Geology and Hydrology of the Fort Belknap Indian Reservation Montana

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1576-F

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

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By DOUGLAS C. ALVERSON

WATER SUPPLY OF INDIAN RESERVATIONS

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1965

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

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

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By Douglas C. Alverson

ABSTRACT

The Fort Belknap Indian Reservation includes an area of 970 square miles in north-central Montana. At its north edge is the Milk River valley, which is underlain by Recent alluvium of the Milk River, glacial deposits, and alluvial deposits of the preglacial Missouri River, which carved and occupied this valley before the Pleistocene Epoch. Rising gently to the south is an undulating glaciated plain broken only by three small syenite porphyry intrusions. Underlying the glacial till of the plain are Upper Cretaceous shale and sandstone of the Bearpaw and Judith River Formations. At the south end of the reservation, 40 miles from the Milk River, an intrusion of syenite porphyry in Tertiary time uplifted, tilted, and exposed the succession of sedimentary rocks overlying the Precambrian metamorphic basement. The sedimentary rocks include 1,000 feet of sandstone and shale of Cambrian age; 2,000 feet of limestone and dolomite of Ordovician, Devonian, and Mississippian age; 400 feet of shale and limestone of Jurassic age; and 3,500 feet of sandstone, siltstone, and shale of Cretaceous age. Extensive gravel terraces of Tertiary and Quaternary age bevel the upturned bedrock formations exposed around the Little Rocky Mountains.

Ground water under water-table conditions is obtained at present from alluvium, glaciofluvial deposits, and the Judith River Formation. The water table ranges in depth from a few feet beneath the surface in the Milk River valley alluvium to more than 100 feet deep in the Judith River Formation. Yields to wells are generally low but adequate for domestic and stock-watering use. Quality of the water ranges from highly mineralized and unusable to excellent; many wells in the Milk River valley have been abandoned because of the alkalinity of their water. Potential sources of additional ground-water supplies are the alluvial gravel of creeks issuing from the Little Rocky Mountains and some extensive areas of terrace gravel.

The uplift and tilting of the sedimentary sequence around the Little Rocky Mountains and the minor intrusions in the central plain have created artesian conditions within aquifers. Wells obtain artesian water from sandstone aquifers in the Judith River, Eagle, and Kootenai Formations. Other potential acquifers, near their outcrop areas, are the Ellis Group and the Mission Canyon Limestone. Most wells that flow at the surface have small yields, but discharges of as much as 150 gallons per minute have been noted. Quality of artesian water ranges from poor to good. Well depths range from less than 50 to more than 300 feet.

INTRODUCTION

PURPOSE AND SCOPE OF INVESTIGATION

This report presents the results of a reconnaissance of the occurrence of ground water on the Fort Belknap Indian Reservation, Mont. The investigation was undertaken as part of the program of the Department of the Interior for the development of the Missouri River basin. Work was carried out under the immediate supervision of F. A. Swenson, former district geologist in charge of ground-water studies in Montana.

Fieldwork included general reconnaissance, well inventory, and geologic mapping in 1958 and additional geologic mapping in 1959. The well inventory entailed obtaining information about the depth of water, depth and diameter of well, method of lift, yield, and geologic source of the water for most of the wells on the reservation. Some wells in areas remote from well-traveled routes and some in Phillips County were not inventoried. Periodic measurements of the water levels were made during the summer of 1958 in 16 wells. Some drillers' logs of water wells and a few lithologic logs of oil-test holes were available.

The geologic map (pl. 1) was adapted from an unpublished geologic map of the reservation made by M. M. Knechtel in 1940 from fieldwork done from 1936–39 and modified in the southeast corner by later work (Knechtel, 1944). The Quaternary geology was added by the present author. Aerial photographs were used extensively in mapping glacial features, the terrace deposits, and alluvium. The geologic data were compiled on a topographic base map prepared by the Bureau of Indian Affairs in 1923 from topographic quadrangle maps made by the U.S. Corps of Engineers about 1916.

Objectives of this investigation were: (1) to determine the possibility of obtaining adequate supplies of ground water of good quality for domestic and stock-watering purposes; (2) to examine the extensive gravelly terraces and other potential aquifers around the north flank of the Little Rocky Mountains as possible sources of irrigation water.

