattered over the shale slopes. The Muddy sandstone member, here considered as the upper member of the Themopolis shale for discussion and geologic mapping, is 34 feet thick and consists chiefly of gray, brown-weathering, medium- to coarse-grained thin-bedded sandstone with a minor amount of black to brown sandy shale. Much of the sandstone is highly fucoidal and to some extent resembles that of the rusty beds of the Cloverly formation. The upper 2-foot sandstone is commonly conglomeratic with small rounded pebbles and granules, and some black grains that may be phosphatic. A few fish teeth are also present in this bed. The Muddy sandstone member generally forms ledges and the underlying shale forms soft smooth slopes.

Composite section of Thermopolis shale in secs. 1 and 12, T. 42 N., R. 107 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 7]

	Feet
Mowry shale.	
Thermopolis shale:	
Muddy sandstone member:	
Sandstone, gray, weathering brown, coarse-grained, conglomeratic; contains small pebbles and black grains that may be phosphatic; a few fish teeth present	2
Shale, black to brown, sandy	4
Sandstone, gray, weathering brown, medium-grained, fucoidal	3
Sandstone, gray, weathering brown, thin-bedded; black silty shale partings	11
Sandstone, gray, weathering brown, moderately thin-bedded, crossbedded, fucoidal, medium-grained, with numerous dark minerals, noncalcareous	14
Lower black shale member:	
Shale, black, soft, laminated; numerous ferruginous concretions, and dahllite concretions	136
	170
Rusty beds member of Cloverly formation.	

No fossils, except fish teeth, were found in the formation. Until recently the base of the Muddy sandstone member was believed to mark the base of the Upper Cretaceous in central Wyoming (Love, Thompson, Johnson, and others, 1945). It has now been established, however, that the Mowry shale is of Early Cretaceous age (Cobban and Reeside, 1951); thus the Thermopolis shale is both underlain and overlain by strata of known Early Cretaceous age.

MOWRY SHALE

The term Mowrie beds was applied by Darton (1904, p. 394–401) to include about 150 feet of hard light-gray shale and thin-bedded sandstone with abundant fish scales, lying within the Benton formation on the east side of the Bighorn Mountains northwest of Buffalo, Wyo. The Mowry shale, now considered as a formation, is widespread throughout Wyoming.

In the Wind River Basin the Mowry shale is overlain by the Frontier formation and underlain by the Muddy sandstone member of the Thermopolis shale; in its lower part it contains equivalents of the upper part of the Thermopolis shale as that formation is defined in the Bighorn Basin. In the Du Noir area the Mowry shale crops out on the flanks of the Dubois anticline and is overturned northwest of the EA ranch. A complete section was measured on the east side of the Little Horse Creek road in sec. 1, T. 42 N., R. 107 W., by Love, Tourtelot, Johnson, and others (1947, p. 6–7). At this locality it is 717 feet thick. The formation consists predominantly of shale with thin beds of bentonite and sandstone. In the lower part the shale is soft, black, and finely laminated whereas in the upper part it is mostly gray, brown, and black, hard, siliceous, blocky, and distinctive silver-gray weathering. The middle one-third of the formation is poorly exposed at the locality where the section was measured and contains the transitional zone between black shale below and siliceous shale above. In this interval is the contact between the Mowry shale and Thermopolis shale as these formations are defined in other areas. Bentonite beds, ranging from a few inches to as much as 8 feet in thickness, occur throughout the formation. Most are impure and contain thin black shale partings. Sandstone is generally confined to the upper part of the formation and is characteristically gray green, fine to medium grained, silty, siliceous, and hard. Beds are 2 to 4 feet thick and commonly have a "salt-and-pepper" appearance due to the abundance of dark grains. Fish scales occur abundantly in the siliceous shale and form one of the most distinguishing features of the formation. A few fish teeth are also present. The weathered slopes of the Mowry shale are characteristically gray and dark-gray banded because of the alternation of black shale and light-colored bentonite and siliceous shale. The siliceous beds commonly form ledges.

Section of Mowry shale in sec. 1, T. 42 N., R. 107 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 6–7]

	Feet
Frontier formation.	
Mowry shale:	
Shale, black, laminated; thin yellowish-gray siltstone, and fine-grained sandstone partings	27
Sandstone, green, fine to medium-grained, slabby, hard, with silty and shaly partings	3
Bentonite, pale yellowish-green, with a few black shale partings	3
Shale, black, laminated, slightly carbonaceous; thin bentonite beds near base	31
Sandstone, dull-green, fine to medium-grained, slabby, hard, silty at base; some shale partings	20
Bentonite, shaly	4
Shale, yellowish-brown to silvery-gray, hard	5
Bentonite, pale-yellow	2
Shale, yellowish-brown to silvery-gray, hard; contains sparse poor pelecypod casts and molds	2
Bentonite with interbedded black shale	4
Shale, dark-gray, weathering silver gray, siliceous, hard, splintery; contains fish scales	24
Sandstone, dull greenish-gray to buff; silty layers; numerous dark grains; numerous fish scales and teeth	4
Bentonite, pale-yellow; a thin black shale at top	2
Sandstone, dull greenish-gray to buff; silty layers; numerous dark grains and fucoidal markings	2
Shale, black, bentonitic, with 0.5 ft of bentonite at base and a thin greenish-gray sandstone in middle	5
Sandstone, dull greenish-gray to buff; silty layers; numerous dark grains; fish teeth and scales	2
Shale, black to brown, weathering gray, hard, silty, with a few poorly preserved lucinoid type pelecypods. A shaly white bentonite 0.5 ft thick is present 15 ft above base, and 90 ft above base are several thin bentonite beds, above which the shale is harder and more siliceous	108

Mowry shale—Continued	*Feet*
Covered interval	245
Shale, black, soft, laminated; thin bentonite layers throughout sequence but less abundant in upper part	113
Bentonite, yellow, hard, with coarser tuffaceous material	6
Shale, black, soft, with numerous soft yellow bentonite beds	73
Shale, black, bentonitic, with a few ironstone concretions	12
Bentonite, gray; thin hard white tuffaceous beds in upper part and black shales in lower part. A few bone fragments present	8
Shale, black, bentonitic; a thin yellowish-green bentonite 2 ft above base	12
	717

Muddy sandstone member of Thermopolis shale.

No fossils of value in dating the formation were found in the Du Noir area. Thin-shelled pelecypods and a few flattened ammonites have been collected at some localities in the Wind River Basin (Thompson, Love, and Tourtelot, 1949). Recent paleontologic studies of ammonites occurring in the Mowry shale and its equivalents at many widely scattered areas in Colorado, Wyoming, and Montana by Cobban and Reeside (1951, p. 1892) indicate an Early Cretaceous age for the formation.

The contact between the Mowry shale and the overlying Frontier formation, which coincides with the boundary between the Lower and Upper Cretaceous in this region, is marked by a change from black shale below to tan, gray, and yellowish sandstone above.

FRONTIER FORMATION

The Frontier formation was named and described by Knight (1902, p. 721) from exposures near the town of Kemmerer in southwestern Wyoming. A comprehensive historical treatment of its application throughout Wyoming and adjacent States is presented by Cobban and Reeside (1952). A detailed surface and subsurface study of the formation in the Wind River Basin has been published (Thompson, Love, and Tourtelot, 1949). Within the basin the Frontier formation is predominantly a sandstone and shale sequence overlain by the Cody shale and underlain by the Mowry shale. It is an important oil- and gas-producing sequence in many fields in Wyoming.

In the Du Noir area the Frontier formation crops out along Little Horse Creek and at some places northwest of the EA ranch. A well-exposed section was measured in sec. 1, T. 42 N., R. 107 W., and sec. 36, T. 43 N., R. 107 W., where it is 752 feet thick (Love, Tourtelot, Johnson, and others, 1947, p. 4–6). The formation consists chiefly of an alternating succession of sandstone and shale with minor amounts of bentonite, tuff, carbonaceous shale, lignite, and coal. The sandstone beds, which range from a few inches to as much as 65 feet in thickness, are white, gray, tan to yellowish, and brown, fine to coarse grained, and commonly crossbedded. Some are hard and tuffaceous; others are soft and moderately porous and friable. Most contain abundant dark minerals and some near the top are glauconitic. The shale is generally black and finely laminated with minor amounts of bentonite and carbonaceous material. Bentonite occurs mainly in the lower half of the formation in beds as much as 14 feet thick. It is generally sandy and shaly, although a few beds appear to be pure. Coal and lignite beds which are also confined chiefly to the lower part, are rarely more than 3 feet thick. The coal is, for the most part, of subbituminous grade. It has been mined for local use but none is being mined at present in the area. The sandstone at the top of the formation in some localities contains shale with numerous black and brown well-rounded flat chert pebbles; these pebbles, however, also occur in the basal beds of the Cody shale. The sandstone in the formation is quite resistant and forms ledges.

Section of Frontier formation in sec. 1, T. 42 N., R. 107 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 4–6]

Cody shale.

Frontier formation:	*Feet*
Covered interval forming dip slope and supporting a heavy growth of trees. One-quarter mile east along strike this zone consists of sandstone containing abundant pelecypods and gastropods overlain by brownish-gray shale, containing numerous flat black chert pebbles. Niobrara fauna (USGS loc. 19534): *Ostrea anomioides* Meek, *Camptonectes* n. sp., *Tellina?* cf. *T. subalata* Meek, *Cardium curtum* Meek and Hayden	20
Sandstone, gray to brown, medium-grained, limy, hard, petroliferous. A highly limy zone 5 ft thick near the center of the unit and one 10 ft thick near the top contain an abundant and well-preserved fauna of pelecypods, bizarre gastropods, echinoids, and ammonites. Niobrara fauna (USGS loc.: 19537): *Inoceramus deformis* Meek, *Ostrea anomioides* Meek, *Exogyra* sp., *Camptonectes* n. sp., *Cardium curtum* Meek and Hayden, *Cardium pauperculum* Meek, *Tellina* n. sp., *Cymbophora* cf. *C. arenaria* Meek, *Gyrodes* sp., *Pugnellus fusiformis* Meek, *Pyropsis?* n. sp., *Volutoderma* sp., *Placentoceras planum* Hyatt, gastropods, several undetermined new forms	30
Partly covered interval. A few gray sandstone ledges visible	40
Shale, black to brown, laminated	15
Sandstone, gray; hard, fine-grained, limy near top. Abundant pelecypods present. Poorly exposed. Niobrara fauna (USGS loc. 19538): *Ostrea sannionis* White	20
Shale, black to brown; sandy in lower part	6
Partly covered interval. A few gray glauconitic sandstone ledges visible	20

Frontier formation—Continued	*Feet*
Sandstone, light-gray to yellowish-gray, highly glauconitic, limy, crossbedded, very fossiliferous with abundant pelecypods and a few ammonites. Niobrara fauna (USGS loc. 19535): "*Gervillia*" *propleura* Meek, *Pteria gastrodes* Meek, *Inoceramus* sp., *Cardium pauperculum* Meek	11
Sandstone, gray, fine-grained, soft, very shaly	16
Shale, brownish-gray, sandy	1
Sandstone, gray, medium-grained, limy; abundant rounded grains of glauconite	6
Shale, black, laminated; yellowish fine-grained slightly carbonaceous sandstone in upper 5 ft	25
Sandstone, gray, fine-grained, limy, crossbedded; soft in lower half	6
Shale, brown, sandy, soft, with a carbonaceous layer near middle	5
Sandstone, yellowish-brown, fine-grained, limy, hard, slightly carbonaceous	11
Covered interval. Lower part probably dark-gray carbonaceous shale and upper part probably black fissile shale	44
Lignite, black to brown, shaly	1
Sandstone, yellowish-brown, medium-grained, crossbedded, limy, locally with ironstone concretions	6
Shale, black, laminated	6
Sandstone, yellowish-brown, medium-grained, crossbedded, limy, locally with ironstone concretions	9
Shale, black, laminated; 0.2 ft of greenish-yellow bentonite at top	1
Sandstone, yellowish-brown, fine-grained, limy, slabby, finely crossbedded	4
Shale, black in lower part; brownish near top; laminated; moderately sandy near middle	16
Sandstone, yellowish-gray, medium to fine-grained, interlaminated black shale near middle	65
Shale, black, laminated in lower 40 ft; abundant secondary gypsum	45
Sandstone, yellowish-gray to white, coarse-grained, soft	4
Shale, dark-gray, sandy, with thin lignite beds	2
Sandstone, yellowish-gray, fine-grained, soft in lower part; coarser and somewhat shaly near top	9
Shale, black, laminated	4
Sandstone, yellowish-gray, fine-grained, soft	1
Shale, black, laminated, poorly exposed	20
Bentonite, yellow; abundant secondary gypsum	5
Shale, black, laminated	2
Sandstone, yellowish-gray, soft, fine-grained, bentonitic	3
Shale, greenish-gray; soft and bentonitic in lower 3 ft, then 2 in. of soft yellowish-gray sandstone overlain by black laminated shale, sandy near top	5
Lignite in lower half; carbonaceous gray siltstone in upper half	1
Shale, black and very lignitic near base; gray and silty in middle and upper parts	7
Bentonite, gray, sandy	10
Sandstone, brownish-gray, very coarse grained, very limy; soft in lower 10 ft; abundant dark minerals	27
Shale, carbonaceous, with thin coal layers	2
Bentonite, white, with coarser tuff beds	12
Coal. This bed has been mined for local use	3
Shale, black to brown, very sandy	4
Sandstone, white to yellowish, crossbedded, fine to medium-grained, nodular; with numerous dark minerals; with thin carbonaceous shale beds	10

Frontier formation—Continued	*Feet*
Shale, black, fine-grained, soft; bentonitic in lower half; slightly sandy, brown, hard, silty in upper half; thin bentonite at top	15
Sandstone, gray to yellowish, soft; carbonaceous and bentonitic near base; abundant dark minerals	11
Shale, black, laminated	2
Coal, black, soft	1
Sandstone, brownish-gray, fine-grained, silty to shaly, soft	3
Shale, brown to black; bentonitic in lower 5 ft	15
Sandstone, gray to brown, weathering black, hard, crossbedded, slightly limy; numerous dark minerals	2
Shale, black, laminated, very bentonitic. Abundance of bentonite makes weathered slopes appear white	11
Lignite and carbonaceous shale; sandstone lenses in middle of unit; more nearly pure lignite near base and top	6
Bentonite, yellow; shaly in lower part	6
Tuff or very fine grained tuffaceous sandstone, gray, with interbedded bentonite	3
Bentonite, gray	9
Bentonite, gray; a highly carbonaceous brown tuff 1.5 ft thick, poorly preserved plant remains in lower part	14
Tuff, brown, highly carbonaceous; abundant poorly preserved plant remains	1
Bentonite, white to yellowish, interbedded with coarser bentonitic tuffs containing plant remains	7
Shale, black, bentonitic, with thin ironstone zone at top	3
Sandstone, dark-gray, very coarse grained, angular, very hard, tuffaceous, with abundant dark minerals and glassy fragments resembling shards	2
Bentonite, gray, very impure, with a thin coarse-grained sandstone containing wood and bone fragments at base of unit	3
Lignite and dark-gray carbonaceous shale	3
Sandstone, gray, coarse-grained, angular; soft in lower part; hard in upper 15 ft; cliff forming; a few thin carbonaceous shale partings; abundant dark minerals	18
Lignite, black, interbedded with black carbonaceous shale	2
Bentonite, gray	2
Sandstone, white, with thin shale partings and thin ferruginous sandstone containing shardlike fragments	2
Shale, black, hard, bentonitic	8
Sandstone, gray to yellowish, coarse- to medium-grained, hard, lenticular; numerous thin shale partings; abundant dark minerals	16
Shale, black to brown, laminated	7
Sandstone, white to yellow, coarse-grained, cross bedded; cliff-forming; sandy gray shale partings	10
Sandstone, gray, medium-grained, moderately soft; numerous black shale partings	8
Sandstone, tan to yellowish, fine-grained, moderately hard; numerous dark minerals and numerous brown glossy fish scales	2
	752

Mowry shale.

The sandstones in the upper part of the Frontier formation, particularly those at the top, are locally very fossiliferous. The uppermost sandstone contains a varied fauna of pelecypods, gastropods, echinoids, and ammonites of early Niobrara age (W. A. Cobban, 1951, oral communication). The lower part of the formation, however, is probably of Carlile age.

There is a sharp lithologic break between the Frontier formation and the overlying Cody shale with a change from resistant sandstone below to soft black shale above. There is also a conspicuous topographic change, with the upper part of the Frontier sandstone commonly forming a dip slope.

CODY SHALE

The Cody shale, which was described and named by Lupton (1916, p. 171) from the town of Cody in the western part of the Bighorn Basin, is widely distributed throughout central Wyoming where it consists of about 4,000 feet of marine shale and sandstone. It is underlain by the Frontier formation and generally overlain by the Mesaverde formation. In the Du Noir area, however, because of overlapping Tertiary rocks only the lower 3,000 feet of the formation is exposed at the surface; no younger Upper Cretaceous rocks are present. A broad poorly exposed outcrop belt extends southeastward from the upper end of Little Horse Creek valley to the vicinity of the EA ranch. The upper part of the formation is further cut out by faulting along the north side of this outcrop belt.

The best exposures are on the east side of the Little Horse Creek road in sec. 36, T. 43 N., R. 107 W. A section was measured at this locality by Love, Tourtelot, Johnson, and others (1947, p. 3–4), who reported 3,000 feet of Cody strata present but only the lower 1,500 feet sufficiently well exposed to be described in detail. The upper half of the formation is mostly obscured by debris from the overlying Tertiary conglomerate. The lowermost 1,080 feet consists chiefly of brownish-gray soft laminated shale with a few thin sandy zones. The overlying 429 feet consists mainly of shale but also contains an increasing proportion of greenish-gray medium- to coarse-grained crossbedded to slabby sandstone. The uppermost 1,500 feet, of which the lithologic character is imperfectly known, probably contains shale and sandstone in about equal amounts. Several ledgy sandstone beds can be observed in the slopes; some of these sandstones are highly glauconitic. The basal bed of the formation on the west side of Little Horse Creek in the S½ sec. 26, T. 43 N., R. 107 W., is a shale zone which contains abundant well-rounded flat chert pebbles that weather out in abundance on the slopes.

Section of Cody shale in sec. 36, T. 43 N., R. 107 W.

[Measured by Love, Tourtelot, Johnson, and others, 1947, p. 3–4]

	Feet
Wind River formation (lower Eocene).	
Cody shale:	
Shale, gray, soft, poorly exposed. Top of shale is obscured by landslide debris. No sandstone of the Mesaverde formation was found in the area, and the Cody shale is apparently overlain by Eocene rocks	1,500+
Sandstone, greenish-gray, medium-grained, soft, crossbedded; abundant dark minerals; interbedded with equal amounts of gray shale	43
Sandstone, greenish-gray, medium-grained, limy, hard, crossbedded, with numerous dark minerals	2
Shale, dark-gray, laminated, with a few thin layers of greenish-gray sandstone	102
Sandstone, greenish-gray, coarse-grained, slabby; interbedded dark-gray shale	28
Sandstone, greenish-gray, coarse-grained, angular; numerous dark minerals, crossbedded; some shale partings	65
Sandstone, greenish-gray, coarse-grained, angular; ledgy near base; shaly in upper part; poorly preserved pelecypods in basal 2 ft. Niobrara(?) fauna (USGS loc. 19539): *Inoceramus* sp., *Cymbophora* sp., *Ostrea* sp	15
Shale, brownish-gray, laminated; sandy in lower 50 ft; 6-in. sandstone, fine to medium-grained, carbonaceous, with sparse pelecypods, 50 ft above base	172
Sandstone, light greenish-gray, coarse-grained, angular, limy; numerous dark minerals	2
Shale, brownish-gray, laminated, soft; some sandy zones	1,080
	3,009+
Frontier formation.	