LOCATION AND EXTENT OF THE AREA

The Fort Belknap Indian Reservation is in north-central Montana approximately between long 108°15′ and 108°45′ W. and lat 47°50′ and 48°30′ N. It includes the southeastern part of Blaine County and an irregular narrow strip of southwestern Phillips County. (See fig. 1.) The reservation extends 25–35 miles southward from the Milk River to the northern crest of the Little Rocky Mountains. It is 28 miles wide across the northern part and 25 miles wide across the southern part. Its total area is 970 square miles, and it includes all or parts of Tps. 25–32 N. within Rs. 22–26 E.

WELL-NUMBERING SYSTEM

In this report, wells are numbered according to a system that permits the easy location of the well with reference to the system of land subdivision used by the U.S. Bureau of Land Management (fig. 2). All wells in this report are in townships that lie north and east of the intersection of the Montana Principal Meridian and the Montana Base Line. The first number in the well designation refers to the township north of the base line; the second number, separated from the first by a dash, indicates the range east of the principal meridian; and the third number (one or two digits) refers to the section in which the well is located, within the indicated township. Sections are further subdivided into quarter sections. Lowercase "a" represents the northeast quarter section, "b" the northwest, "c" the southwest, and "d" the southeast. A second lowercase letter may indicate the quarter-quarter section, if known. For example, well 25–23–22bc locates the well in the southwest quarter of the northwest quarter of section 22, Township 25 North, Range 23 East and shows that it was the only well inventoried in that quarter-quarter section. If two or more wells are found in a quarter-quarter section, the wells are numbers serially in order of inventory date.

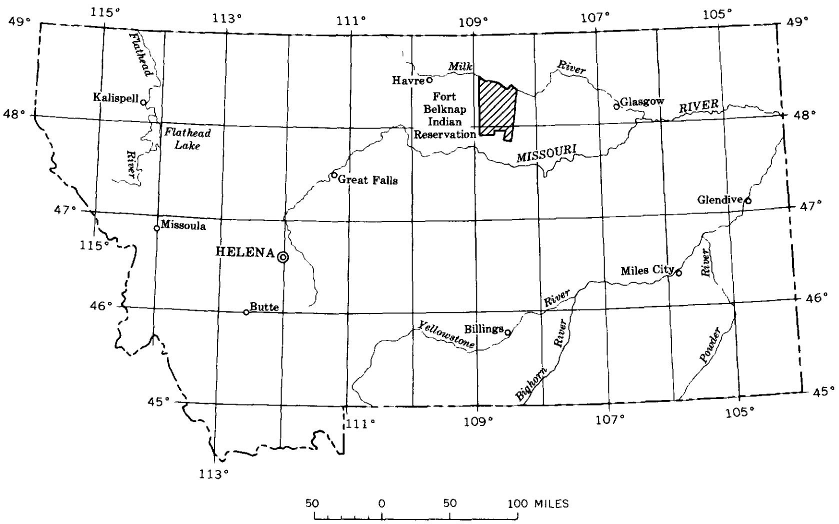

FIGURE 1.—Index map of Montana.

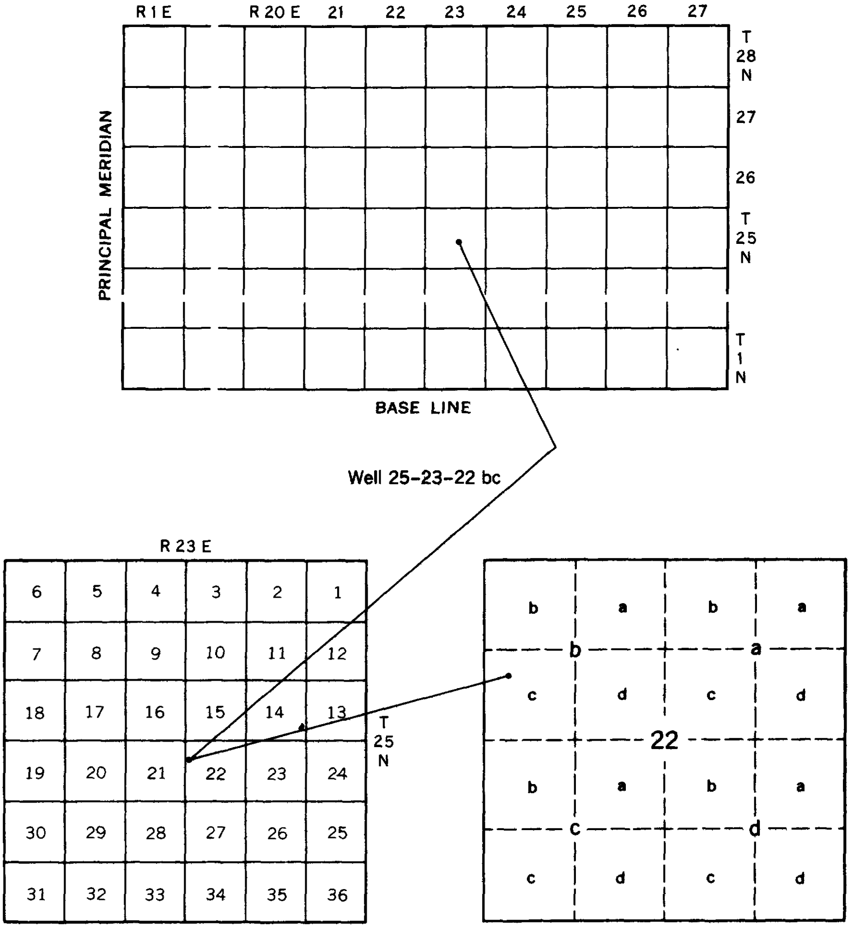

FIGURE 2.—Sketch illustrating well-numbering system.

HISTORY

Before white men first came to north-central Montana, Indians of the Assiniboine and Gros Ventre tribes controlled the land that included the present Fort Belknap Indian Reservation. Earlier tribes had been displaced toward the Rocky Mountains by the westward migration of the Assiniboines. In 1874, that part of Montana Territory north of the Missouri and Sun Rivers and east of the Rocky Mountains was set aside as a reservation for the Gros Ventre, Piegan, Blood, Blackfeet, and River Crow Indians. The present Blackfeet, Fort Peck, and Fort Belknap Reservations were established in 1887, and the remainder of the original reservation was opened for white settlement. Gold was discovered in the southern part of the Little Rockies in 1893, and a minor gold rush ensued. In 1895, that part of the area of potential mining development within the boundaries of the Fort Belknap Reservation was retroceded to the government and, immediately after survey, was opened for mining. The geological basis for the retrocession was provided by the first geological report on this area (Weed and Pirsson, 1896).

When the Fort Belknap Reservation was established, land was allotted to the residents on the basis of 160 acres to the family head, 80 acres for every child 18 or over, and 40 acres for every child under 18. The allotments are held today by descendants of the original holders. Irrigated plots in the Milk River valley and around Hays are worked individually, but the vast stretches of prairie between the mountains and the Milk River valley, best suited for stock raising as open range, are held in common by the tribes. Under treaty rights, the Indians of the reservation are entitled to 150 cfs (cubic feet per second) of the natural flow of the Milk River for irrigation.

PREVIOUS GEOLOGIC INVESTIGATIONS

Hayden (1868, p. 72) apparently made the first scientific comment on the Little Rocky Mountains: "* * * the Little Rocky Mountains seem to be composed for the most part of granite and other rocks, with igneous protrusions here and there * * *."

The first systematic geologic study of the Little Rocky Mountains was made by Weed and Pirsson (1896, p. 399–428), who made a geologic sketch map and described the igneous and metemorphic rocks and ore bodies of the then newly discovered gold deposits. Detailed descriptions of the mines and ore deposits were later made by Emmons (1908). The mining district, which is just south of the reservation, also has been described by Corry (1933) and Dyson (1939). Bryant (1953) described the mining history of the district.

Other early geologists whose work touched briefly on the Fort Belknap Indian Reservation were Stanton and Hatcher (1905), who described the Judith River Formation near Havre and postulated its occurrence to the east, and Calhoun (1906), who mapped the glacial deposits of the Montana lobe of the Keewatin ice sheet through the reservation. Pepperberg (1910) described the geology and coal deposits along the Milk River between Havre and Harlem; his map included a small part of the northwest corner of the reservation. Later he extended his mapping to the south (Pepperberg, 1912).