The Cody shale is sporadically fossiliferous. The following fossils, which were identified by W. A. Cobban, were collected in 1949 by J. D. Love, and the writer, from about 1,500 feet above the base of the formation: *Inoceramus stantoni* Sokolow, *Baculites asper* Morton, *B. codyensis* Reeside, *B.?* n. sp., and *Scaphites vermiformis* Meek and Hayden var. *binneyi* Reeside. This assemblage is of late middle Niobrara age. W. A. Cobban and J. B. Reeside visited the section in the summer of 1951 and collected fossils of an earlier Niobrara age in the lower part of the formation. No fossils were collected from the uppermost 1,500 feet of the Cody shale, but regional relationships in the Wind River Basin (Yenne and Pipiringos, 1954) suggest that the age probably ranges from late Niobrara (uppermost Colorado) into possibly Telegraph Creek and Eagle ages (lower Montana). In the Jackson Hole region to the west the uppermost marine Cretaceous strata are of middle Niobrara age (Love, Hose, Weitz, and others, 1951), thus indicating that the withdrawal of the Cretaceous seas was from west to east.

The top of the Cody shale within the mapped area is everywhere delimited by overlapping Tertiary strata or by thrust faulting.

TERTIARY SYSTEM

PALEOCENE(?) SERIES

FORT UNION(?) FORMATION

The presence of Paleocene rocks in the Du Noir area has not been fully substantiated. The rocks here referred to the Fort Union(?) formation crop out only locally in the Dubois anticlinal complex and have been strongly folded and faulted (fig. 65). They occur as-

FIGURE 65.—Fort Union(?) formation (Tfu) and Mowry shale (Km) strongly folded and faulted at southeastern end of Dubois anticlinal complex, NE¼ sec. 13, T. 42 N., R. 107 W. (T on overriding block of thrust fault; Twdr, Wind River formation).

sociated with Cretaceous rocks and are overlain uncomformably by strata of the Wind River formation (early Eocene). The total thickness of the sequence is not known, but as much as 50 feet is exposed west of Little Horse Creek. The Fort Union (?) formation is largely conglomeratic with the pebbles and rock fragments derived entirely from Mesozoic rocks. Angular light-colored Mowry shale chips form the most conspicuous element in the conglomerate. Fragments of "upper Sundance" limestone and sandstone and Morrison and Cloverly sandstone and siltstone are also present. Red and gray siltstone and claystone are present in some places.

No fossils were found in the Fort Union(?) formation, but the presence of Mesozoic rock fragments, complete absence of Paleozoic rocks, and the structural relationships of the formation suggest that this sequence of conglomerate, siltstone, and claystone is older than those rocks of known early Eocene age. The Fort Union(?) strata were most probably deposited during the initial stages of folding of the anticline.

EOCENE SERIES

INDIAN MEADOWS FORMATION

The name Indian Meadows formation was applied by Love (1939, p. 58) to a series of interbedded red clay, shale, sandstone, and conglomerate nearly 1,000 feet thick which lies along the east side of the North Fork River, approximately 4 miles east of the southeast edge of the Du Noir area. Massive conglomerate beds, containing fragments of granite, Paleozoic limestone, dolomite, and chert, and conspicuous algal-ball limestone beds, were considered to be distinguishing lithologic features of the formation. Vertebrate fossils at the type section indicate an earliest Eocene age, equivalent to that of the Gray Bull faunal zone in the Bighorn Basin. The close resemblance between the fine-grained strata of the Indian Meadows formation and those of the overlying Wind River formation, however, makes it impossible to differentiate the two formations in areas where they occur in juxtaposition except where there are fossils or mappable unconformities. No fossils were found in the strata assigned to the Indian Meadows formation in the Du Noir area; they have been so designated because of their conglomeratic character, similarities to the type section, and structural relationships. In the southeast portion of the mapped area where both the Indian Meadows and Wind River formations are believed to be present, they have been mapped as Wind River and Indian Meadows formations, undifferentiated.

The Indian Meadows formation crops out along the West Fork of the Du Noir River, on the south flank of Spring Mountain, and along the Wiggins Fork River. It is probably also present on the north sides of the Wind River and Wind Ridge fault, but at these localities it cannot be distinguished from the Wind River formation (fig. 66). At the localities where the formation can be observed in contact with the underlying Paleozoic and Mesozoic rocks there is a pronounced angular unconformity measuring as much as 60°. This is best seen along the east side of Horse

FIGURE 66.—View of lower Eocene rocks along north side of Wind River southeast of Dubois. Wind River flows along base of cliffs.

FIGURE 67.—Angular unconformity between Indian Meadows formation (Tim) and Chugwater formation (Ꞧc) on east side of Horse Creek, near junction of secs. 32 and 33, T. 43 N., R. 106 W., and secs. 4 and 5, T. 42 N., R. 106 W. Top of Spring Mountain on skyline at left.

Creek north of the EA ranch (fig. 67). The thickness varies greatly from one place to another, and no detailed section of the formation was measured. The maximum thickness is unknown because on the south edge of Spring Mountain the lower part is delimited by faulting and the upper part is poorly exposed, and because in the southeastern part of the mapped area the total stratigraphic interval represented by the formation could not be determined. The massive conglomerate beds attain an aggregate thickness of as much as 150 to 200 feet near the EA ranch and along the West Fork of the Du Noir River, but the thickness diminishes rapidly northward to a wedge edge as the formation laps up against the highlands along the south flank of the Washakie Range.

The strata assigned definitely to the Indian Meadows formation consist chiefly of red, crudely stratified to massive conglomerate overlain in some places, as on the south flank of Spring Mountain, by variegated fine-grained sandstone, siltstone, claystone, and shale. The conglomerate beds are hard and indurated and form massive cliffs throughout most of their area of outcrop. They consist chiefly of cobbles and subrounded boulders as much as 6 feet in diameter of Paleozoic sandstone, limestone, dolomite, and chert in a matrix of red and gray limy coarse-grained sandstone. No Precambrian rock fragments are in the exposures along the West Fork of the Du Noir River and on the south flank of Spring Mountain, and no volcanic material was observed. The lowermost Eocene rocks along the north sides of the Wind River and Wind Ridge fault, which probably belong to the Indian Meadows formation, consist of 10- to 20-foot beds of conglomerate interbedded with variegated fine-grained strata. These conglomerates are not so coarse as those that lie adjacent to the highlands of folded Paleozoic rocks to the north, and the boulders are not more than 2 feet in diameter. These conglomerates also contain fragments of deeply weathered granite, gneiss, and schist. At some localities along the north side of the Wind River these strata contain algal-ball limestone beds which are characteristic of the formation at the type section. Similar beds were observed at one locality on the south edge of Spring Mountain. These beds are gray and appear to be very conglomeratic, but they consist almost entirely of rounded masses of limestone as much as 2 inches in diameter. The limestone is arranged in concentric layers around a nucleus. A detailed study of these nuclei was not made by the writer, but Love (1939, p. 60) reported that they were commonly *Goniobasis* sp. (gastropod), clay balls, chert, limestone, arkose, shale, sandstone, and granite fragments.

The Indian Meadows strata probably formed during the active erosional period which followed the folding of the Washakie and Wind River Ranges. The red color, which characterizes much of the formation, is very similar to that of the Triassic Chugwater formation. Where the conglomerates are in direct contact with the Chugwater formation, as in the locality north of the EA ranch, the colors are identical. The Indian Meadows formation lies horizontally upon the upturned edges of the folded and eroded rocks of Paleozoic age along the West Fork of the Du Noir River and on both Paleozoic and Mesozoic rocks along the south flank of Spring Mountain. The formation has been involved in later thrust faulting in the southeastern part of the mapped area.

WIND RIVER FORMATION

The term Wind River formation is used throughout the Wind River Basin to include all the strata of early Eocene age except the Indian Meadows formation. A historical summary of its definition and application has been given by Tourtelot (1948, p. 114). In the northeastern part of the basin the Wind River formation is separated into two distinct lithologic and faunal units: the Lysite member at the base and the Lost Cabin member at the top (Tourtelot, 1948, p. 114–119). Faunally, the two members are differentiated by the presence or absence of *Lambdotherium*, which occurs only in the Lost Cabin member. *Lambdotherium*-bearing strata are present in the Du Noir area, but the presence of Lysite strata has not been substantiated.

The Wind River formation is the most widespread lithologic unit in the Du Noir area; it crops out extensively in the southern and central parts of the mapped area. Vertebrate fossils indicate that all the lower Eocene rocks west of Horse Creek belong in the formation. Wind River strata probably comprise the bulk of the lower Eocene rocks east of Horse Creek, but, as previously discussed, could not be differentiated from the finer grained facies of the Indian Meadows formation. The thickness of the Wind River formation varies considerably from one locality to another because of pronounced unconformities both at the base (where not in contact with the Indian Meadows formation) and at the top. The thickest section is in the central part of the area, where the formation crops out in an uninterrupted sequence from the Wind River north to the upper end of Little Horse Creek valley.

Five units were recognized within the formation: a lower variegated sequence, a greenish-gray and drab tuffaceous sequence, a middle variegated sequence, a conglomerate sequence, and an upper variegated sequence. The lower three units are the most widespread and are best exposed along Bench Creek where they are 1,618 feet thick. The units could not be mapped, however, because of the gradational nature of their contacts. A series of generalized sections, presented in figures 68 and 69, shows the writer's interpretation of the relationships between the different facies of the Wind River formation and the approximate positions of fossil collections.

The lower variegated sequence along Bench Creek is at least 554 feet thick, with the base concealed. West-

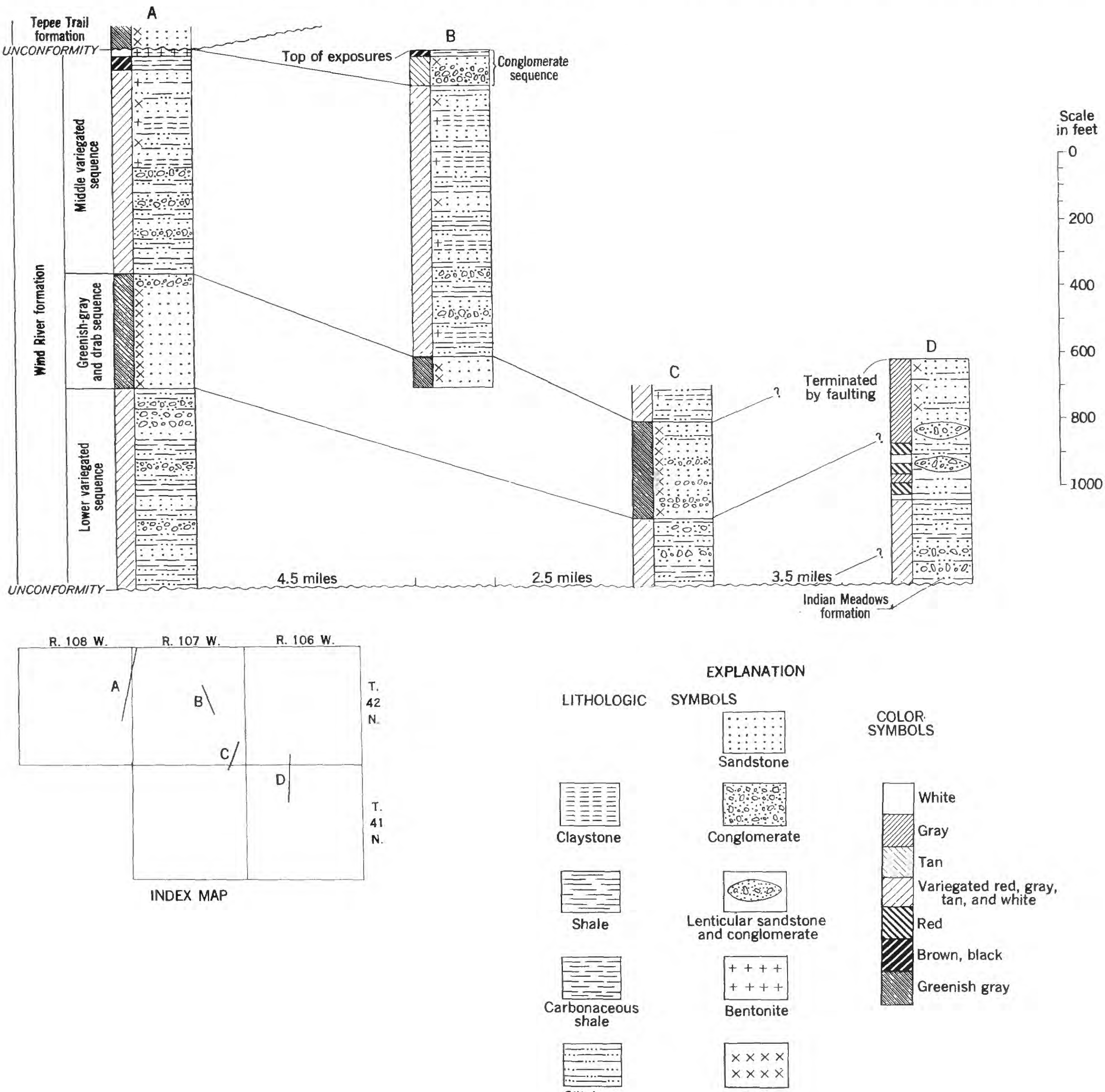


FIGURE 68.—Chart showing lateral variation of the Wind River formation.

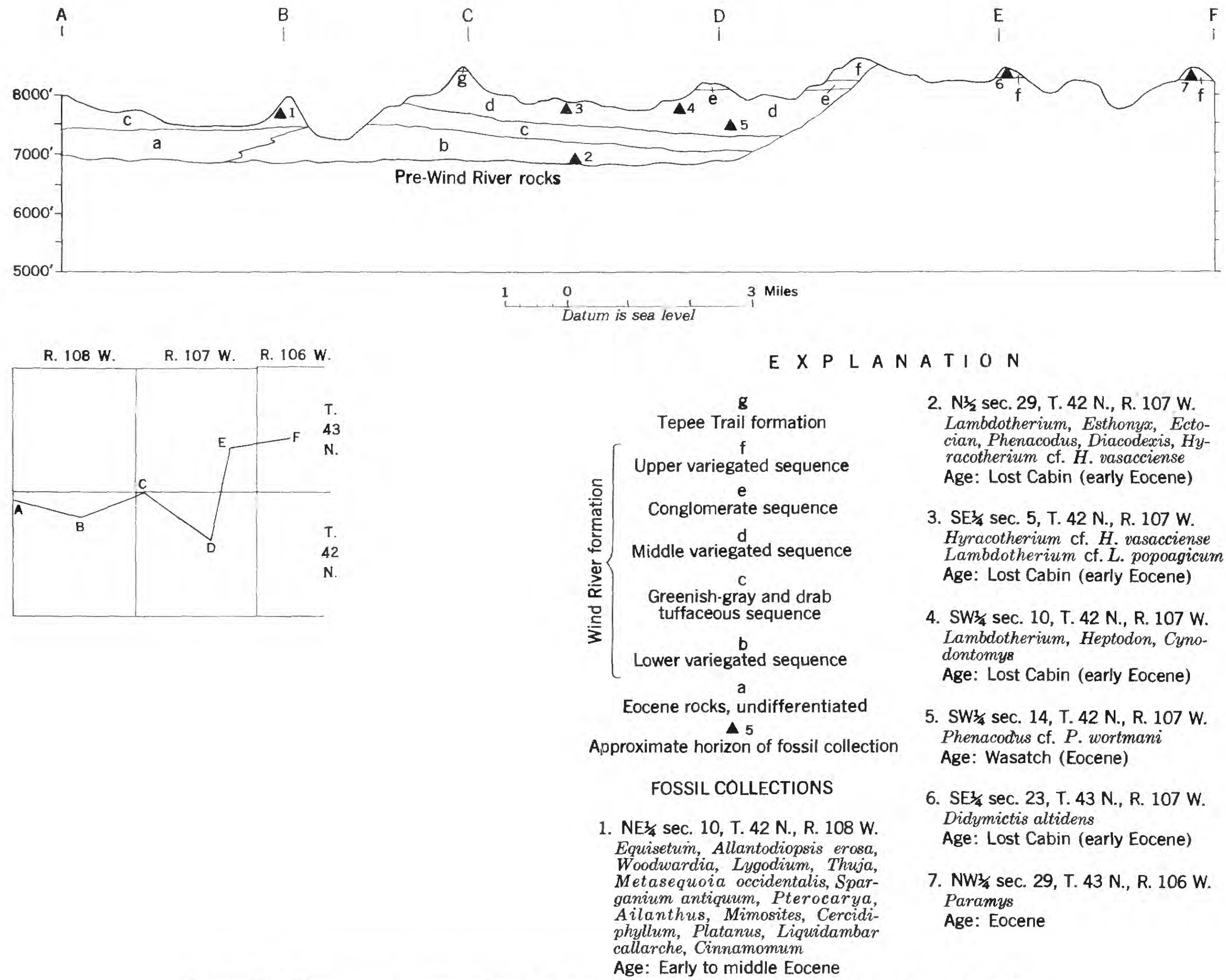


FIGURE 69.—Diagrammatic cross section showing apparent relations of facies of Wind River formation.

ward the thickness decreases to a wedge edge west of the mouth of the Du Noir River, where it apparently intertongues with arkosic facies of Eocene rocks, undifferentiated (fig. 69). Eastward the thickness varies considerably because of the pronounced basal unconformity. The lower variegated sequence, which forms conspicuous badlands, consists chiefly of red siltstone and shale, soft to hard buff fine-grained shaly sandstone, and white to buff cobble and pebble conglomerate. The conglomerate beds contain rounded fragments as much as 6 inches in diameter of rocks of Paleozoic age and a subordinate amount of Precambrian granite. Many of the shale and siltstone beds in the upper part are bentonitic and plastic. Just east of Stony Point, in the SW¼ sec. 19, T. 42 N., R. 107 W., the basal beds are chiefly tan and white arkose interbedded with minor amounts of gray and tan siltstone and brown carbonaceous shale with black coaly partings. The arkose is composed of coarse-grained to granule-sized angular fragments of quartz and feldspar with some dark grains in a fine-grained limy matrix. In a distance of a few hundred yards east of this locality the tan and gray beds grade into redbeds. It is interesting to note that this pronounced color change coincides closely with the base of the redbeds of the Chugwater as the trend of that formation is projected northwestward across the Wind River from the Harrison ranch, suggesting that much of the red sediment in the lower part of the Wind River formation was derived from the Chugwater formation.

The contact between the lower variegated sequence and the overlying greenish-gray and drab sequence is gradational. The interfingering between the two units can best be seen in the high hill on the east side of Bench Creek, NE¼ sec. 13, T. 42 N., R. 107 W. East of Horse Creek are some lenticular conglomeratic sandstone beds, which occur both in the upper part of the lower variegated sequence and the lower part of the greenish-gray and drab sequence making the contact between the two units difficult to determine. These sandstones may be channel deposits.