Bowen (1914) mapped the area between the reservation and the Bearpaw Mountains, in Tps. 28–31 N., including some land on the reservation. Collier (1918, fig. 2) mapped the extreme southeast corner of the reservation at a scale of 2 miles to the inch, but only parts of the rest of the reservation were included in his small-scale map

(1918, pl. 1). His text contained much information on the stratigraphy of the reservation.

Collier and Cathcart (1922) investigated the stratigraphy and structure of the small laccolithic domes south of the Little Rocky Mountains and named the Warm Creek Shale, Mission Canyon Limestone, and Lodgepole Limestone from local exposures.

Reeves (1924a) made a geologic map of the area adjoining the reservation to the west and south, in Tps. 25–27N., Rs. 22–23E. He mapped the extensive thrust-fault system connected with the Bearpaw Mountains structure and in this and subsequent papers (1924b, 1925, 1946) advanced theories for its explanation. He also presented much stratigraphic data on Cretaceous exposures near the boundary of the reservation.

Alden (1932) made extensive studies of the physiography and glacial geology of eastern Montana, including the Little Rocky Mountains. Plate 35 in his report showed the distribution of high and low terraces, the ice margin, and glacial lakes and bedrock during the Wisconsin Glaciation around the Little Rocky Mountains. The report contained much information on unconsolidated sediments of the reservation.

The first description of the water resources of this part of Montana was by Perry (1934), who described the general geology and artesian water resources in a large area of northeast and central Montana, including the Fort Belknap Reservation.

Knechtel (1942) described the Snake Butte boulder train and other glacial features and discussed the Pleistocene history of the reservation. He later (1944) made a detailed geologic map of the structurally complex plains adjacent to the south flank of the Little Rocky Mountains. He also (1959) discussed the stratigraphy of the Little Rocky Mountains and encircling foothills.

In 1953, the Billings Geological Society held its Fourth Annual Field Conference in the Little Rocky Mountains area. Its guidebook (Parker, 1953) contains excellent road logs and summary articles on local and regional geology and history.

Lemke (1958, p. 279) noted the elongate linear drumlins on the reservation southeast of Harlem and advanced theories for their origin.

ACKNOWLEDGMENTS

The author gratefully acknowledges the wholehearted cooperation given by Mr. Howard Dushane, superintendent of the Fort Belknap Indian Reservation, Mr. James Howell, assistant superintendent, and many officials, scientists, and other employees of the Bureau of Indian Affairs; by personnel of the Division of Indian Health, U.S. Public

Health Service; by Mr. R. C. Simpson, well driller of Malta, Mont.; and by the residents of the Fort Belknap Indian Reservation.

GEOGRAPHY

PHYSIOGRAPHY

The Fort Belknap Indian Reservation may be divided into three physiographic units: (1) the Milk River valley; (2) the central plain; and (3) the Little Rocky Mountains and adjacent foothills.

The Milk River valley is a relatively broad, flat flood plain, deeply incised by an underfit river and bounded on the north and south by low bluffs that rise to glaciated rolling plains. The valley was carved and originally occupied by the Missouri River before the advance of Pleistocene glaciers forced the river south of the Little Rocky Mountains to its present course. After the retreat of the ice, the Missouri never regained its former channel, which was occupied by the Milk River, a much smaller stream. The flood plain is thus the result of deposition of fine-grained materials by floods of the Milk River and its tributaries onto glacial till and glaciofluvial materials, which in turn overlie alluvium of the preglacial Missouri River. Repeated flooding has built a barely perceptible natural levee about a mile wide along the Milk River. This levee hinders the drainage of tributaries into the main stream and complicates irrigation drainage. Slopes as much as 1° from the river to the margin of the flood plain can be measured. The river's meander pattern seems to have two orders of magnitude: a small-scale pattern of meanders, having radii of curvature on the order of a few hundred yards and a larger set of meanders having radii of curvature of 4 or 5 miles, which swings the river from the north edge of the flood plain to the south edge and back. Meander scars and oxbow lakes are abundant near the present channel and are striking on aerial photographs.