Vertebrate fossils identified by C. L. Gazin, were found at several localities in the lower variegated sequence. A Lost Cabin age for the basal part of the unit west of Horse Creek is indicated by a collection containing *Lambdotherium* (coll. 2, fig. 69) obtained in the N½ sec. 29, T. 42 N., R. 107 W. North of the 2N Ranch, S½ sec. 32, T. 41 N., R. 106 W., a lower jaw of *Hyracotherium* cf. *H. vasacciense* of possible Lost Cabin age was collected from the base of the lower variegated sequence, suggesting that the Indian Meadows formation is not represented at the base of the lower Eocene this far westward. The following fossils were collected from the top of the sequence in the SW¼ sec. 30, T. 42 N., R. 106 W., opposite the entrance to the Rocking Chair ranch: lower jaw close to *Paramys buccatus* Cope, maxilla with three teeth of *Hyracotherium* cf. *H. index* (Cope), and upper and lower jaws of *Hyopsodus*, close to *H. wortmani* Osborn. The latter suggests a Lost Cabin age as does *Hyracotherium* cf. *H. index* (Cope), which is found associated with *Lambdotherium* in the Green River Basin although it has been recorded from Gray Bull (lowermost Eocene) faunas in the Bighorn Basin as well.

The greenish-gray and drab tuffaceous sequence is well exposed in the high bluff on the north side of U. S. Highway 287 east of the Long Creek Inn and along both Bench and Long Creeks. It is 390 feet thick along Bench Creek, but it thins eastward to 290 feet north of Dubois in the SE¼ sec. 25, T. 42 N., R. 107 W. (fig. 69). Its stratigraphic thickness on the east side of Horse Creek (section *D*, fig. 68) could not be specifically determined because the upper part of the section is cut by faulting and the lower contact is not well defined. The unit consists chiefly of greenish-gray, gray, and olive-drab soft porous friable tuffaceous fine- to coarse-grained sandstone and minor amounts of shale, carbonaceous shale, and conglomerate. A thin-section study indicates that the sandstone contains much clayey material in addition to distinct grains of quartz, plagioclase, and biotite. Both the biotite, which occurs as euhedral hexagonal flakes readily observed in a hand specimen, and the feldspar are probably of volcanic origin but the quartz appears to have been derived largely from nonvolcanic sources. At the locality north of Dubois (section *C*, fig. 68; fig. 70) the unit contains some hard limy highly tuffaceous "cannonball" concretions as much as 4 feet in diameter. The conglomerate beds are 20 to 30 feet thick, commonly lenticular, and contain round stones of Precambrian quartzite, granite, and schist and Paleozoic limestone, sandstone, and chert as much as 6 inches in diameter as well as sporadic pebbles of volcanic rocks. The presence of quartzite fragments, some of which have pressure scars, is especially significant because they have not been observed in any other Tertiary conglomerate

FIGURE 70.—Exposures of a part of the Wind River formation in SE¼ sec. 25, T. 42 N., R. 107 W. (*A*, lower variegated sequence; *B*, greenish-gray and drab sequence; *C*, middle variegated sequence). Top of butte covered by a veneer of coarse gravels, representative of the Black Rock cycle of erosion.

on the north side of the Wind River. They occur in Eocene strata in some places south of the river, however. As far as is known this is also the lowest stratigraphic occurrence of volcanic pebbles in the Eocene rocks of the Du Noir area. Thin sections of these rocks were not obtained. Thin beds of carbonaceous shale and gray shale are present in the sequence at some localities, most notably along the north side of U. S. Highway 287 west of the Long Creek ranch. The contact between the greenish-gray and drab sequence and the middle variegated sequence is not well exposed and their relationships are not readily observed. It appears, however, that the contact is gradational and similar to that at the base of the greenish-gray and drab sequence.

Only one tooth fragment was found in the greenish-gray and drab sequence and it is not identifiable. There is, however, an abundance of well-preserved plant remains at many localities. A large and varied collection of fossil leaves (coll. 1, fig. 69) was obtained in the NE¼ sec. 10, T. 42 N., R. 108 W. Some of the forms were identified by R. W. Brown as follows: *Equisetum* sp., *Allantodiopsis erosa* (Lesquereux) Knowlton and Maxon, *Woodwardia* sp., *Lygodium* sp., *Thuja* sp., *Metasequoia occidentalis* (Newberry) Chaney, *Sparganium antiquum* (Newberry) Berry, *Pterocarya* sp., *Ailanthus* sp., *Mimosites* sp., *Cercidiphyllum* sp., *Platanus* sp., *Liquidambar callarche* Cockerell, and *Cinnamomum* sp. According to Brown (1954, oral communication) this flora is similar in many respects to that found near the middle of the Green River formation of Eocene age in northwestern Colorado and southwestern Wyoming. Another plant collection from approximately the same horizon by Dorf (1953) was interpreted by him to have close affinities with late Eocene to early Oligocene floras of the Pacific Coast region. However, the preponderance of both paleontologic and stratigraphic evidence favors a lower Eocene age (fig. 69).

The middle variegated sequence is best exposed in the high bluff along the north side of Tappan Creek westward from the Warnock ranch, and at White Pass. At the Bench Creek locality, where it is overlain by the Tepee Trail formation, the unit is 674 feet thick, but it thickens eastward to a maximum of about 800 feet (section *B*, fig. 68) in secs. 14, 15, and 23, T. 42 N., R. 107 W. Its total thickness east of Horse Creek could not be determined because of structural complications.

The sequence is characterized by bright red, purple, and gray bentonitic claystone and siltstone and white to gray tuffaceous sandstone and siltstone. The individual color bands are generally thicker and the claystones and siltstones more bentonitic than those in the lower variegated sequence. The lower 300 feet commonly contains 10- to 15-foot beds of sandstone and massive conglomerate with pebbles and cobbles of Paleozoic chert, limestone, and sandstone. The tuffaceous sandstone contains much biotite and is generally silty. In the high hill on the north side of White Pass the top 48 feet of the middle variegated sequence contains a 37-foot bed of brown carbonaceous shale with thin coal partings overlain by 11 feet of white bentonite and bentonitic claystone (section *A*, fig. 68). This highly bentonitic zone can be traced northeastward from White Pass for about 3 miles along the contact between the Wind River and Tepee Trail formations. The middle variegated sequence has been highly folded along the south flank of the Dubois anticlinal complex. Vertebrate fossils collected from about the middle of the unit at various localities along the north side of Tappan Creek indicate a Lost Cabin age (colls. 3 and 4, fig. 69).

In the central part of the mapped area, capping the high bluff on the north side of Tappan Creek and overlying the middle variegated sequence, is a 100-foot conglomerate, sandstone, and carbonaceous shale unit (section *B*, fig. 68). The lower 40 feet is a tan massive conglomerate with rounded to subrounded fragments as much as 6 feet in diameter. Rock types represented include limestone from the Gros Ventre, Gallatin, and Madison formations, sandstone and quartzite from the Flathead and Tensleep sandstones, dolomites from the Bighorn and Darby formations, and Precambrian granite, gneiss, and schist. The matrix is coarse grained and limy, with most of the grains angular. The overlying 40 feet consists mainly of tan fine- to coarse-grained limy sandstone with conspicuous grains of biotite and of minor amounts of gray claystone and brown carbonaceous shale. The upper 20 feet is brown carbonaceous shale with numerous black coal partings.

The conglomeratic sequence is also present on top of the Dubois anticlinal complex where it lies horizontally upon the folded Mesozoic rocks (fig. 71). These conglomerates can be distinguished from those in the Indian Meadows formation, which crop out farther east along Horse Creek, by their color and Precambrian rock content. Although the conglomeratic sequence lies conformably upon the middle variegated sequence along the north side of Tappan Creek, there is an unconformable relationship between the two in the vicinity of the Dubois anticlinal complex where the middle variegated sequence is involved in the folding and the conglomeratic sequence appears to be little disturbed. No fossils were collected from the latter unit.

FIGURE 71.—Angular unconformity between the conglomeratic sequence of the Wind River formation (Twdr) and Mowry (Km) and Frontier (Kf) formations on Dubois anticlinal complex in center of sec. 1, T. 42 N., R. 107 W.

The uppermost beds assigned to the Wind River formation occur in isolated outcrops at the upper end of Little Horse Creek valley and at the northwest end of Horse Creek Basin. These strata, constituting the upper variegated sequence, consist chiefly of gray, greenish-gray, and pale-red highly tuffaceous and bentonitic shale, claystone, siltstone and fine-grained sandstone. Much landsliding has occurred in these beds at the upper end of Little Horse Creek valley. The thickness varies considerably; it is at least 100 feet in the NW¼ sec. 20, T. 43 N., R. 106 W., where the sequence is overlain by the Wiggins formation. A few vertebrate teeth were collected from the upper variegated sequence (colls. 6 and 7, fig. 69). These include *Paramys* and *Didymictis altidens*. C. L. Gazin of the U. S. National Museum concludes that the latter is a Lost Cabin species.

In areas to the east the lower Eocene rocks are overlain by the middle Eocene Aycross formation (Love, 1939, p. 66–75) which is characterized by variegated clays, shales, sandstones, conglomerates, and volcanic rocks. This formation has not been specifically recognized in the Du Noir area because all the uppermost variegated Tertiary strata seem to be of early Eocene age and they have therefore been assigned to the Wind River formation. The possibility exists, however, that the two upper units of the formation in the Du Noir area may be lateral equivalents of some parts of the Aycross formation. This interpretation is suggested by the unconformable relationship between the conglomeratic sequence and the middle variegated sequence on the Dubois anticlinal complex; this unconformity may correlate with that noted by Love (1939, p. 70) at the base of the Aycross formation in areas to the east. As will be discussed below, some parts of the Aycross formation may also be represented in the basal beds of the Tepee Trail formation, as the latter formation is defined in this report.

TEPEE TRAIL FORMATION

The Tepee Trail formation was named and described by Love (1939, p. 73) from exposures along the East Fork River about 12 miles east of the Du Noir area. There the strata contain a high percentage of volcanic material, are generally well bedded, green or brown, and have textures ranging from coarse angular breccias to finely laminated shale and tuff beds. The volcanic rocks are chiefly basic and typically are biotite-augite andesites and hypersthene-augite andesites. Fragmentary fossil evidence at the type section and its vicinity indicates an upper Eocene age. Either angular or erosional unconformities are present both at the top and at the base of the formation (Love, 1939, p. 74).

Because the Tepee Trail formation in the Du Noir area is apparently everywhere underlain directly by the lower Eocene Wind River formation, without any recognizable Aycross strata between them, it is possible that the basal part of the Tepee Trail formation, as it is defined in this report, may contain equivalents of the Aycross formation. This conclusion is further strengthened by the fact that the lower part of the Tepee Trail formation in the Du Noir area contains hornblende- and biotite-rich volcanic rocks similar to those described by Love (1939, p. 67, 77) as being characteristic of the Aycross formation, whereas the rocks in the upper part, which contain conspicuous amounts of pyroxene, are more like those of the Tepee Trail volcanics at the type section. Inasmuch as all the strata lying between the Wind River and Wiggins formations are green and brown, with none of the brightly variegated beds characteristic of the Aycross formation, the entire sequence is designated as the Tepee Trail formation in the mapped area.

The Tepee Trail formation crops out in a wide belt which extends westward from Burroughs Creek to at least as far as the western edge of the mapped area. Bright-green tuffaceous sandstone in the vicinity of bench mark 8818, near the top of Spring Mountain, is included in the formation. As far as could be determined it is not present around the base of Elkhorn Ridge between Horse Creek and the Wiggins Fork River, although here some of the coarse basal conglomerate of the Wiggins formation is similar in color to the Tepee Trail strata. In general the formation is poorly exposed; this is due mainly to the large amount of forest cover and to talus debris from the overlying Wiggins formation. However, some parts of the sequence are well exposed at the upper ends of the drainages of Little Horse and Sixmile Creeks, where conspicuous cliffs occur at the heads of large slump areas. No detailed measured section of the formation was obtained in the mapped area. The thickness varies greatly from one locality to another; it is about 575 feet thick on the west side of Du Noir Butte, where the basal bed is in sharp contact with the Madison limestone but where its upper contact with the Wiggins formation could only be approximately located. In the central part of the area the thickness is probably as much as 1,500 feet.

The Tepee Trail formation is a very distinctive unit because of its predominant bright-green color; it may include shades of olive drab, grayish green and brown. The sequence consists chiefly of interbedded sandstone, conglomerate, shale, and tuff, with rather well-defined bedding which indicates that most, if not all, of the strata are water laid. The conglomerate is composed mainly of angular to subrounded fragments of volcanic rock in a tuff or tuffaceous sandstone matrix. Most of the sandstone is highly tuffaceous, with both crystal and lithic fragments. The brown shale commonly contains abundant leaves and fresh-water invertebrates.

Everywhere that the basal strata were observed they consist of grayish-green fine-grained and well-bedded tuffaceous sandstone. The rocks contain a high percentage of quartz in addition to angular grains of plagioclase feldspar, biotite, hornblende, and magnetite. A few pyroxene crystals may be present and fragments of volcanic rocks are common. The microcrystalline groundmass is probably mostly clay, but it may also include some glassy material. Detailed studies of the feldspars were not made, but the plagioclase appears to range from andesine to labradorite, thus indicating that the tuffs are both andesitic and basaltic. Because no quartz was found in any of the volcanic rocks studied from this area, it is concluded that the quartz in the sedimentary rocks was derived from a nonvolcanic source; the other constitutents were derived in large part from volcanic sources.

The Tepee Trail strata become progessively coarser and more conglomeratic toward the top. The basal beds directly overlying the Madison limestone on the southwest edge of Du Noir Butte in the extreme northwest corner of the mapped area contain cobbles of volcanic rocks as much as 6 inches in diameter in a fine-grained tuff matrix. These beds, although forming the base of the formation at this locality, probably belong to the upper part of the sequence inasmuch as they lie at a higher elevation than the occurrences on Long Creek and at White Pass. Similar conglomerate is present in the upper part of the formation at the south end of The Ramshorn in the central part of the mapped area.

The volcanic rocks in the upper part of the Tepee Trail formation are mostly bright green to dark green, the color being due mainly to the conspicuous amount of chlorite(?) present. Much of the material is highly altered, as is indicated both by the large amount of chlorite(?) and by the altered condition, probably kaolinization, of much of the plagioclase. Volcanic pebbles in the conglomerate are invariably porphyritic, and they generally contain a higher percentage of augite and less hornblende and biotite than the tuffs and lithic fragments near the base of the formation. Some olivine may also be present. Some of the volcanic pebbles are red; these contain an abundance of red-brown hornblende and probably hematite in the groundmass. The plagioclase phenocrysts, where not considerably altered, exhibit excellent zoning and range from andesine to labradorite. Both basalt and andesite are thus represented. In contrast to the lowermost beds of the formation, no quartz grains were observed in the upper coarse conglomerate.

Fossil leaves were collected from the Tepee Trail formation at several localities along Sixmile Creek. The following specimens were identified by R. W. Brown: *Lygodium kaulfussi* Heer, *Salvinia preauriculata* Berry, *Sparganium antiquum* (Newberry) Berry, *Potamogeton* sp., *Carya* sp., *Zizyphus* sp., *Equisetum* sp., *Lemna scutata* Dawson, *Salix cockerelli* Brown, *Populus?* sp., *Platanus* sp., and *Cercidiphyllum?* sp. According to Brown (1952, written communication) this assemblage is of middle to late Eocene age. As mentioned previously, Love (1939, p. 78) assigned a late Eocene age to the sequence at the type section.

The Tepee Trail formation rests with a pronounced angular and erosional unconformity on the rocks of Paleozoic age along the north flank of the Du Noir anticline. Everywhere that the formation was observed in contact with the Wind River formation conformable relationships appear to exist. Inasmuch as the two upper units of the Wind River formation are not present at White Pass and in adjacent areas to the west, a period of erosion before the deposition of the Tepee Trail strata is suggested.

The contact between the Tepee Trail formation and the overlying Wiggins formation is nearly everywhere concealed by the dense forest around the southern margin of the Absaroka Range. This contact, inferred throughout, was determined from isolated outcrops in which the predominantly green strata of the Tepee Trail formation are overlain by the light-colored strata of the Wiggins formation. No Tepee Trail rocks were recognized east of Burroughs Creek, and the Wiggins formation rests upon rocks ranging in age from Precambrian to early Eocene. This relationship is due either to nondeposition of Tepee Trail strata or to deposition followed by complete removal by erosion before deposition of the overlying Wiggins formation. Probably both interpretations are possibilities. Tepee Trail strata lap up on the Paleozoic highlands of the Washakie Range and may not have been deposited on all surfaces at higher elevations. On the contrary, this formation occurs at higher altitudes than that of Horse Creek Basin, where Wiggins strata rest on the upper part of the Wind River formation, suggesting that Tepee Trail rocks were once present in Horse Creek Basin but were eroded away before deposition of the Wiggins formation.

EOCENE ROCKS, UNDIFFERENTIATED

Eocene rocks, undifferentiated, crop out in extensive areas on the northeast flank of the Wind River Range. These rocks, whose constituents were apparently derived from the higher parts of the Wind River Range to the west, were deposited over a surface of considerable relief that was developed before Eocene time and represent mountainward facies of the various Eocene formations that occur on the north side of the Wind River. Because of the lack of fossil evidence and the lithologic dissimilarity between these strata and the other Eocene rocks in the region, the sequence was not referred to a specific formation. The thickness of the Eocene rocks, undifferentiated, was not determined; it varies greatly in short distances. Where the preexisting surface was relatively high the deposit is only a veneer, whereas in preexisting valleys it is several hundred feet thick. The maximum thickness is developed in secs, 21 and 22, T. 42 N., R. 108 W., where the rocks form a high rounded hill which rises more than 200 feet above the pass through which the Du Noir tie camp road enters Warm Spring Creek valley. Apparently much of the debris that was deposited on the mountain flank was transported eastward from the higher parts of the Wind River Range through this pass. The lowermost exposures are found on the north side of Crooked Creek west of its mouth and along the north side of the Wind River in the E½ sec. 15, T. 42 N., R. 108 W. The strata are nearly flat lying, but there is a slight regional dip northeastward into the basin which may, in part, be a reflection of depositional dip.

The sequence consists chiefly of white to tan arkose and sandstone containing angular fragments of quartz and feldspar as much as one-fourth inch long and some dark grains. The beds are commonly limy. At several localities thin beds of carbonaceous shale with coal partings and tan siltstone and shale are interbedded with coarser grained strata. Coal beds, as much as 2 feet thick, are present in the NW¼ sec. 25, T. 42 N., R. 108 W., and have been mined in the past. A notable feature of the Eocene rocks, undifferentiated, is the almost complete absence of red beds that are so prominent in the Tertiary sequence on the north side of the Wind River. Some red strata mapped as Eocene rocks, undifferentiated, occur in an isolated outcrop on the steep dip slope of the Tensleep sandstone in the center of sec. 23, T. 42 N., R. 108 W.

The arkose beds are well exposed on the south side of Hat Butte. There they contain much volcanic material similar to that in both the lower part of the Tepee Trail formation and the middle drab sequence of the Wind River formation. Forming the prominent rim at the top of the butte is a 20-foot bed of brown slabby to crossbedded tuffaceous sandstone and conglomerate that is arkosic in part and contains fragments of chert and quartzite as much as 3 inches in diameter, in addition to smaller fragments of volcanic rocks. The principal constituents of the tuffaceous matrix include quartz, green-brown biotite, hornblende, plagioclase, and magnetite. One volcanic pebble contained an abundance of hornblende. The beds on top of the butte are finer grained and contain fragments of leaves and other organic material.

The relationships of the Eocene rocks, undifferentiated, to the thick sections of Eocene formations on the north side of the Wind River are not fully understood. The beds along the north side of Crooked Creek appear to underlie the middle drab sequence of the Wind River formation. The arkose beds at the base of that formation east of Stony Point are quite similar to those in the Eocene rocks, undifferentiated; both sequences also contain carbonaceous shale. The conglomerate with quartizite and volcanic pebbles near the top of Hat Butte is similar to the conglomerate which occurs at the base of the Tepee Trail formation along Long Creek, although the latter contains no quartzites, and also to the conglomerate near the top of the middle drab sequence of the Wind River formation on the east side of Bench Creek, in the SE¼ sec. 12, T. 42 N., R. 108 W., which contains both quartzite and volcanic fragments. The middle drab sequence of the Wind River formation also contains carbonaceous shale. It seems best, therefore, to correlate the major part of the Eocene rocks, undifferentiated, with the Wind River formation. The rocks with abundant volcanic pebbles may be equivalent to some part of the Tepee Trail formation, and the basal strata may represent some part of the Indian Meadows formation.

OLIGOCENE SERIES

WIGGINS FORMATION

The Wiggins formation includes the youngest Tertiary rocks in the Du Noir area and forms the spectacular scarps which outline the southern margin of the Absaroka Range (fig. 72). Based on a study of the vertebrate fossils the unit, named by Love (1939, p. 79) from the Wiggins Fork River, was assigned an Oligocene age (Love, 1956, p. 88).

In the Du Noir area the Wiggins formation is more than 1,000 feet thick and is composed of flat-lying massive volcanic conglomerates and breccia with volcanic rock fragments as much as 3 feet in diameter, interbedded with fine-grained tuffs. The volcanic rock is commonly dark whereas the matrix is mainly pink, gray, and white and contrasts sharply with the underlying dark-green strata of the Tepee Trail formation. The tuff is generally of lighter color than the conglomerate so that the alternation of tuff and con-

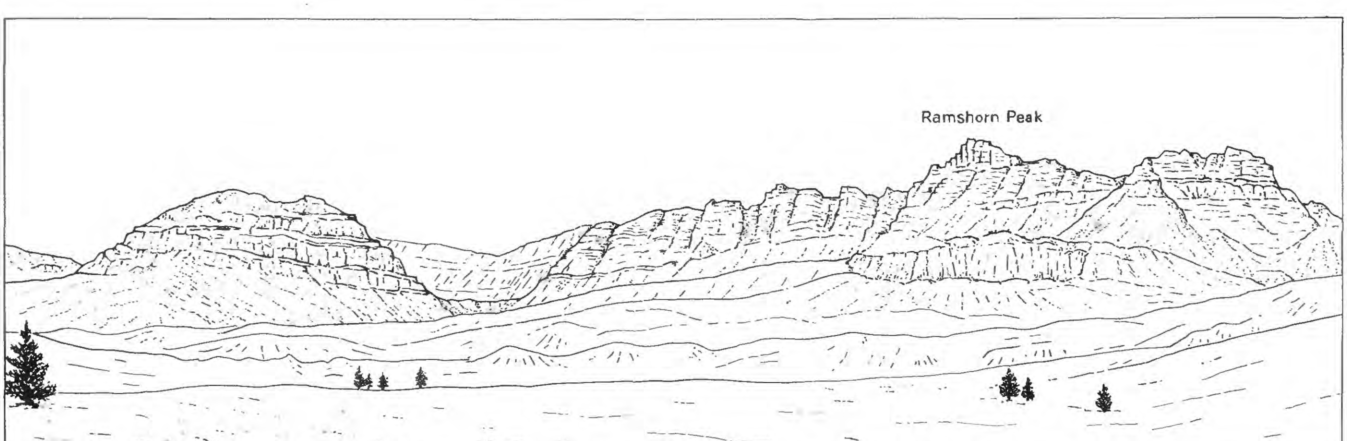


FIGURE 72.—The Ramshorn as viewed from the SW¼ sec. 24, T. 43 N., R. 108 W. Ramshorn Peak is highest point on skyline near right side of sketch. Wiggins formation forms massive cliffs and Tepee Trail sediments form rounded hills beneath.

glomerate produces the pronounced stratified appearance of the sequence. No flows were observed in the Du Noir area, but Love (1939, p. 80) noted some flows near the top of the formation in areas to the east.

A detailed stratigraphic section of the Wiggins formation was not measured, but thin sections of representative volcanic pebbles and tuff from different horizons were examined. The volcanic rocks are predominantly rich in pyroxenes, both augite and hypersthene, and, except for the red pebbles which have an abundance of red-brown hornblende, contain little or no hornblende and biotite. Plagioclase phenocrysts average about Ab_{45}. Olivine is common and magnetite is invariably present. An appreciable amount of what may be a feldspathoid mineral was observed in one pebble. The groundmass of most thin sections is microcrystalline and probably contains some glass. The tuff contains both lithic and crystal fragments and those near the base have a small amount of quartz which was probably derived from nonvolcanic sources.

The volcanic rocks described above differ from those noted by Love (1939, p. 81) to be characteristic of the type section a few miles to the east. There the rocks are commonly rich in biotite and hornblende, and the plagioclase is andesine in about 80 percent of the thin sections studied by Love. Enough data were not obtained in the present study to offer a suitable explanation for this variance in composition of the rocks between the Du Noir area and the type section. In general it would be expected that all the volcanic vents in a given area at a given time would have a common magmatic source but too little is yet known of possible source areas for the volcanic material in the Wiggins to draw any definite conclusions on this point.

Love (1939, p. 110–111) observed that some of the volcanic debris in the Wiggins formation was derived from small localized vents along the southern margin of the Absaroka Range, but suggested that the greater part came from "a great chain of tremendously active volcanos [which] must have extended from this area northwestward to Yellowstone National Park" as indicated by a thickening of the volcanic conglomerates to the north and northwest as well as an increase in the size and angularity of individual boulders. Hague and others (1899) have described large volcanic centers along the eastern margin of Yellowstone Park. The writer agrees that a larger source than small local vents must have existed because of the vast quantities of volcanic detritus involved.

QUATERNARY SYSTEM

Several kinds of Quaternary deposits, including moraines, landslide debris, terrace gravel, residual basalt debris, colluvium, travertine, and alluvium, are present in the Du Noir area. A detailed study of many of these deposits and their related physiographic features was made as an aid in the interpretation of the Quaternary history of other parts of the Wind River Basin. Further, since in this region the Wind River and Absaroka Ranges are in close proximity, an excellent opportunity is afforded for correlation of the glacial and erosional cycles of the two ranges. Although many of the deposits are composed of similar materials, there are sufficient differences in occurrence and terrain to distinguish one source from another in most places.

RESIDUAL BASALT DEBRIS

Extensive areas on Spring Mountain are covered by a deposit of angular boulders and cobbles, which is referred to as residual basalt debris (fig. 73). The debris consists almost entirely of blocks of dark-brown to black very hard basalt as much as 8 to 10 feet on a side and is unlike any of the debris derived from the Wiggins formation. The rock is commonly vesicular and consists mostly of small crystals of labradorite with a moderate amount of olivine and a minor amount of pyroxene. Excellent flow structure is exhibited in thin section. The basalt is not perceptibly weathered and this, in addition to the extreme angularity of the individual fragments, suggests that the rock was derived from a volcanic sequence younger than either the Tepee Trail or Wiggins formations, and that the blocks have been subjected to very little transport. Although the deposit is only a few feet thick, the blocks are sufficiently numerous to conceal effectively the underlying bedrock in most places. The basalt blocks are present at elevations ranging from about 8,600 feet near the top of Spring Mountain to about 7,500 feet along the north side of Little Alkali Creek; the occurrences at lower elevations

FIGURE 73.—Angular blocks of basalt on southwest flank of Spring Mountain, NE¼ sec. 22, T. 42 N., R. 106 W.

are found only on small interstream divides. Isolated occurrences are also present on the south side of Little Alkali Creek. It is concluded that the deposit was derived from a continuous basalt layer, probably a flow which at one time covered the area, and, as the easily eroded underlying bedrock was removed, the basalt was broken up into large fragments which were in effect let down in place. Nowhere is the basalt preserved as true bedrock nor were any feeder dikes observed in the area covered by the debris. This basalt is similar to that on Lava Mountain, 6 miles west of the mapped area. The Lava Mountain basalt was described by Love (1947) as the youngest Tertiary or early Quaternary volcanic rock in the region but older than at least some of the glaciation.

MORAINES

Extensive deposits of glacial debris are present in both the Du Noir and upper Wind River valleys and the Horse Creek-Wiggins Fork area. All these deposits are believed to be composed of till; no outwash material was recognized except that which may occur in terrace deposits. The moraines have not been differentiated on the geologic map, but two or more cycles of glaciation are represented. Because complete and detailed descriptions of these deposits involve many geomorphologic considerations, they are discussed under "Geomorphology."

LANDSLIDE AND GLACIAL DEBRIS, UNDIFFERENTIATED

Extensive areas on both sides of the Du Noir valley and on the east side of upper Horse Creek valley contain deposits that exhibit characteristics of both landslide debris and glacial debris. The deposits are best developed along the Du Noir valley, where their general upper surface slopes downward toward the valley from the glacial moraines which occupy the drainage divides. The terrain is very hummocky and irregular, with as much as 50 to 75 feet of relief in the vicinity of Dry Lakes. The deposits consist of a veneer of boulders and cobbles of Tertiary volcanic rock and a minor amount of rock of Paleozoic age. Some boulders are as much as 20 to 30 feet in diameter. Many small recent slides and flows have occurred in areas of sharp relief. The debris is underlain for the most part by the soft plastic bentonitic and tuffaceous beds of the middle variegated sequence in the Wind River formation. These beds were probably saturated by glacial melt water and the material moved down the slopes along the Du Noir valley by the process of solifluction. Some of the coarser material may have originated from ground moraines deposited by the receding glaciers. The deposits on the east side of upper Horse Creek valley exhibit somewhat similar characteristics, although here the landslides were motivated in large part by the steepness of the slopes which rise in elevation eastward to the nearly vertical cliffs along the west side of Elkhorn Ridge.

LANDSLIDE DEBRIS, UNDIFFERENTIATED

Extensive mass movements of soil and rock have occurred at many localities throughout the Du Noir area. The combination of high relief, abrupt and steep valley walls, and the soft plastic character of a large part of the Tertiary sequence is particularly favorable for large-scale mass wasting. Some of the land forms thus produced have been extensively modified by erosion but others are so recent as to be still almost devoid of vegetation. The more recent occurrences, especially mudflows, are strikingly illustrated on aerial photographs.

An attempt is made in this report to classify the various types of mass movements, as completely as observations and field relationships permit, according to the scheme proposed by C. F. S. Sharpe (1938). The term "landslide debris," however, is used on the geologic map for all deposits resulting from mass wasting. Sharpe recognizes slides, flows, and subsidence as the three main types of mass movements. The first two types are differentiated on the basis that true slides have a slip plane separating the moving mass from the stable ground whereas flows do not; the third type, subsidence, is distinguished by having no free fall. Further subdivision of the main types of mass movement is based on rate of movement, kind of material involved, and relative water or ice content. The following terms, as defined by Sharpe, are used in the discussions to follow:

1. *Rockslide*—the downward and usually rapid movement of newly detached segments of the bedrock sliding on bedding, joint, or fault surfaces or any other plane of separation.
2. *Slump*—the downward slipping of a mass of rock or unconsolidated material of any size, moving as a unit or as several subsidiary units, usually with backward rotation on a more or less horizontal axis parallel to the cliff or slope from which it descends.
3. *Debris-slide*—rapid downward movement of predominantly unconsolidated and incoherent earth and debris in which the mass does not show backward rotation but slides or rolls forward, forming an irregular hummocky deposit which may resemble morainal topography.
4. *Earthflow*—a flow whose movement is relatively slow, usually confined to gentle slopes.
5. *Mudflow*—a flow which has a rapid rate of movement, high water content, and relatively steep gradient, and which is usually confined to former stream channels.

The extensive deposits of landslide and glacial debris, undifferentiated, in areas on both sides of the Du Noir valley have been described previously in this report as being partly the product of mass wasting because of the saturation of the bedrock by glacial melt water. The material probably flowed very slowly downslope toward the valley. The distance any particular mass moved, however, was probably slight but sufficient to warp the surface and produce irregular ridges and impound water in small ponds. Small recent slides and flows are present in some parts of these areas.

A large rockslide occurs on the east side of the Du Noir River southeast of the Pickett ranch, where it forms a conspicuous lobe extending into the valley. This slide is superimposed upon the older deposits of landslide and glacial debris, undifferentiated, which lie both north and south of it. The rockslide merges with other mass-wasting debris which originated farther up Sixmile Creek. At the upper end of the slide, in the SE¼ sec. 3 and NE¼ sec. 10, T. 43 N., R. 108 W., there is a large troughlike scar from which the debris was derived. At its northern end resistant Paleozoic rocks are inclined at about 25° southward, and furnished glide planes upon which the slide probably originated. Both Paleozoic and Tertiary strata, in addition to the deposits of landslide and glacial debris, undifferentiated, are involved.

Landslide and flow debris has accumulated in extensive areas on the west side of the upper Du Noir valley. The southern end of this series of mass movements has been the most active, as is shown by the large lobe extending into the west side of the valley in the S½ sec. 16, T. 43 N., R. 108 W. Tuffaceous porous sandstone of the Tepee Trail formation, which forms a cliff 100 feet or more in height, is involved. The margin of the cliff is receding westward, the cliff face remaining more or less parallel to the Du Noir valley. Great masses of rock are continually breaking away from the cliff, and, as a consequence, the entire area lying between the cliff and the valley appears as a single mass of slide and flow debris with highly irregular topography and innumerable small ponds and swamps. The original mass movement was probably that of earthflow, but it is difficult to classify the process, described above, that is still active at the present time. The freshly fallen masses at the base of the cliffs, which still have trees and other vegetation growing on them, do not appear to have backward rotation characteristic of slumps and, on the contrary, are not composed of unconsolidated material characteristic of debris-slides. The process, which also applies to many other localities in the area, is probably best described as a combination of these two types of mass movement.

Large earthflows characterize the extensive mass-wasting in the Sixmile Creek drainage and have involved, for the most part, plastic strata in the Tepee Trail formation. Numerous large vertical scars, devoid of vegetation, mark points from which much of the debris was derived. The upper parts of the flows coalesce in a large swampy area of extremely irregular terrain. Although some of the movement in the accumulated debris closely approximates that in mudflows, most of the material probably moved down Sixmile Creek valley at a slow rate. At present new material is being added at the upper ends of the flows largely by the process of slumping or debris-sliding.

In the northwestern part of the mapped area, north of the West Fork of the Du Noir River, a large earthflow involves both the Tepee Trail formation and the more resistant Madison limestone with the latter furnishing a surface over which the flow moved. Large conspicuous scars are present in the north and northwest parts of the flowage area, as well as large lakes and ponds. The hummocky topography can readily be seen along the road on the north side of the West Fork. Although small mudflows are apparent in the northern part of the flow mass, the movement at its lower end appears to have been much slower.

Another relatively large area of mass wasting occurs south of the Wind River on the west side of the Du Noir tie camp road. Tertiary arkose strata are involved in what appears to be a rockslide whose glide plane was probably the northward dipping underlying Paleozoic rocks. Steep scarps rise abruptly from the head or southern extremity of the slide. A small more recent mudflow in the SE¼ sec. 15, T. 42 N., R. 108 W., has diverted the course of the Wind River so that it now flows in a northeastward direction across a wide alluvial flat instead of through the old channel which lies along the base of the steep slopes to the south.

Numerous small earthflows and mudflows have occurred along the west side of Little Horse Creek north of the Sinclair-Wyoming Oil Co. Dubois Unit well 1. High relief, the east-west trend of the Mesozoic rocks and the plastic nature of much of the Tertiary sequence as well as the underlying Mesozoic rocks account for most of this mass wasting. The flat meadowland near the upper end of Little Horse Creek valley was doubtless developed because flows blocked the drainage farther downstream. The region lying north and west of this meadow is largely covered by slide and flow debris. This series of mass movements was developed in the Tepee Trail formation and in soft plastic strata of the uppermost part of the Wind River formation, which crops out extensively in the central part of the area. Prominent cliffs formed by the lower part of the Tepee Trail formation rise abruptly above the north edge of the slide area. This cliff presents an almost continuous scar from which large slumps and debris slides originated. Much of the material moved valleyward as earthflows and mudflows. Recurrent movements of some parts of the mass are clearly indicated by recent mudflows that are superimposed on older ones. The lowermost extremities of these flows terminate in low concentric ridges, the outlines of which in plan view are convex downslope. These ridges are composed largely of locally derived material that was pushed up in front of the moving debris.

One of the most spectacular mudflows in the region occurs north of the junction of secs. 28 and 29, T. 43 N., R. 107 W., near the center of the mapped area. This flow is confined to a narrow valley and is about three-fourths of a mile long. The debris originated in the high cliff at the upper end of the flow and moved down a slope inclined at not more than 15° in some places.

The large earthflow on the southwest side of Horse Creek near the Livingston ranch involves mostly Mesozoic rocks, although the Indian Meadows formation, which crops out near the top of the ridge along the south edge of the flow, contributed some of the debris. The conspicuous red sediments in the debris were derived largely from the Triassic Chugwater formation which underlies the area. High relief was the primary cause of the flow. In some places along its upper, or south, edge small mudflows have developed in the plastic claystone of the Cloverly and Morrison formations. Numerous small lakes and ponds are present in the hummocky terrain. Some of the material in this deposit may have originated as glacial debris, inasmuch as glacial deposits occur at the same level in adjacent localities to the northwest along Horse Creek.

One of the most extensive and clearly outlined earthflows in the mapped area descends northward from the north end of Table Mountain (figs. 74 and 75). The flow originated near the top of the mountain in soft bentonitic strata of the Wind River formation. Some of the movement may have approximated that of a mudflow. The northern edge of the flow rises about 10 feet above the smooth slopes to the north and the material advances down these slopes without any apparent disturbance of the underlying rocks.

Many of the small local slides and flows, except those of special interest, have not been specifically mentioned in the foregoing discussion, since they are so very numerous. Most of them are slumps and debris-slides which occur on steep slopes along the edges of steep hills and cliffs, very similar to those that have already been described. Accumulations of talus debris are common along the escarpments which outline the southern margin of the Absaroka Range, but none of these have been shown on the geologic map.

FIGURE 74.—Mudflow at north end of Table Mountain.

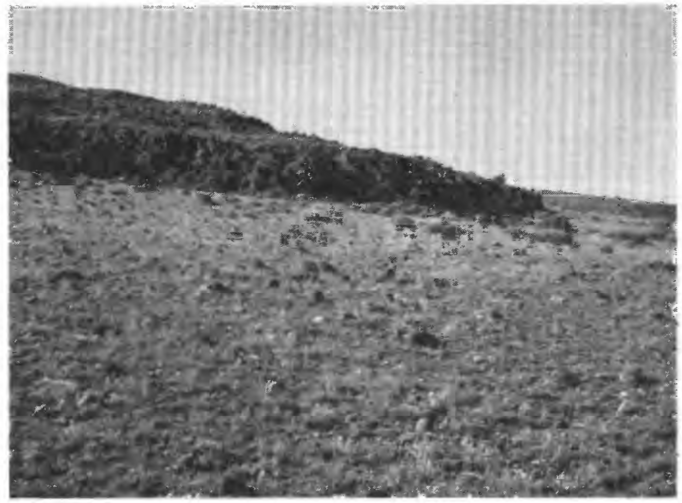


FIGURE 75.—View of front edge of mudflow shown in figure 74. Outermost margin about 10 feet high.

TERRACE DEPOSITS AND COLLUVIUM

Seven levels of terrace deposits, classified according to their respective heights above the present stream drainages, have been distinguished in the Du Noir area. A detailed study of these deposits reveals a complex erosional history for the northwestern part of the Wind River Basin. Inasmuch as the terraces are closely related to glacial features, the detailed descriptions and correlations of the various terraces are given under "Geomorphology."