In T. 31 N., Rs. 24–26 E., large bedrock "islands," mantled in places by glaciofluvial deposits and till, rise from the flat flood plain of the Milk River. At the confluence of Three Mile Creek with the Milk River valley, several islands probably represent the highest parts of a preglacial ridge between the Milk River valley and the valley of Three Mile Creek. After the ice front retreated, the accumulation of glaciofluvial material and coalescence of alluvium from both streams filled the valleys and low interstream areas, leaving only the islands. Another such island, occupying most of secs. 29 and 30, T. 31 N., R. 25 E., was isolated by the accumulation of alluvium from White Bear Creek, the Milk River, and glaciofluvial deposits of a glacial melt-water channel. Other islands, such as the one bisected by the Blaine-Phillips County line in sec. 24, T. 31 N., R. 25 E., are the result of a deviation in the course of the Milk River from the course of the preglacial Missouri River. The broad flood plain south of the island probably was the course of the preglacial Missouri River. Immediately after the glacial retreat, this area may have been blocked by a residual ice mass; and the nascent Milk River was forced to cut its own channel in the Judith River Formation north of the present island.

The lowest point on the reservation is in the extreme northeast corner, where the Milk River leaves the reservation at an altitude of about 2,300 feet.

The central plain extends from the low bluffs overlooking the south margin of the Milk River flood plain to the foothills of the Little Rocky Mountains, a distance of 20–30 miles. The overall flat or gently rolling appearance of the central plain is broken by Snake Butte, Wild Horse Butte, and Twin Buttes, which are masses of resistant igneous rock that have been exposed by erosion of the soft sedimentary rocks into which they were intruded. Snake Butte rises abruptly 100–200 feet above the plain; but it has a relatively flat surface, which slopes gently to the southwest. Wild Horse Butte, about halfway from the Fort Belknap Agency to Hays, is an irregular mass of igneous rock rising about 200 feet above the level plains. Twin Buttes, actually three in number, rise about 700 feet abruptly above the plains. The surfaces of the upper part of the middle butte are regular enough to suggest an Egyptian pyramid. All the buttes were created during the Tertiary Period by the intrusion of syenite porphyry as laccoliths, sills, or small stocks into the flat-lying sedimentary rocks.

Most of the central plain is mantled by 1–80 feet of glacial till or glaciofluvial deposits, except where Recent streams have cut into the underlying Cretaceous rocks. Streambanks are generally steep, and in these places the few bedrock outcrops are to be found. Like the Milk River, the streams draining the central plains meander in complicated patterns and have incised their channels several feet into their flood plains. Many of the streams flow in relatively broad evenbanked troughs that were the channels through which glacial melt water drained after the latest period of glaciation. In several places these channels are completely dry, and there are no traces of Recent drainage, and in some places the present drainage reverses the direction of glacial drainage.

About 3 miles southeast of the Fort Belknap Agency, where the Harlem-Hays road makes a broad turn to the south, are the most accessible examples of what Lemke (1958) termed "elongate linear drumlins." These are long low gravelly ridges, reaching heights of 25 feet above the surrounding glaciated plain, but attaining lengths of as much as 10 miles, uninterrupted except by scarce Recent streams. Most linear drumlins trend roughly northwest-southeast; however, some trend almost north-south and others almost due east-west. The drumlins may represent local adjustment of the direction of ice flow to the preglacial topography. The ridges consist of glacial till and possibly some glaciofluvial material. In long profile, their summits undulate gently over long distances, but seem to become lower toward the southeast. They have a profound effect on drainage consequent to the surface left by the last glaciation, and most streams in areas of drumlins run parallel to and between them. Southeast of the Fort Belknap Agency, the drumlins are several hundred feet apart, and in plan they are remarkably straight and have very few and slight curves. Similar features in North Dakota and elsewhere in glaciated regions have been described and their origin discussed by Lemke (1958), Gravenor and Meneley (1958), and Stalker (1960).

A long line of shonkinite blocks and fragments trending southeastward across the reservation from Snake Butte to the eastern boundary of the reservation was described by Knechtel (1942), who named it the Snake Butte boulder train. Knechtel's theory that the latest advance of ice flowed southeastward, parallel to the boulder train, would seem to be verified by the trends of the linear drumlins.