The term "colluvium" is used in this report to designate gravels which have been let down on the steep slopes which separate major terrace levels. The material is derived from the terrace deposit next above it and has moved downhill by gravity. Deposits of colluvium commonly only a few feet thick were mapped only where the underlying bedrock was completely obscured over wide areas.

TRAVERTINE

Deposits of travertine occur near the mouth of Warm Spring Creek and in the NW¼ sec. 23, T. 42 N., R. 108 W. The travertine is very porous and contains much silty material. In places along Warm Spring Creek much bouldery debris, with some rock fragments as much as 3 feet in diameter, are incorporated in the deposits. Many travertine outcrops also occur near the south (upper) edge of the conspicuous terrace which lies south of the Wind River and east of Warm Spring Creek. Enough data were not obtained within the mapped area to explain adequately the origin of these deposits. In some places it appears that they coincide closely with the contact between the Tensleep and Phosphoria formations. Their nearly linear pattern is suggestive also of fault control, but no faults are present at least west of Warm Spring Creek. That the travertine is closely associated with the development of the prominent terrace level on the south side of the Wind River is clearly evident from the fact that the gravels in the terrace contain much carbonate material which has cemented the terrace deposit into a massive conglomerate. Such an occurrence was observed in the center of W½ sec. 1, T. 41 N., R. 107 W., at the west end of the terrace upon which the Dubois airport was constructed. To the southeast J. F. Murphy (1953, oral communication) found tuffaceous material in travertine deposits. None was observed in the mapped area, but it may be present in small amounts.

ALLUVIUM

Alluvial deposits, which form relatively wide belts along most of the major streams, consist chiefly of gravel, sand, and silt. In the Du Noir valley large alluvial fans, consisting of coarse gravels, have spread valleyward from the mouths of Fivemile and Sixmile Creeks and the East and West Forks of the Du Noir River. In part, the alluvial material has been derived from slope wash of the adjacent steep valley walls; consequently most of the deposits are red because of a partial source in the lower Eocene rocks. In the Du Noir valley, however, the soil has been extensively modified and reworked by the meandering of the Du Noir River and is commonly very dark in color because of the large amount of organic material in it. Unlike the other major streams in the area the Wiggins Fork River, bounded in most places by steep canyon walls, flows through a channel that is entirely covered by coarse boulder and cobble debris. The course of the stream is continuously being changed by the slight shifting of gravels from one place to another within the channel.

IGNEOUS ROCKS

DIKES

The only dike observed in the mapped area occurs near the center of sec. 20, T. 43 N., R. 106 W., cutting vertically through strata in the uppermost part of the Wind River formation. The dike is from 1 to 3 feet thick and crops out for a distance of about 100 feet. The rock is dark green in the center, but it becomes lighter colored and in places red along its outer margin. Thin sections of the rock were not studied, but it appears similar to some of the basalts studied from the Tertiary volcanic conglomerate sequence. It is slightly vesicular, suggesting that the present exposed part of the dike was near the surface at the time of the emplacement of the dike. The significance of this intrusive is not known. Perhaps it represents a small feeder dike for some of the volcanic material in the Wiggins formation and, as such, may be associated with a local vent that now lies buried under the conglomerates of the Wiggins formation of Elkhorn Ridge. On the contrary, the dike may have been emplaced later and is related to the basalt which forms the surficial deposit on Spring Mountain, although none of this residual basalt debris occurs in the vicinity.

STRUCTURE

The Du Noir area is comprised essentially of three major structural divisions: the northeast flank of the Wind River Range on the south, an intervening synclinal basin thought to be a northwestern extension of the Wind River Basin, and the Washakie Range on the north (fig. 76). The relationships between the folds

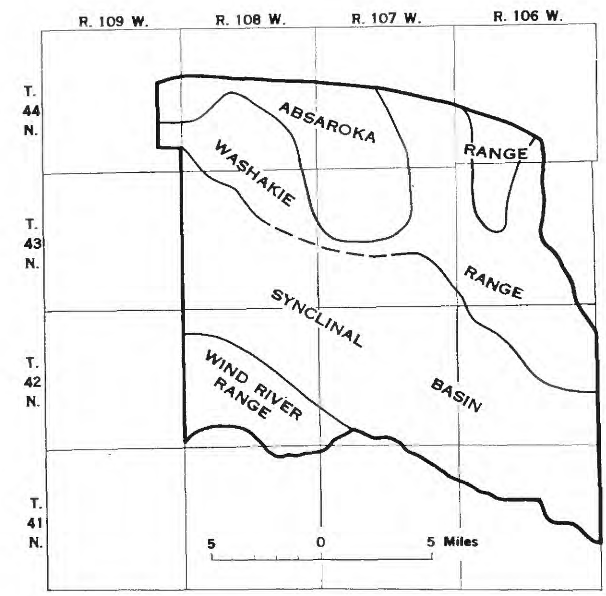


FIGURE 76.—Sketch map showing major structural divisions of the Du Noir area.

and faults in the mapped area to those of adjacent areas are shown in figure 77. No structure is apparent in the Tertiary volcanic rocks along the southern margin of the Absaroka Range, which is an erosional remnant and will not be considered in the following discussion on the structural geology of the region.

The trend of the structural features throughout most of the mapped area is approximately N. 45° W., but in the western part it is more westerly. The most intense folding and faulting has occurred along the south edge of the Washakie Range and in the northern portion of the synclinal basin. Elsewhere, as along the flank of the Wind River Range and in the Du Noir anticline, folding has been more gentle and few faults are present. Asymmetric anticlinal folds have their

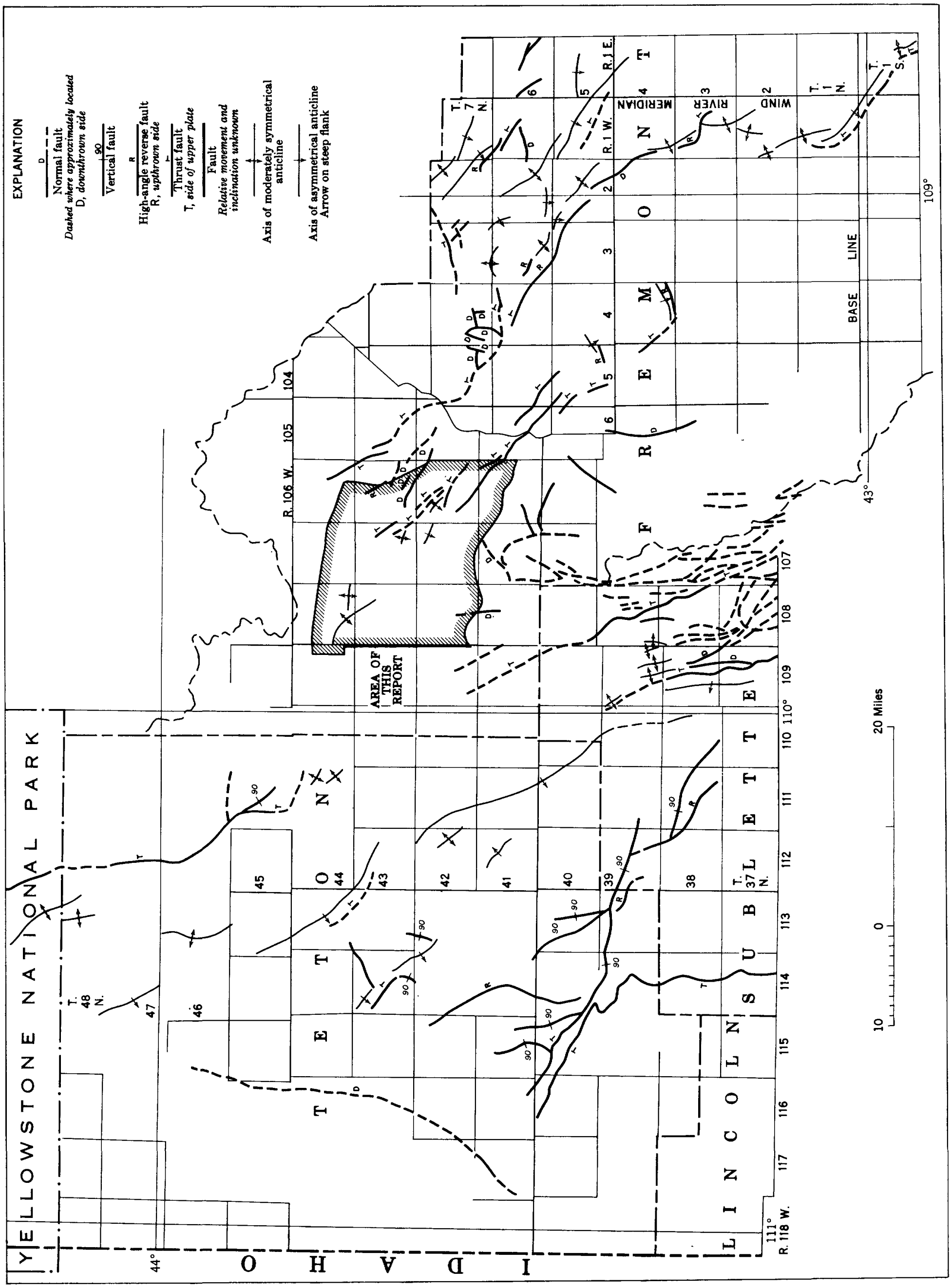


FIGURE 77.—Tectonic map of a part of west-central Wyoming.

steep flanks on the southwest, and, with one exception, the movement of the overriding blocks of thrust or high-angle reverse faults has been relatively southwestward. The overriding block of the Wiggins Fork Trail fault in the northeast corner of the area has moved relatively northeastward. The lower Eocene rocks have been highly folded and faulted in the eastern half of the synclinal area, but no structure was observed in the Tertiary rocks in the western half. It is concluded, therefore, that the initial broad synclinal and anticlinal folding of the Laramide Revolution in the Du Noir area was effected before the deposition of the lower Eocene rocks and that the more intense deformation restricted in large part to the synclinal basin occurred during or after deposition of these rocks.

METHOD OF STRUCTURE CONTOURING

Two contour horizons were selected to portray the general structure of the region; the top of the "upper Sundance" served as the horizon on the Dubois anticlinal complex and the adjacent synclinal area to the south, and the top of the Precambrian was utilized as a datum for other regions. The structure contour interval is 500 feet. On the large-scale geologic map of a part of the Dubois anticlinal complex (pl. 27) contours were drawn on the top of the Gypsum Spring formation at 100-foot intervals. Surface elevations were obtained by aneroid barometer, and, because at many places lines of elevations were projected many miles from bench marks, it was impossible to maintain a high degree of accuracy for vertical control.

In areas where intense deformation had occurred it was impossible to project with any degree of accuracy contours on the datum horizon from surface elevations and dips. The lack of subsurface data and limited exposures also contributed much to the uncertainty of structure contouring. Throughout most of the northeastern part of the mapped area, lines of cross section were considered the best means for obtaining control points for structure contours and several sections, in addition to those that accompany this report, were constructed. Because of asymmetry of folding only the approximate position of the traces of the axes of folds on the contour horizons are shown. In some cases the inclination of the fault planes was observed whereas in others the subsurface traces were subject only to the writer's interpretation. In areas of moderately gently dipping strata, with dips usually less than 30°, datum elevations were computed readily from the surface elevations, surface attitudes, and stratigraphic thicknesses. Structure contours are generally limited to the outcrop belts of the Mesozoic and Paleozoic rocks. Where extensive overturning is present, as in the belt on the north side of the EA fault, structure contouring was not attempted. This belt served as a convenient boundary between contours drawn on the top of the Precambrian and those on top of the "upper Sundance." On much of the large anticlinal uplift which forms the main part of the Washakie Range in the northeast portion of the mapped area, structure contours were not drawn.

WIND RIVER RANGE

The Wind River Range is formed from a large anticlinal uplift that trends northwest through west central Wyoming for a distance of about 100 miles. The range is asymmetric, with the steep flank on the southwest, and there is large-scale thrust faulting at its northwestern end (Richmond, 1945; Baker, 1946). In contrast, moderate monoclinal dips generally prevail along the northeastern flank of the range.

In the Du Noir area the Paleozoic strata dip about 20° northeastward into the Wind River Basin. The continuity of the beds is interrupted by a normal fault which trends nearly north-south along the west edge of Warm Spring Mountain. The fault is here referred to as the Warm Spring Creek fault, from the stream upon whose south bank the fault is best exposed. The west side of the fault is downdropped, placing Flathead sandstone against Precambrian rocks along an almost vertical plane. Structure contours show that the vertical movement along the fault was between 1,500 and 1,750 feet. A small normal fault may be present in the SW¼ sec. 22, T. 42 N., R. 108 W., where an offset can be seen in light-colored beds on the hillside. At this locality, however, the exposures are poor and definite evidence for faulting is lacking. It is possible that this fault, if present, is a continuation of the Warm Spring Creek fault and the contact between the Paleozoic and Tertiary rocks on the west side of Warm Spring Mountain is a fault contact because it is along a nearly straight line between the two faulted localities. Here again, exposures are poor and the relationships cannot readily be observed. The offset in the Tertiary beds, however, is not nearly so great as the offset in the Paleozoic strata.

SYNCLINAL BASIN STRUCTURES

The synclinal basin which separates the Wind River Range from the Washakie Range is considered a northwestern extension of the Wind River Basin. It has been referred to as the North Fork syncline by Love (1939, p. 94–96). The entire west half of the basin is covered by Tertiary or younger rocks so that pre-Eocene structures in the underlying Paleozoic and Mesozoic rocks are effectively masked. With one exception, no deformation, other than regional northward dips of from 2° to 4°, is apparent in the Tertiary rocks in that part of the basin, which leads to the conclusion that after early Eocene time very little deformation took place. The one exception is an 8° southward dip in the Wind

River formation along the north side of Sixmile Creek (E½ sec. 15, T. 43 N., R. 108 W.) which may reflect renewed uplift of the Du Noir anticline. However, movement of this fold after early Eocene time is not reflected in the Indian Meadows formation along the West Fork of the Du Noir River so that the inclination of the beds of the Wind River formation may be the result of slumping which is very prevalent in that area. Inasmuch as the lower Eocene rocks rest with marked angular discordance on the Paleozoic and Mesozoic rocks in the southern part of the mapped area as well as in other areas, much pre-Eocene deformation is indicated and the center of the basin may therefore contain broad anticlinal and synclinal folds that are not reflected in the Tertiary strata.

Outcrops of Mesozoic rocks at Dubois and along Horse Creek and Little Horse Creek provide enough data to determine the major structural elements in the central part of the basin. In this part of the basin there are two large synclines separated by the Dubois anticlinal complex (cross section *C—C''''*, pl. 26). Enough data are not available, however, to indicate the structural relief of either syncline, but both are believed to be of major proportions.

The southernmost syncline, which forms approximately the south half of the basin, is hypothetically shown on cross section *C—C'* (pl. 26). At Dubois, northward dips in the Mesozoic strata range from 10° to 15°. The dips in the Mesozoic rocks along the south limb of the Dubois anticlinal complex are 35° southward, but they may steepen considerably at depth, producing much more asymmetry than is shown in the cross section. Geophysical data suggest that the Little Alkali Creek fault extends westward from Horse Creek along the south edge of the anticline. This extension has not been confirmed by drilling and has not been shown on the cross section. Broad flexures in the lower Eocene rocks northeast of Dubois, south of the Wind Ridge fault, lead to the conclusion that there is folding or faulting in the center of the syncline.

The Dubois anticlinal complex is so designated because it consists of several anticlines and synclines superimposed on a large anticlinal uplift. Only the eastern part of the structure is visible on the surface; the western extension is covered by Tertiary strata. The total structural relief between the crest of the fold and the troughs of the adjacent synclines could not be determined accurately; it may be as much as 4,000 to 5,000 feet. Oil is produced from the Phosphoria formation in the Sinclair-Wyoming Oil Co. Dubois Unit well 1 which is on a small independent closure as shown on plate 27. The anticlinal complex is asymmetric to the southwest and, as previously discussed, may be much more asymmetric than is shown on the accompanying cross sections, or even faulted. The small subsidiary folds plunge to the southeast, as does the structure as a whole. Data are not available to indicate whether the anticline plunges to the northwest as well. The oldest strata exposed on the anticline are in the upper part of the "lower Sundance."

The southwest flank of the anticlinal complex was intensely deformed. At least 5 small folds, 3 anticlines and 2 synclines, and 3 thrust faults as well as numerous cross faults and abundant fractures are present. Plate 27 is an enlarged geologic map of this area. The southwest flanks of the anticlines are commonly overturned, but this feature may become less pronounced at depth although the beds are still vertical to overturned in the bottom of the Dubois Unit well 1. The northernmost thrust faults are best exposed on the west side of Little Horse Creek, whereas on the east side of the creek their traces are largely obscured by landslide debris. Both faults have little stratigraphic displacement and involve Morrison and Cloverly strata for the most part. The northern fault places both "lower" and "upper Sundance" upon beds of the Morrison and Cloverly formations in the vicinity of the Dubois Unit well 1, but passes eastward into a small sharp asymmetric anticline. At the west end of the southern fault the Fort Union(?) formation appears to have been faulted over Mowry shale. Eastward along this fault the lower part of the Morrison and Cloverly sequence, rusty beds, and Thermopolis shale are involved. On the west side of Little Horse Creek the plane of the northern fault dips northward about 30°, yet no evidence was found in an electric-log study of the two wells to indicate that faulting had occurred so near the surface in either well. As is suggested in cross sections *A—A'—A''* and *B—B'* (pl. 27) the faults probably become bedding-plane faults; in this case, it would be difficult to detect faulting from the electric logs, and the faults could be much more extensive than shown on the cross sections. There is also the possibility that the two faults may come together at depth, forming one large bedding-plane fault. The presence of an extensive but shallow thrust here could account, at least partly, for the intense folding along the crest of the anticlinal complex.

From available evidence it could not be definitely determined whether any faults are present near the bottom of the Dubois Unit well 1. Only a small part of the Tensleep appears to have been encountered and the structure can be interpreted as being that of an overturned anticline rather than that of a fault (cross section *A—A'—A''*). If a fault is present between the crest of the fold and the bottom of the well, the displacement is slight. However, in following the structural pattern of many of the large anticlines in this region, it is highly probable that the Dubois anticlinal complex is faulted somewhere along its southwest flank, the fault plane being below the bottom of the Dubois well 1. Either the Wind Ridge or Little Alkali Creek faults could extend underneath the complex, but, because of the almost complete lack of subsurface information, such an interpretation has not been presented on cross section *C—C′—C″* or by structure contours.

Another small thrust fault is present at the extreme southeast end of the structure where Mowry shale has been faulted upon beds of the Fort Union (?) formation, which have been sharply infolded along with the Mowry shale directly on the south side of the fault (fig. 65). This fault apparently passes into an overturned syncline to the northwest, but the relationships in the Mowry shale are quite obscure. Tertiary strata are involved in this fault at its extreme eastern end. Only the larger cross faults could be shown on the geologic map; most are normal faults with only slight displacement. Many of the smaller cross faults, which are most conspicuous in the basal white sandstone of the rusty beds, show only lateral movement.

At least two anticlines are present on the north flank of the Dubois anticlinal complex, one along Brent Creek in sec. 26, T. 43 N., R. 107 W. (cross section *B—B′*, pl. 26), and the other southeast of the EA ranch in secs. 8, 9, and 16, T. 42 N., R. 106 W. (cross section *D—D′*, pl. 26). Both are moderately symmetrical and plunge to the southeast. Structure contours on the top of the "upper Sundance" show the writer's interpretation of the relationships of these folds to the main anticlinal structure. Mowry shale is the lowest exposed formation in the fold along Brent Creek, where outcrops are exceedingly poor because of a large amount of landslide material and forest cover. Only the eastern end of the fold is exposed, so that its overall extent and value as a potential oil trap could not be determined. It trends nearly east-west and plunges about 30° eastward. Structural relief between the crest of the anticline and the trough of the adjacent syncline to the north is about 1,500 feet.

The structural relationships of the anticline southeast of the EA ranch are also very obscure. Evidence for the fold is found in the limited exposures of the Cody shale along the east edge of Horse Creek valley. A small outcrop of sandstone and shale, which, because of the presence of sandstone, is at least 1,200 to 1,300 feet stratigraphically above the base of the Cody shale, on the section line between secs. 8 and 9, T. 42 N., R. 106 W., has a northeastward dip of 42°. Southerly dips were obtained in the Cody shale in the vicinity of the junction of secs. 8, 9, 16 and 17. The fold, which plunges eastward, is probably cut at depth by the Little Alkali Creek fault. Its western extent could not be determined; therefore its actual structural relationship to the main anticlinal complex is not known. The syncline adjacent to this fold on the south is well defined in the Indian Meadows formation which overlies the Cody shale in that area.

East of Horse Creek the lower Eocene rocks have, in places, been highly deformed (cross section *E—E′*, pl. 26) in front of low-angle thrust faults. Although no large folds are present in the Tertiary strata, the thrust-fault belt of deformation falls in direct line with the Dubois anticlinal complex. The Wind Ridge fault, mapped and described by Love (1939, p. 95–96), extends northwest from the eastern margin of the mapped area along the south edge of Table Mountain to Horse Creek. No traces of the fault were found west of Horse Creek. The Wind Ridge fault plane is well exposed at many localities (fig. 78). In the SW¼

FIGURE 78.—Wind Ridge fault, SW¼ sec. 34, T. 42 N., R. 106 W. Beds above fault are massive conglomerates of Indian Meadows formation; those below are soft variegated beds of Wind River formation.

sec. 34, T. 42 N., R. 106 W., the dip of the fault plane is 23° north. Southeast of the road that leads from Dubois to Little Alkali Creek massive conglomerate in the Indian Meadows formation is thrust over soft variegated beds of the Wind River formation, whereas northwest of the road fine-grained variegated beds of either the Wind River or Indian Meadows formations occupy the overriding block. This change in stratigraphic horizon is caused by progressively younger beds swinging around the northwest-plunging end of a small anticline on the north side of the fault. This fold is well developed for a mile or more on each side of the road, but at its southeast end it dies out into sharp drag dips along the fault. As the fold has little structural relief and is closely associated with drag folding, it is probably confined to the overriding block.

The thrust fault which passes near the Wind River triangulation station on the eastern edge of the area could not be traced west of Table Mountain. Along this fault Cody shale has, in places, been thrust over Indian Meadows strata.

The Little Alkali Creek fault extends northwest from the north end of Table Mountain at least as far as Horse Creek. Its trace could not be found east of Table Mountain, but the fault may be present in the subsurface west of Horse Creek, as suggested by geophysical data. Both Cody shale and massive conglomerate beds of the Indian Meadows formation have been thrust over the middle variegated sequence of the Wind River formation. The fault relationship can best be seen from the road that leads to the EA ranch. Dips in the lower Eocene strata in the high hill on the east side of Horse Creek valley change abruptly from nearly horizontal to vertical. The fault plane, however, is rather obscure and its inclination was not determined. The stratigraphic displacement is not known, but it is thought to be appreciable.

The northernmost syncline of the basin, which separates the Dubois anticlinical complex from the Washakie Range, is almost completely overriden by the south flank of the range along the EA fault (section *D—D′—D″*, pl. 26) so that only the south limb of the syncline is visible. The magnitude of the syncline is indicated by the 30° to 40° north dips in the Cody shale in the vicinity of EA Mountain and the EA ranch, but otherwise very few observable data are available for determining its structural relief and overall extent. In some areas, such as north of Brent Creek in the NE¼ sec. 26, T. 43 N., R. 107 W. (cross section *B—B′*, pl. 26), it might be possible to reconstruct the overturned north limb of the syncline without faulting it, but the amount of overturning in the strata along Burroughs Creek and the structural relationships farther southeast suggest that the entire north limb of the syncline has been extensively thrust faulted. This interpretation has been presented on all the cross sections that were constructed across this feature.

WASHAKIE RANGE

The Washakie Range has been described by Love (1939, p. 5) as being a "series of faulted folds, en échelon, beginning with the eastern flank of Black Mountain, extending 70 miles northwest of the western end of the Owl Creek Mountains, and ending with the western flank of Buffalo Fork Mountain, west of Togwotee Pass." The Du Noir area includes the middle part of the range as it is thus defined (fig. 57). This extensive anticlinical uplift, which reaches mountainous proportions with elevations of more than 10,000 feet in places, was completely buried by Tertiary pyroclastic rocks and has now been partly exhumed. As noted by Love (1939, p. 6) the flanking strata of Paleozoic age are at generally higher elevations than the Precambrian rocks; this is well illustrated by the Paleozoic outcrops north of Carson Lake along the north edge of the mapped area. In some regions the range is still completely buried, as beneath The Ramshorn in the north-central part of the Du Noir area. The northeast flank is nearly everywhere concealed so that very little is known of its structural characteristics. Love (1939, p. 5) expressed the opinion, and the writer concurs, that the still-buried parts of the Washakie Range are not much higher, if at all, than the highest elevations attained in its presently exposed parts. Thus it is believed that in many places the central Precambrian core of the range is now visible. Where the central and southwestern parts of the Washakie Range are exposed they commonly consist of large anticlinical folds which have been extensively faulted along their southwest margins.

In the Du Noir area the Washakie Range is represented by the Du Noir anticline in the northwestern corner (cross section *A—A′*, pl. 26) and by a broad anticlinal uplift that occupies nearly the entire northeast quarter (cross section *B′—B″*, pl. 26); these two large folds appear to be in echelon.

The Du Noir anticline extends northwest throughout the area of outcrop of the Paleozoic rocks in the northwestern part of the mapped area. The dips on the south flank are as much as 45° but average around 25°. The north flank is more gentle, with dips generally less than 18°. The oldest formation exposed in the fold is the Darby formation, in East Fork Canyon. The axial trend describes an arcuate curve, convex to the north, and the axis plunges southward about 15° to 20°. The large bulge in the structure contours along the east side of the structure is part of a small subsidiary anticline and syncline which plunge eastward. No westward closure is apparent within the mapped area. Distinctive features are local reversals in dip on the south flank of the anticline near the mouth of the West Fork and again on the north side of the West Fork along the western margin of the mapped area. The significance of these small warps is not fully understood. It is possible that faulting accompanied the folding of the anticline and that the reversals in dip represent drag dips on the toe of a thrust plate, but, because there is no positive evidence for faulting in the exposed parts of the fold, such a conclusion is not warranted. It is notable, however, that features such as these, only on a much larger scale, are present on the upper plates of the Burroughs Creek and North EA faults.

The large complex anticlinical uplift in the northeast quarter of the mapped area has an extensive core of Precambrian rocks that is flanked on the north, west, and south sides by high ridges of Paleozoic rocks that attain elevations of as much as 10,000 feet. This uplift is believed to represent a portion of the in-echelon central core of the Washakie Range. Except for the west side of Wiggins Fork Canyon and the area north and west of the T-Cross ranch, the Precambrian core of the uplift is almost completely concealed by Tertiary or glacial debris.

The southwest flank of the uplift is steep and highly faulted. The EA fault, although classified as an inferred or approximate fault throughout its entire length, is believed to be the most extensive thrust fault in the entire area and the dividing line between the Washakie Range and the synclinal basin to the south. The fault is nowhere exposed, but there is abundant evidence that it exists in the approximate position shown on the geologic map. The fault is named from the ranch across which it passes and near which the best fault relationships can be seen.

The most conclusive evidence for faulting is found just east of the EA ranch, where sandstone and shale about 1,200 to 1,300 feet stratigraphically above the base of the Cody shale dip 42° N. in normal position whereas only a quarter of a mile to the north Mowry shale is overturned and now dips about 70° N. The apparent displacement, measured on the base of the Frontier formation along the fault plane, may be as much as 3,500 feet at this point, as is shown on cross section *D′—D″* (pl. 26). Northwest of the EA ranch the entire sequence between the upper part of the Frontier formation and the lower part of the Morrison and Cloverly formations, undifferentiated, is overturned. Along the south edge of this sequence Cody shale also contains northward dips, but it is concluded that these beds are in normal position like those to the northwest and that the fault lies between them and the overturned Frontier strata. Farther northwest in the vicinity of EA Mountain and in alinement with the strike of the overturned sequence, Cody shale is in an upright position, dipping between 32° and 40° to the north. The fault is then thought to pass under EA Mountain and to continue on to the northwest somewhere between the inverted sequence of Triassic and Jurassic rocks along the road northwest of the Horse Creek Ranger Station and the Frontier and Mowry formations in normal attitude along Brent Creek, although here, because the two exposures are more widely spaced, the evidence for the existence of a fault is not so conclusive as farther to the southeast.

Another thrust fault, nearly parallel to the EA fault, is present about half a mile north of the EA ranch and is designated the North EA fault. The fault relationship is best seen in the SW¼ sec. 4, T. 42 N., R. 106 W., where the "upper Sundance" on the south flank of a syncline overlies overturned beds of the Morrison and Cloverly sequence. These two formations are involved in the faulting throughout the exposed parts of the North EA fault; the stratigraphic displacement is therefore not great. Although the fault plane itself was not sufficiently well exposed to measure its inclination, it is assumed that the dip of the plane had to be somewhat less than the overturning of the strata in order to have effected that overturning. Similar reasoning also influenced, to a large extent, the reconstruction of the EA fault plane. A peculiar phenomenon associated with the North EA fault, in the vicinity of the EA ranch, is the development of the small syncline in the overriding block directly adjacent to the fault (cross section *D′—D″*, pl. 26). Farther to the northwest, however, southward dips in the "upper Sundance" beds indicate the presence of a small anticline on the north side of the fault (cross section *C‴—C⁗*, pl. 26) which is normal in the overriding block of a thrust fault.

The syncline and anticline mentioned above are almost entirely covered by landslide debris. The syncline is clearly outlined only east of Horse Creek, while only the south flank of the small anticline is anywhere visible. Both are slightly reflected, however, in the Phosphoria formation along Horse Creek northwest of the Livingston ranch where the beds are observed to swing abruptly from their normal northwest trend to an east-west strike for a short distance. It is interesting to note that the stream channel follows almost precisely this bend in structural trend. The beds along the north flank of the syncline rise steeply to form the south flank of Spring Mountain and the main anticlinal uplift.

The Paleozoic and lower Mesozoic strata along the Burroughs Creek fault have been highly folded and faulted. Gently dipping beds of the Madison, Amsden and Tensleep formations in a small syncline were faulted in contact with vertical to overturned beds of the same formations (cross section *B′—B″*, pl. 26). The overturning, which can be observed in strata as young as the "lower Sundance," is best exhibited in the regular succession of strata in the Phosphoria formation on the steep east wall of Burroughs Creek Canyon about a mile northwest of the Horse Creek Ranger Station, where the beds dip eastward into the hill at an angle of approximately 40°. Throughout its entire length the fault is largely concealed by forest cover. The fault relationships are best observed along the U. S. Forest Service trail that leads north from the Horse Creek Ranger Station on the east side of Burroughs Creek Canyon. It is assumed that the dip of the fault plane is less than the dip of the overturned strata, giving it an inclination of generally less than 40°. Its stratigraphic displacement is not great. In common with the North EA fault northeast of the EA ranch, there is also a small syncline developed on the overriding block of the Burroughs Creek fault. The lower part of the Phosphoria formation is exposed in the center of the syncline, and both to the northwest and southeast the axis of the syncline is intersected by the fault. Here, also, there is no indication of a reversal that must be present to connect the west limb of the syncline with the overturned sequence on the west side of the fault. The Burroughs Creek fault passes southeastward into a very sharp flexure in the upper part of the Madison limestone.

Spring Mountain is a high prominent ridge which forms a major part of the southeastern flank of the Washakie Range anticlinal uplift. The mountain has an asymmetric topographic profile, with a relatively gentle southwest flank and a steep to nearly vertical northeast flank which descends abruptly northward into Horse Creek Basin, a small topographic and structural basin lying between Spring Mountain and the south end of Elkhorn Ridge. The southwest flank, although overlain in large part by Tertiary or younger rocks, appears to be little disturbed by folding or faulting, with Paleozoic and Mesozoic strata dipping southwestward about 45°. In contrast, much faulting has occurred both on the crest and along the northeast flank of the mountain, as well as on the east side of Horse Creek Basin. Most of the faults are normal, with their north sides downdropped (cross section *D′—D″*, pl. 26).

The longest of the normal faults, here referred to as the Spring Mountain fault, can be traced from the SE$\frac{1}{4}$ sec. 29, T. 43 N., R. 106 W., where the Bighorn and Darby formations are in fault contact with the Madison limestone, southeastward along the crest and northeast flank of the mountain to the east side of the Wiggins Fork River. The precipitous cliffs of Madison limestone on the northeast corner of the mountain in secs. 1, 2, 11, and 12, T. 42 N., R. 106 W., may be fault scarps. The fault relationships are best observed in secs. 33 and 34, T. 42 N., R. 106 W., southwest of bench mark 8885, where a repetition occurs in both the Darby and Madison formations. At its northwest end the fault appears to die out in the Madison limestone. The amount of movement increases southeastward, and at the eastern edge of the area structure contours indicate it to be more than 1,000 feet.

Just southwest of bench mark 8885 the Bighorn dolomite has been almost completely omitted by a reverse fault, probably high-angle, which closely parallels the Spring Mountain fault. Highly distorted remnants of the Leigh dolomite member of the Bighorn dolomite are present in two places along the south side of the fault. In the northeast corner of sec. 33, T. 43 N., R. 106 W., dips in the Gallatin limestone, in the overriding block, are vertical to slightly overturned. The southeastern extent of this fault is not known, but to the northwest it is thought to extend at least as far as the center of sec. 29, where outcrops of Flathead sandstone are in close proximity to the Madison limestone (cross section *C‴—C⁗*, pl. 26).

A normal fault of large displacement extends through the N$\frac{1}{2}$ sec. 35, T. 43 N., R. 106 W., where a repetition of Flathead sandstone and Gros Ventre formation occurs. Here the stratigraphic displacement is about 500 feet, but to the west in the center of the S$\frac{1}{2}$ sec. 27 the displacement reaches nearly 1,000 feet. In the S$\frac{1}{2}$ sec. 22 both the Flathead sandstone and the Gros Ventre formation have been downdropped against Precambrian rocks along another normal fault. The fault relationships are not clear because of poor exposures and the overall magnitude of the fault could not be determined. To the north another fault has produced a small offset in the Death Canyon member of the Gros Ventre formation.

A sharply folded syncline lies along the northeast edge of the mapped area. The southwest limb of the syncline, overturned in some places, is broken by the Wiggins Fork Trail fault. This fault is named after the U. S. Forest Service trail which parallels the small stream traversing the structure in the NW$\frac{1}{4}$ sec. 10 and S$\frac{1}{2}$ sec. 3, T. 43 N., R. 106 W., and along which the fault relationships are exposed. In contrast with all the other reverse faults in the mapped area, the plane of the Wiggins Fork Trail fault is inclined to the southwest; the amount of inclination was not observed, but it is believed to be high angle (cross section *B′—B″*, pl. 26). Gallatin limestone occupies the north side of the fault throughout its extent and the Death Canyon member of the Gros Ventre formation or the Flathead sandstone forms the overriding block. The amount of movement, from a maximum of nearly 1,500 feet, decreases rapidly to the northwest in the NW$\frac{1}{4}$ sec. 10 and apparently soon dies out in the soft beds in the upper part of the Gros Ventre formation. A small reverse fault, with its plane inclined to the east, occurs at the southeast end of the syncline, along the axis of the fold.

SUMMARY OF LATE CRETACEOUS AND EARLY TERTIARY EVENTS

Because there are no Upper Cretaceous strata younger than the Cody shale in the Du Noir area, or in adjacent areas to the east, the Late Cretaceous history of the northwestern part of the Wind River Basin is not adequately known. Throughout many regions in Wyoming, however, it has been noted that the first pulsations of the Laramide Revolution occurred before the close of the Cretaceous period as evidenced by unconformities and conglomeratic beds within the Upper Cretaceous sequence. In the Jackson Hole region to the west Love, Hose, Weitz, and others (1951) observed a conspicuous unconformity at the base of the Lance(?) formation (uppermost Cretaceous) as well as thick massive conglomerate beds within the formation.

The presence of Paleocene strata in the Du Noir area has not been definitely established, but the unit referred to in this report as the Fort Union(?) formation is provisionally assigned to the Paleocene because of its structural relationships and the nature of its conglomerate, which consists entirely of Mesozoic rock fragments and are therefore unlike any of the conglomerates of known lower Eocene age. The Fort Union(?) strata, sharply infolded and faulted with the Mowry shale (fig. 65) along the south flank of the Dubois anticlinal complex, were most probably derived during the intial stages of development of the anticline; the first evidence of Laramide folding in the Du Noir area therefore occurred before the deposition of these beds.

The Wind River and Washakie Ranges were folded to mountainous proportions and subsequently deeply eroded before the deposition of the lower Eocene Indian Meadows formation. Along the south flank of the Du Noir anticline and south face of Spring Mountain coarse conglomerate of the Indian Meadows formation lies horizontally upon steeply inclined strata of Paleozoic and Mesozoic age (fig. 67). At these localities the conglomerate consists entirely of Paleozoic rock fragments, but farther out in the basin, as along the north edge of the Wind Ridge fault, there are some extremely weathered Precambrian rocks in the conglomerate, indicating that at least some part of the Precambrian core of either the Washakie Range or Wind River Range, or both, had been exposed. Eocene rocks, undifferentiated, were deposited over a surface of considerable relief along the north flank of the Wind River Range (fig. 71). These strata are nearly flat lying, as is the Wind River formation, which attains a maximum northward dip of 4°, on the north side of the Wind River. Thus, only a minor amount of uplift of the Wind River Range could have occurred since early Eocene time. This is also true for the Washakie Range inasmuch as the original essentially horizontal position of the overlapping Indian Meadows formation has been preserved to the present. The Eocene rocks along the northeast flank of the Wind River Range may have been subjected to small-scale normal faulting as shown by the probable fault in secs. 22 and 27, T. 42 N., R. 108 W., although the evidence for faulting here is by no means conclusive. Definite evidence of an unconformity, either angular or erosional, between the Wind River and Indian Meadows formations is lacking in the Du Noir area, but in adjacent areas to the east Love (1939, p. 58 ff.) found evidence indicating that there was folding at the end of Indian Meadows time, followed by a period of erosion.

The center of the synclinal basin, however, was intensely deformed during late early Eocene time, apparently between the time that the middle variegated sequence of the Wind River formation was deposited and before the deposition of the overlying massive conglomerate of the Wind River formation. This deformation was manifested by large-scale thrust faulting in the northern part of the synclinal basin and along the south flank of the Washakie Range and by at least renewed folding and faulting of the Dubois anticlinal complex. Strata in the middle variegated sequence of the Wind River formation dip southward off the south flank of the anticline as much as 32°, essentially parallel to the underlying Mesozoic rocks, whereas the overlying conglomeratic sequence on top of the fold is nearly horizontal (fig. 71); along the north side of Tappan Creek, however, these two sequences are conformable. None of the pronounced overturning that is present in the Mesozoic rocks along the south flank of the Dubois anticlinal complex was observed in the middle variegated sequence at the southeast end of the fold, but these latter rocks were involved in the faulting. Nearly all of the thrust faults east of Horse Creek involve lower Eocene strata, and the syncline lying north of the Little Alkali Creek fault is clearly reflected in the Indian Meadows formation. These strata, however, do not appear to have been affected by the North EA fault. West of Horse Creek much of the area is covered by the upper variegated sequence of the Wind River formation, which does not anywhere seem to be deformed.

The age of the normal faulting along the north edge of Spring Mountain and at the east end of Horse Creek Basin could not be definitely ascertained. No Tertiary rocks are involved in the faulting except at the extreme eastern end of the mountain where the Indian Meadows formation appears to have been faulted. The ages of the Burroughs Creek and the Wiggins Fork Trail faults are also not known. It is concluded, however, that they were probably formed sometime during the initial stages of folding of this large anticlinical uplift, which was before early Eocene time.

Erosional unconformities are thought to be present both at the base and at the top of the Tepee Trail formation, but there appears to be no angular discordance between this formation and either the underlying Wind River formation or the overlying Wiggins formation. In areas to the east, however, Love (1939, p. 77, 83) noted that deformation had occurred at the end of middle Eocene time and also at the close of late Eocene time.

The first noticeable evidence of Tertiary volcanism in the Du Noir area is in the tuffaceous strata of the greenish-gray and drab sequence of the Wind River formation. Younger beds contain progressively more volcanic material, and the upper part of the Tepee Trail formation and the Wiggins formation consist entirely of coarse volcanic conglomerate, interbedded with tuff.

These strata are crudely stratified, and many of the boulders are rounded, suggesting that much of the volcanic debris was reworked by streams. Most of the pyroclastic material was probably derived from the large Tertiary volcanic centers to the north of the Du Noir area.

GEOMORPHOLOGY

Most of the main valleys in the northwestern part of the Wind River Basin have been extensively glaciated and contain an abundance of glacial deposits. Blackwelder (1915) studied many of these deposits during his investigations of the Quaternary history of west-central Wyoming. Richmond (1941, 1948) also examined glacial features in the northwestern part of the Wind River Range. The most recent work on the glacial and erosional features in the region has been done by J. F. Murphy (oral discussions) along Bull Lake Creek and adjacent drainages, about 35 miles southeast of Dubois. As a result of these studies the relative ages of the various erosional and glacial periods have, for the most part, been accurately determined. In those areas the morainal debris of one glacial period is, in many places, clearly superimposed on the deposits of an older glacial or erosional period. In some places, too, outwash deposits can be traced into terrace gravels. The moraines contain an abundance of large resistant granite boulders and, though weathered in varying degrees, most are still largely intact and continuous. Therefore, criteria, such as the composition of the gravels, topography, and degree of modification by erosion and weathering, have been established by means of which the deposits of one glacial stage can be differentiated from those of another. Many of these criteria are utilized in the interpretation of the geomorphologic history of the Du Noir area.

There are several reasons, however, why the distinguishing characteristics of the different deposits in the Bull Lake region may not be applied with the same degree of assurance in the determination of the various glacial stages in the Du Noir area or in the correlation of these deposits with those farther to the southeast. The following characteristics are generally true of the glacial deposits in the Du Noir area: (1) the moraines are largely discontinuous, (2) there is no well-defined superposition of deposits, (3) the moraines are likely to be more easily modified by erosion because they consist chiefly of volcanic conglomerate fragments which have disintegrated to form a gravel composed of much smaller rock fragments and with a large proportion of fine-grained material derived from the conglomerate matrices, (4) there is an almost complete lack of recognizable terminal moraines, (5) the rock fragments in the various moraines are not perceptibly weathered, and (6) the composition of the gravels seems to have little significance because the variations can be accounted for largely by the local differences in source rock.

Probably the most significant difference between the moraines of the two regions is the relative amounts of erosion and weathering that have taken place. Because the moraines in the Bull Lake region consist predominantly of large granite boulders they have withstood erosion to a greater degree than the moraines in the Du Noir area, where, because of the larger percentage of finer grained debris, they have apparently been more easily modified. The almost complete absence of terminal moraines in the mapped area can be partly explained by the relatively greater amount of erosion that has taken place. Another contributing factor for the absence of such features at the lower end of the Du Noir valley may be, however, that the erosive power of the combined drainage of the Du Noir and Wind Rivers was enough to erase nearly all traces of the terminal moraines, whereas, in comparison, the smaller streams farther to the southeast did not have the requisite erosive power. Furthermore, when the advancing Du Noir valley glaciers reached the Wind River at least some of the debris that was pushed up in front of the glacier must have been carried off immediately downstream and the terminal moraines were thus relatively reduced in size. The type of bedrock underlying the glacial deposits also has a direct influence on the ease and degree to which the moraines will be modified; in the Du Noir valley the moraines were deposited for the most part on soft, easily eroded Tertiary sediments.

The quantitative effects that these factors may have had on the moraines in the Du Noir area relative to the same factors operating in the valleys farther to the southeast are not known. The interpretation of the glacial history in the mapped area, based of necessity on criteria established in other regions, is therefore tentative and until more data are obtained in the entire northwestern part of the Wind River Basin more definite conclusions cannot be drawn. The same difficulties are not encountered in the classification of the terrace deposits because the various levels are more continuous and are differentiated by their relative heights above the present stream levels. The more precise determination of the erosion cycles in the Du Noir area aids to some extent the interpretation of its glacial history.

The following erosion cycles and glacial stages, listed from oldest to youngest, and their distinguishing characteristics were determined by Blackwelder (1915, p. 307–333) and have provided the basis for all subsequent studies of the Quaternary deposits in this region:

Fremont and Union Pass erosion cycles—These two older erosion cycles, recognized by Blackwelder (1915, p. 310–312), are confined to the high mountain areas and are not discussed here. The highest and oldest cycle, the Fremont, is probably represented by the plateaulike surface which now forms the general summit level of the Absaroka Range at elevations of about 11,000 feet, but the Union Pass cycle was not specifically recognized.

Black Rock erosion cycle.—Terrace surfaces generally from 500 to 800 feet above the present stream drainages.

Buffalo glacial stage.—Moraines exist only in the form of remnants on flat-topped divides or isolated hills. Canyons have been excavated, not only through the deposits, but 200 to 1,000 feet into the underlying bedrock. From the distribution of the deposits it is evident that the Buffalo ice covered a much larger area than the Bull Lake and Pinedale glaciers, which were mainly confined to valleys.

Circle erosion cycle.—Includes terrace surfaces that are generally from 100 to 200 feet above present drainage levels, but some may be as much as 400 feet. Bull Lake moraines rest upon the Circle terraces, and the terrace gravels may consist largely of outwash deposits of this glacial stage.

Bull Lake glacial stage.—Moraines are still largely intact, but modified by erosion to a greater degree than the Pinedale moraines. In places streams have cut rather wide flat-bottomed valleys through the terminal moraines. Large boulders are not nearly as abundant on the surface as in the Pinedale moraines.

Lenore erosion cycle.—Includes the shallow inner trenches of the Wind River and its tributaries. Surfaces are generally 10 to 30 feet above present stream levels and were developed before the deposition of moraines of the Pinedale stage of glaciation.

Pinedale glacial stage.—Morainal deposits are rough and fresh in appearance and large boulders predominate on the surface. Moraines are generally intact and continuous.

Postglacial erosion.—Includes postglacial terracing and erosion of Recent age.

Although little active glaciation is going on at present, small permanent icefields, such as the Du Noir glacier, still persist at higher elevations along the southern margin of the Absaroka Range. Cirques and hanging valleys high up on the cliffs of the Wiggins formation are probably indicative of very late stages of glaciation.

EROSION CYCLES

BLACK ROCK CYCLE

Table Mountain, a conspicuous flat-topped prominence approximately 2 miles long and from one-fourth to three-fourths of a mile wide near the southeast corner of the area, contains the highest erosion surface in the Du Noir area, with the possible exception of the Fremont cycle; it has been described by Blackwelder (1915, p. 312) and Love (1939, p. 116) as being representative of the Black Rock cycle of erosion, which preceded any known glaciation in the region. The elevation of the top of Table Mountain is more than 8,000 feet, about 1,400 feet above the adjacent Wind River valley floor. Comparable features, such as Coulee and North Mesas (Love, 1939, p. 116), are present in adjacent areas to the east, but no other remnants are in the Du Noir area.

The surface of Table Mountain has very little relief and slopes gently from north to south. Table Mountain is veneered with a smooth pavement of coarse cobble and boulder debris which is, for the most part, deeply weathered and overgrown with grass. The terrace deposit is best observed at the northeast corner of the mountain where landslide material has broken away to expose the gravels as well as the underlying Tertiary strata. At this locality the gravels are 30 feet thick and are composed entirely of rounded to subrounded volcanic cobbles and boulders as much as 2 feet in diameter. At the south end of the mountain the upper surface more closely approximates one of actual erosion, because the gravels form only a thin veneer and contain a conspicuous amount of Paleozoic rock fragments, which were probably derived in large part from the underlying folded conglomerate in the Indian Meadows formation.

Two isolated terrace surfaces, one in the SE¼ sec. 25, T. 42 N., R. 107 W., on the north side of Tappan Creek (fig. 70) and the other near Dubois triangulation station, lie about 500 feet above the present drainages and are also considered to be remnants of the Black Rock cycle. However, because their heights relative to present drainage is much less than that of Table Mountain, they are not contemporaneous with the Table Mountain surface but represent a different level similar to those described by Blackwelder (1915, p. 315–316) as follows: "Between the Black Rock cycle and the next one clearly discriminated [Circle] there may well have been one or more cycles now represented by terraces visible here and there in the Wind River and Green River badlands. These are, however, but little known and appear not to have left notable marks in any but the softest strata." At the Tappan Creek locality the gravels are about 10 feet thick and consist chiefly of rounded volcanic cobbles as much as 1 foot in diameter with a very minor amount of rocks of Paleozoic age. No Precambrian rocks were observed. At the Dubois triangulation station locality the deposit also consists of chiefly volcanic rocks but, in addition, contains rounded cobbles of Precambrian quartzite. Here the volcanic rocks are, in large part, very dark colored and dense, of a type not conspicuous in the other terrace deposit. Although the composition of the gravel varies, the two remnants are believed to be contemporaneous, but with different sources of debris, one from the Horse Creek-Tappan Creek drainage basin and the other from the upper Wind River drainage basin.

CIRCLE CYCLE

The Circle cycle of erosion is represented in the Du Noir area by terrace levels that are from 100 to 300 feet above the present drainage. It is evident that two or more subcycles occur within the major cycle, however.

Along the Wiggins Fork River, near the mouth of Little Alkali Creek, are two distinct levels, 100 feet and 200 feet, respectively, above the present river channel. The type area for the Circle terraces is a few miles downstream from Little Alkali Creek along the North Fork of the Wind River where Blackwelder (1915, p. 316) described only one prominent level standing about 150 feet above the river. The terraces near the mouth of Alkali Creek are covered by a thin veneer of unconsolidated gravels underlain for the most part by conglomerate of the Indian Meadows formation from which most of the Paleozoic rock fragments in the deposits were derived. The uppermost deposit is comprised of 75 percent volcanic, 5 percent Precambrian, and 20 percent Paleozoic rock fragments. The lower terrace contains only 10 percent volcanic rocks, with the remainder equally divided between Paleozoic and Precambrian rocks. In contrast, the present riverbed is almost wholly comprised of volcanic debris.

On the south side of the Wind River, extending southeastward from Stony Point, the Circle cycle of erosion is represented by a well-developed series of terraces which lie 150 to 250 feet above the river. Only the western end of this series is within the mapped area. All traces of the terraces have been erased from the north side of the river except for those at Stony Point and the surface upon which the Dubois airport was constructed. Although the detailed relationships between this terrace building and the warm-spring activity along the south side of the Wind River southeast of the Harrison ranch were not worked out, it is clearly evident that the two were closely related.

Southwest of the Harrison ranch, NW¼ sec. 32, T. 42 N., R. 107 W., the gravel consists chiefly of Precambrian quartzites and granites with a minor amount of volcanic and Paleozoic rocks, indicating that most of the material at this point was derived from the Warm Spring Creek drainage area. On the whole, however, where the deposits were not appreciably affected by debris from local tributary streams but were derived chiefly from the drainage basin of the master stream, they contain a large proportion of volcanic rocks. In a cut along the road leading from U. S. Highway 287 to the Dubois airport the gravels are nearly 90 percent volcanic with Paleozoic rocks comprising the remainder. About a quarter of a mile westward, at the west end of this terrace remnant and lying about 60 feet lower than the level of the airport, is a small outcrop of terrace gravel which has been cemented into a conglomerate by carbonate material that was derived from the warm-spring activity farther upstream. This conglomerate, which is comprised chiefly of volcanic rocks and some Paleozoic and Precambrian rock fragments, is at the same level as those directly opposite on the south side of the river which bevel the upturned redbeds in the Chugwater formation. Further evidence of cementation of the terrace gravels by travertine is present around the mouth of Warm Spring Creek where the conspicuous travertine deposits have incorporated many pebbles and cobbles. No distinct terrace levels were observed north of Dubois along Horse Creek, but some of the gently inclined gravel-capped slopes along the east side of the creek, the lower ends of which are about 200 feet above the present valley floor, may be representative of the Circle cycle of erosion.

The broad benchland north of Stony Point is also considered to be a remnant of the Circle terrace, although it occurs about 300 feet above the Wind River, slightly higher than the terraces across the river and farther downstream toward Dubois (fig. 79). Core-drill data obtained from the U. S. Bureau of Reclamation indicate that the gravel underlying this surface is about 200 feet thick near the south end of the terrace. It consists of boulders and cobbles and much sand and silt. Clayey material near the base may have been reworked from the Wind River formation or may have been deposited by ponded glacial melt water. Rounded fragments of volcanic rocks constitute about 80 percent of the debris, and Paleozoic rock fragments make up the remainder. The gradual increase in altitude of the surface northward changes to an abrupt steepening at the north end of the terrace. The slope at the north end contains volcanic cobbles as much as 40 feet above the terrace surface. Paleozoic rock fragments occur farther up the slope and are probably residual gravels derived from underlying conglomerate in the Wind River formation. Because of the thickness of this deposit at Stony Point true terrace deposits probably constitute only the upper few feet of the gravels with the remainder originating as glacial debris. Another terrace level, only 135 feet above the Wind River, is present at Stony Point (fig. 79). This surface contains very little detrital material and is essentially one of erosion.

Two distinct terraces were developed along Warm Spring Creek near the abandoned Du Noir tie camp. The upper level is 130 feet above the present stream channel and may represent a mountainward extension of the Circle terrace, whereas the lower level, 70 feet above the creek, does not apparently represent either the Circle cycle or the younger Lenore cycle. The gravels in the upper deposit consist chiefly of well-rounded cobbles of Precambrian quartzite and a very minor amount of volcanic rock fragments. The deposit is best exposed along the road on the north side of Warm Spring Creek. Along the south edge of this upper terrace the gravel is 10 feet thick and is underlain by arkose and soft gray clay shale of the Eocene rocks, undifferentiated. From here northward steep slopes descend into the drainage basin of Crooked Creek, and the tablelike surface forms the drainage divide between Crooked Creek and Warm Spring Creek in this area. The lower terrace deposits contain a conspicuous amount of granite cobbles in addition to a minor amount of Paleozoic and volcanic rock fragments. Along the north bank of the creek, SW¼ sec. 28, T. 42 N., R. 108 W., is a small outcrop of Tertiary arkose, indicating that the entire series of terraces is underlain by Eocene rocks, undifferentiated. According to J. D. Love (1953, oral communication), Eocene rocks on the Continental Divide, in the vicinity of Fish Lake Mountain near the headwaters of Warm Spring Creek, contain conglomerate with fragments of both quartzite and volcanic rocks. C. L. Baker (1946, p. 581) reports quartzite boulder beds resting on Precambrian rocks 4 miles south of the Du Noir tie camp. These strata would provide a ready source for the material in the terrace deposits. The two terrace levels probably represent successive stages in the downcutting of lower Warm Spring Canyon. Evidence is too fragmentary to attempt a specific correlation of these terraces with those near the mouth of Warm Spring Creek.

LENORE CYCLE

Remnants of the Lenore terrace occur west of the Harrison ranch on the south side of the Wind River, both east and west of Stony Point on the north side of the river (fig. 79) and in the broad alluvial plain near the confluence of the Wind and Du Noir Rivers. These terraces range in elevation from 15 to 35 feet above the present Wind River channel. The deposits are generally finer grained than the older Circle deposits, but, as in the majority of the Circle terraces, volcanic rocks are the dominant constituents. There are two distinct levels downstream from Stony Point; the lower and most conspicuous one is 25 feet above the river and the other is 10 feet higher. The Lenore Plain is probably also represented by the relatively broad alluvial-covered surfaces extending along the north side of the Wind River from Stony Point to the southeast corner of the mapped area, but, because these surfaces are covered largely by locally derived material from the easily eroded Tertiary strata, they have been mapped as alluvium.

POSTGLACIAL EROSION

Downstream from Stony Point the Wind River has become entrenched 20 feet or more below the level of the terraces of the Lenore cycle of erosion. The present flood plains are relatively narrow. Upstream from Stony Point, however, the flood plain becomes very broad and flat and remains so throughout the Du Noir River valley. The Wind River near the western edge of the mapped area is again confined to a relatively narrow steep-walled valley. South of the mouth of the Du Noir River the remnants of the Lenore terrace rise 10 to 15 feet above the present flood plain.

The Du Noir River valley is unique in that it is the only one within the mapped area in which a continuous broad and flat flood plain has been developed during the postglacial period. The alluvium consists chiefly of clay and silt with a large amount of organic material. Miner and Delo (1943, p. 137) concluded that the flat floor of the valley was once the bottom of a large lake, 300 feet deep, that was ponded behind glacial moraines of the Pinedale stage of glaciation which had completely blocked the mouth of the valley, and that the sediments lying in the valley originated as lake silt. The writer did not find evidence to support this conclusion; a more detailed appraisal of this possibility, however, is presented in the discussion on glaciation.

An alternative explanation for the development of the flat-floored valley and the one favored by the writer, is that of lateral planation by the Du Noir River. The local base level of the combined drainage of the Wind and Du Noir Rivers is the narrow gap at Stony Point through which the Wind River now flows (fig. 79).

FIGURE 79.—View looking east toward Stony Point. Wind River flows through gap near right side of picture. Terrace in foreground is representative of Lenore cycle of erosion, whereas those on skyline at the center and left side of photograph are two different levels of the Circle cycle.

The gap is cut in resistant Tensleep sandstone, and limestone and chert of the Phosphoria formation, whereas the valleys of the Wind and Du Noir Rivers upstream from Stony Point are eroded in soft Tertiary strata. The rate of downcutting of the flat-floored valley is directly controlled by the rate of downcutting at Stony Point. As the Tertiary rocks are much more easily eroded, the Du Noir River has reached a temporary grade controlled by the stream level at Stony Point and its erosive power has since been directed toward lateral planation of the valley. North of the Cross ranch the river has been crowded to the west side of the valley by the large alluvial fan developed around the mouth of Sixmile Creek. Conspicuous alluvial fans are also present at the upper end of the valley near the confluence of the East and West Forks.

Perhaps a more difficult problem is to explain why, near the western edge of the mapped area, the Wind River valley, which is also cut in Tertiary strata, is relatively narrow in comparison with the Du Noir River valley. This part of the Wind River valley is choked with much glacial debris, and it is concluded that the erosive power of the river is directed toward downcutting of the morainal boulder debris and has maintained a relatively steep gradient.

GLACIAL STAGES

BUFFALO STAGE

The lateral moraines which occupy the drainage divides on both sides of the Du Noir valley are similar in many respects to the deposits described by Blackwelder (1915, p. 328–333) as belonging to the Buffalo stage of glaciation. Supporting this correlation are the height of the moraines above the present stream drainage and the fact that the associated terminal moraine has been almost completely eroded away. To the writer's knowledge no Buffalo moraines have previously been reported in this region.

The deposits are at elevations of 8,000 to 8,100 feet, about 600 to 700 feet above the present level of the Du Noir River. The best exposure of the moraine on the east side of the valley is found along Fourmile Creek above the Larsen ranch in the SW¼ sec. 24, T. 43 N., R. 108 W. (fig. 80). The moraines are extremely hummocky and contain many small ponds. They are composed of an unconsolidated mass of boulders and cobbles of Tertiary volcanic rocks and Paleozoic rocks in a matrix of finer material. No striae or polish was observed on any of the rock fragments, and most do not appear to be appreciably weathered.

The eastern end of the glacial deposit on the northeast flank of the Wind River Range west of the Harrison ranch forms a high rounded hill and its westward extent is marked only by smooth boulder-strewn slopes. Tertiary volcanic boulders comprise 70 percent of the deposit, whereas Paleozoic rocks make up 25 percent and Precambrian rocks 5 percent. Volcanic boulders of a type not found in place south of the Wind River indicate that much of the debris most probably was derived from the drainage basin of the Du Noir River. The deposit is slightly lower in elevation than the lateral moraines, but it is still about 600 feet above the present level of the Wind River. Isolated outcrops of gravel in secs. 15 and 23, T. 42 N., R. 108 W., also contain conspicuous amounts of volcanic rocks and are thought to be morainal deposits. These deposits lying on the south side of the Wind River are believed to be remnants of a terminal moraine and to be correlative with the lateral moraines discussed above.

FIGURE 80.—Lateral moraine of Buffalo stage of glaciation along Fourmile Creek, SW¼ sec. 24, T. 43 N., R. 108 W. Ramshorn Peak in right background.

Extensive glaciation is also believed to have occurred during the Buffalo stage of glaciation in the Horse Creek-Wiggins Fork region. On the north flank of Spring Mountain the moraines are at elevations of as high as 8,500 feet, nearly 1,400 feet above the adjacent Wiggins Fork valley one-half mile to the east. These are characterized by low ridges which are elongated parallel to the flank of the mountain and probably represent a large lateral moraine. The debris consists chiefly of Paleozoic cobbles and boulders and a minor amount of volcanic rocks.

The highest glacial deposit observed in the Horse Creek-Wiggins Fork area occurs near the top of the high ridge north of the Horse Creek Ranger Station at an elevation of 8,800 feet, about 1,000 feet above the present level of Horse Creek. These gravels contain Precambrian, Paleozoic, and volcanic rocks in about equal amounts. Granite boulders as much as 25 feet in diameter are present. Other prominent hills in the area, such as the one near the junction of secs. 18, 19, 29, and 30, T. 43 N., R. 106 W., also contain remnants of glacial moraines; many of these were too limited in extent to be shown on the geologic map.

Horse Creek Basin, with elevations ranging from 8,100 to 8,200 feet, has gently rolling topography with large alluvial flats separated by ridges composed of coarse boulder debris. There are many small lakes in the basin. Near its eastern end the terrain is more hummocky and irregular; gullies as much as 100 feet deep are cut into the deposits. The terrain of the area lying between the east edge of Elkhorn Ridge and Wiggins Fork Canyon is also slightly hummocky, with a few low ridges elongated parallel to the Wiggins Fork River. Erratics of Bighorn dolomite are common in this area, and many outcrops of Precambrian granite exhibit planed and faintly grooved surfaces. The deposits in Horse Creek Basin appear to have originated as a ground moraine.

The general distribution of these high-level glacial deposits suggest that during the Buffalo stage large glaciers descended both the Wiggins Fork and Horse Creek valleys and probably coalesced in Horse Creek Basin. The ice sheet had a minimum thickness of 400 feet and filled the valleys to heights ranging from 8,500 to 8,800 feet in elevation. No terminal moraines of the Buffalo glaciers were observed in either valley. The precipitous Wiggins Fork Canyon has been cut since the deposition of the moraines.

BULL LAKE AND PINEDALE STAGES

Glacial moraines younger than the Buffalo stage are in the Du Noir area, but no definite criteria were found to enable discrimination between the two younger stages. They are therefore discussed as a single topic.

The glacial deposits which extend northwestward from Stony Point along the east side of the Du Noir valley appear to represent a younger glacial stage than the moraines correlated with the Buffalo period. Although much of the debris consists of small well-rounded water-worn fragments, there are enough large boulders to attest to its glacial origin. This occurrence has been referred to as a lateral moraine of the Bull Lake stage of glaciation by both Blackwelder (1915, p. 327) and Miner and Delo (1943, p. 134). No terminal moraines are in evidence, but the thick sequence of gravels that underlies the Circle terraces north of Stony Point may possibly represent a part of this younger series of moraines. Although Bull Lake moraines commonly rest upon the terraces of the Circle cycle of erosion, Blackwelder (1915) found that in places the two types of deposits were nearly contemporaneous, with the terrace gravels composed largely of outwash material from the glacial moraines.

The Bull Lake glacial deposits have been rather extensively modified by erosion. The downcutting by the Wind River at Stony Point is about 300 feet. The lateral moraine could be traced for only a short distance upstream along the east side of the Du Noir valley, but, because it overlies soft Tertiary strata, it may have been so altered by slumping and erosion as to render it unrecognizable as a moraine. Neither were any certain traces of moraines found along the west side of the valley upstream from the Spencer ranch, but the gravel deposits directly west of the ranch may be remnants of a Bull Lake moraine.

The glacial deposits which lie along the Wind River west of its junction with the Du Noir River, and extending to the west edge of mapped area, are still largely intact and the conspicuous hummocky topography has been preserved. For these reasons they appear to be younger than any of the glacial deposits at the lower end of the Du Noir valley and therefore may be representative of the Pinedale glacial stage. This moraine, which forms a large lobe, is thought to have a direct influence on the course of the Wind River as it bends to the south at the Long Creek ranch. The deposits extend from the present level of the river to about 300 feet above the river. The most conspicuous rock type observed was a dark-brown to black vesicular basalt of a type not common in the volcanic rocks derived from the drainage basin of the Du Noir River, but more like those from the upper Wind River valley in the vicinity of Lava Mountain. The relationships of this moraine to probable glacial deposits upstream on the Wind River were not studied, but it is probably the terminal moraine of a glacier which extended eastward only to the western edge of the Du Noir valley.

Miner and Delo (1943, p. 134–135) reported a lateral moraine, to which they assigned a Pinedale age, about 50 feet above the present valley floor along the east side of the Du Noir valley. They also mentioned glaciers as having existed in the drainage basins of the Fourmile, Fivemile, and Sixmile Creeks during this period. The writer did not recognize any evidence that glaciation younger than the Bull Lake stage occurred either in the Du Noir valley or in its tributary streams. Miner and Delo (1943, p. 137) concluded, furthermore, that the Du Noir valley was completely blocked by the Pinedale moraines behind which was impounded a large lake, 300 feet deep, that drained into Long Creek through the vicinity of Dry Lakes on the west side of the valley and into Bench Creek and Wagon Gulch on the east side of the valley. No evidence of channels were observed in these areas by the writer. The elevation of the Dry Lakes is between 7,700 and 7,800 feet. If a lake had maintained this level, then it would have extended up East and West Fork Canyons one-half mile or more. No evidence of lacustrine deposits was observed in those canyons, although it is conceivable that such deposits could now be completely eroded away. Terrace remnants of the Lenore cycle of erosion, presumably older than the Pinedale stage of glaciation, do not appear to have been disturbed by glaciation along the Wind River west of Stony Point.

Most of the glacial deposits that lie along Horse Creek are representative of either the Pinedale or Bull Lake, or both, stages of glaciation. Some lie at or near the present stream level, but others occur as much as 300 to 400 feet above the stream.

North of the Utzinger ranch, on the steep west slope of upper Horse Creek valley, the glacial deposit is only a thin veneer of coarse boulder debris. Similar deposits also occur along the west side of Horse Creek below its junction with Burroughs Creek. The glacial moraine along the east side of Horse Creek, extending northwest of the Livingston ranch, forms a high rounded hill and contains boulders as much as 6 feet in diameter.

The deposits which extend northward along Horse Creek from the vicinity of the Rocking Chair ranch to the EA ranch have in part been extensively eroded and modified. The topography is mildly hummocky and irregular, and the general surface slopes toward the present level of the valley. The broad meadowland that extends southward from the EA ranch for about 2 miles and through which Horse Creek now follows a meandering course was probably developed while the stream was eroding through the morainal debris at its lower end. In some parts of this locality it is difficult to distinguish glacial debris from residual gravels derived from the lower Eocene conglomerate which underlies much of the area, but in general the glacial gravels contain volcanic rock fragments and the residual gravels do not. Further, there is commonly a pronounced change in topography from the relatively smooth grassy hills underlain by lower Eocene conglomerate to the hummocky terrain of glacial debris. The most convincing evidence for the glacial origin of these gravels along Horse Creek is the moraine southeast of the EA ranch at the upper end of Little Alkali Creek. Here the deposit forms a series of low ridges which parallel the valley slopes for a short distance and swing around convex downstream in the middle and southeasternmost portions of the moraine. Small-scale knob and kettle topography is exhibited. At its northwestern end the deposit lies about 200 feet above the adjacent Horse Creek valley. The southernmost exposures of glacial debris in Horse Creek valley are considered parts of a terminal moraine, which is still relatively intact. The areas that lie both southeast and west of the EA ranch represent topographically low localities along the edges of the valley into which glacial ice pushed and subsequently deposited its debris. Most of the isolated outcrops farther upstream are remnants of lateral moraines and those on the valley floor around the Utzinger ranch probably originated as a ground moraine.

It could not be definitely determined whether the moraines along Horse Creek were all developed during the same glacial period. The relatively small amount of modification of some of the deposits suggests that they belong to the Pinedale stage. Supporting this interpretation is the limited amount of downcutting since the close of the glacial period. Horse Creek, just above its junction with Burroughs Creek, has incised a sharp channel about 40 feet deep into the underlying bedrock in postglacial time; some of the other deposits are at present stream level.

ECONOMIC GEOLOGY

OIL AND GAS

The best opportunities for successful oil and gas exploration are in structures along the northern margin of the synclinal basin and along the south flank of the Washakie Range where most of the surface rocks are post-Paleozoic, and where the greatest amount of folding has occurred. Outcrops of rocks older than Tertiary are so limited in extent, however, that a complete and accurate appraisal of potential oil traps is not possible from surface data alone. Only small parts of the anticlinal folds are visible, and their western extensions are commonly completely obscured. The upper part of the Wind River formation, which overlies much of the Dubois anticlinal complex, does not reflect the structure of the underlying rocks and the northwestern extent and character of this large fold, and its relationships to the Du Noir anticline farther to the northwest cannot be determined from the Tertiary rocks at the surface.

Two wells have been drilled in the Du Noir area, both on the Dubois anticlinal complex: the Sinclair-Wyoming Oil Co. Dubois Unit well 1, NENENE sec. 11 T. 42 N., R. 107 W., in 1946 and the Stanolind Oil and Gas Co. Dubois Unit well 2, SWSWSW sec. 1, T. 42 N., R. 107 W., in 1949. Oil in commercial quantities was found only in well 1, and up to the end of 1953 it had produced 21,741 barrels of crude oil with an average API gravity of 20°; production for 1953 totaled 935 barrels. No other wells have been drilled in the area since 1949, but both seismic and surface explorations have been conducted periodically by various oil companies.

The Dubois anticlinal complex has at least 100 feet of closure in the vicinity of the Dubois Unit well 1. This well, which is near the surface crest of the fold, was drilled to a total depth of 3,430 feet and produces from nearly vertical beds of the Phosphoria formation on the steep southwest limb of the fold. The Dubois Unit well 2, with a total depth of 2,721 feet, is north of the surface crest and was in a better structural position to test adequately the Tensleep sandstone, but it proved to be dry in both the Tensleep and Phosphoria formations. Cross section *A—A′—A″* and the structure contours on plate 27 show the writer's interpretation of the structural position of these two wells. The plunge at the southeastern end of the major fold may be as much as 2,500 feet; the total amount of plunge at its western end could not be determined, but it is probably greater than the 100 feet now exposed.

The two anticlines which lie on the north flank of the Dubois anticlinal complex are almost completely concealed and consequently very little of the nature of these folds is known. The fold southeast of the EA ranch is probably cut at depth by the Little Alkali Creek fault and appears to have no western closure. Only the sharply plunging eastern end of the fold along Brent Creek is visible in surface exposures. This fold, which lies farther down on the north flank of the anticlinal complex, may broaden westward into a large structure. Mowry shale is the oldest formation exposed. Much subsurface and geophysical data are needed before the structure of these two anticlines can be worked out and an evaluation of their oil and gas possibilities made.

The Du Noir anticline, in the northwestern corner of the area, is breached to the Darby formation, so that the possibilities of potential oil and gas reservoirs in the underlying rocks are limited. The axis plunges southward at its southeastern end but there is no apparent westward closure within the mapped area.

The broad belt of folded rocks of Paleozoic and Mesozoic age, which includes the Dubois anticlinal complex and associated folds and the Du Noir anticline, must continue through the central part of the mapped area. Because several anticlines extend into this region there is a possiblity of the existence of local structural highs along the anticlinal trends. This region is therefore thought to be promising for geophysical exploration.

Within the mapped area the Nugget sandstone thins from a maximum of 120 feet at Dubois to a wedge edge northwest of the Horse Creek Ranger Station. The formation is 65 feet thick in the Sinclair-Wyoming Oil Co. Dubois Unit well 1 and only 31 feet thick along Horse Creek about 1 mile north of the EA ranch. The wedge edge therefore lies somewhere along the southwest flank of the Washakie Range, where the prevailing dips are southwestward. Thus it is likely that the pinchout is updip in some places and that the conditions are favorable for the stratigraphic accumulation of oil and gas.

COAL

Small amounts of coal have been mined in the Du Noir area in the past, but no mining operations are being carried on at present. Only a very few seams are thick enough to be economically important and surface exposures are so few that detailed studies of coal were not made. The only available coal analyses are those published by Eldridge (1894, p. 62) who mentioned three samples that were collected in the upper Wind River region. The ranges of these analyses are as follows: moisture, 7.73 to 9.95 percent; volatile matter, 41.39 to 44.89 percent; fixed carbon, 35.45 to 41.87 percent; ash, 3.88 to 12.90 percent; and sulfur, 2.88 to 4.77 percent. As no localities were given, these analyses cannot be related to a specific coal bed. No samples were collected for analysis in the present study.

Several thin somewhat continuous coal beds occur near the base of the Frontier formation. Some of these beds have been mined periodically for local use. A shallow caved shaft is in the NW¼ sec. 1, T. 42 N., R. 107 W., and a few prospect pits have been dug in its vicinity. A section of the Frontier formation, measured by Love, Tourtelot, Johnson, and others (1947, p. 4–6) along the east side of Little Horse Creek near the abandoned mine, lists 2 coal beds, one occurring 163 feet and the other 206 feet above the base. The upper bed, which has been mined, is 3 feet thick and the lower is only 1 foot. On the north side of Brent Creek, in sec. 28, T. 43 N., R. 107 W., several thin coal beds are found in limited exposures. Northwest of the EA ranch, CW½ sec. 5, T. 42 N., R. 106 W., coal has been mined in an adit which penetrates the hillside for a distance of at least 50 feet. The coal bed, which is near the base of the Frontier formation, is 3 feet thick, but exposures are too limited for a more detailed study. A few prospect pits are present in the vicinity of the shaft.

At some localities on the north flank of the Wind River Range the Eocene rocks, undifferentiated, contain carbonaceous shale and thin coal beds. In the past small strip and underground mining operations have been carried on in the NW¼ sec. 25. T. 42 N., R. 108 W. At this locality the following section was measured:

Top.	*Inches*
Shale, bluish-gray and brown; black coal partings	7
Shale, brown, carbonaceous; black coal partings	12
Claystone, gray, plastic	7
Shale, black, lignitic	4
Shale, gray and brown, carbonaceous, clayey	18
Coal, black, nearly pure	24
Shale, black to brown, lignitic	12
Claystone, gray, plastic	6

Base.

The 24-inch coal bed is the seam that was mined. The bed has no great lateral extent, for it was deposited in a narrow valley cut in Paleozoic rocks.

Minor amounts of brown carbonaceous shale with thin black coal partings are present in the lower drab tuffaceous sandstone unit of the Wind River formation along Long Creek. A 37-foot unit of interbedded carbonaceous shale and coal occurs at the top of the formation on the north side of White Pass in the NW¼ sec.

6, T. 42 N., R. 107 W. The coal is in very thin beds, not more than a few inches thick, and none are thick enough to be economically important.

BENTONITE

Bentonite is common in the Mowry and Frontier formations. Some beds appear to be quite pure, but most are impure, with varying amounts of shale, sand, tuff, and organic material. Thicknesses range from a few inches to as much as 14 feet, with the thickest beds occurring in the Frontier formation. No detailed studies of these bentonite beds have been made in the region and no analyses are available.

A bed of white bentonite and bentonitic claystone, 11 feet thick, forms the uppermost bed of the Wind River formation near the top of the steep hill on the north side of White Pass. It occurs directly above the 37-foot unit of carbonaceous shale and coal. This highly bentonitic zone can be traced northeastward from White Pass for about 3 miles along the contact between the Wind River and Tepee Trail formations, but, because of poor exposures, could not be studied in detail. X-ray analyses of samples from White Pass reveal that the rock contains montmorillonite and a zeolite, moderate amounts of quartz, and traces of feldspar.

GOLD

Gold-bearing stream deposits are present along Warm Spring Creek west of the former site of the Du Noir tie camp. Few data are available concerning the operations of Clark's placer mine, now abandoned, which was located on the north side of Warm Spring Creek near the tie camp. The placer mine was mentioned by Schrader (1913, p. 136 ff.) who stated that the gold seems to be derived from prominent quartz ledges reported to crop out extensively in the granite and schist near the headwaters of the stream. Another possible source of the gold is the quartzite pebble conglomerate of the Eocene rocks, undifferentiated, along the north side of Warm Spring Creek. Love, Keefer, Duncan, and others (1951) reported flour gold in similar conglomerate of Paleocene age along the Gros Ventre River to the west. No placer mining operations are being carried on in the region at present.

URANIUM

The Du Noir area was not examined for radioactive minerals during the present investigation. Commercial quantities of uranium are present in other parts of the basin, however, in rocks of the Wind River formation as well as in older and younger strata. Because Wind River rocks are widespread in the mapped area, reconnaissance prospecting for uranium has been conducted in recent years, chiefly by local interests. How extensive this coverage has been is not known to the writer, but as yet no significant discoveries have been reported. There are, however, two localities of interest in adjacent areas. One is in the vicinity of Whiskey Mountain in the SE¼ sec. 12, T. 40 N., R. 107 W., where Gruner and Smith (1955, p. 31) have reported carnotite associated with barite and fluorite in rocks of Cambrian(?) age. The other is along Little Warm Spring Creek where a uraninite deposit was discovered in Precambrian rocks. The extent and potentialities of these occurrences are not known.

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