Knob and kettle, and other types of irregular topography common to regions that have undergone continental glaciation, are developed in the southern part of the central plain, and the terminal moraine of the latest glaciation is well preserved in many places along the north flank of the Little Rocky Mountains. A large flat glacial outwash plain occupies parts of the south half of T. 29 N., R. 25 E., and the north half of T. 28 N., R. 25 E.

Flat gravelly terraces of late Tertiary or early Quaternary age are widely developed around the north flank of the Little Rocky Mountains. They are most extensive in the southwest corner of the reservation and near Lodgepole. The terraces everywhere have been severely dissected by postglacial erosion, and a highly indentate to jagged outline results on the geologic map (pl. 1). Generally, the terraces slope gently away from the Little Rocky Mountains, but west of Suction Creek, they slope away from the Bearpaw Mountains. In the Lodgepole area, three distinct terrace levels can be distinguished at altitudes of 3,700, 3,650, and 3,400 feet. Projected entirely around the north flanks of the Little Rocky Mountains, the highest (oldest) terrace level would completely conceal the exposures of sedimentary rocks younger than Mississippian. Alden (1932) described the terraces and correlated them with the Flaxville Formation and other erosion surfaces in this region.

Where underlain by shale, the terraces are subject to much slumping, being lubricated by ground water percolating downward through the highly permeable gravel. The slumped areas have a highly irregular topography of low gravel ridges, which are arcuate in plan, a few square yards in area, roughly parallel to the terrace edge, and commonly separated by small undrained depressions.

The Little Rocky Mountains are composed of a central core of metamorphic and intrusive rocks and surrounded by sedimentary rocks that were deformed by the emplacement of the intrusive rocks. The intrusive rocks have been eroded into steep-sided ridges and peaks that rise to an altitude of 5,300 feet.

The more resistant sedimentary rocks, where not covered by terrace deposits, form steep cuestas and hogbacks that dip away from the Little Rocky Mountain core. The most prominent of these ridges is the wall of the Mission Canyon Limestone of Mississippian age which nearly surrounds the base of the mountains. This limestone wall is more than 100 feet high in places, and dips of 90° or slight overturning are not uncommon. Streams that originate in the mountains have cut deep V-shaped gorges through the limestone wall. The road from Hays to Landusky passes through one of these gorges, along the South Fork of Peoples Creek. The limestone walls of the gorge are nearly vertical, and in one place a natural bridge has been carved.

Outward from the Mission Canyon Limestone wall, successive ridges are formed on the resistant beds of the Kootenai Formation, the Mowry Shale, the Mosby Sandstone Member of the Warm Creek Shale, the Eagle Sandstone, and the Judith River Formation.

DRAINAGE

The largest part (about 919 square miles or 95 percent) of the Fort Belknap Indian Reservation is drained by the Milk River and its four principal northeastward-flowing intermittent tributaries—Three Mile, White Bear, Peoples, and Beaver Creeks. The Milk River is a major perennial tributary of the Missouri, joining it below Nashua, Mont.

Three Mile and White Bear Creeks are minor tributaries, together draining 279 square miles of the reservation; Peoples Creek, however, is a major intermittent stream, draining 508 square miles of the central plain. In sec. 20, T. 29 N., R. 25 E., the North Fork of Peoples Creek, which heads near Cleveland in the Bearpaw Mountains, joins the South Fork, which heads in the Little Rocky Mountains. Tributary in turn to the South Fork are Lodgepole and Jim Brown Creeks, as well as many smaller unnamed creeks, all intermittent. These head in the Little Rocky Mountains and flow generally northward. After the spring thaw, flow in all creeks in the central plains is limited to the runoff from intense summer rainstorms.

In the southeastern part of the reservation, 132 square miles are drained by Beaver Creek and its tributaries, Warm Spring and Wild Horse Creeks. Warm Spring Creek is perennial, as it is fed by a major group of perennial warm springs in T. 26 N., R. 25 E. Most of the drainage basin of Beaver Creek is outside the reservation.

An area of 51 square miles in the southwest corner of the reservation is drained by Suction Creek, which flows intermittently into Cow Creek, a tributary of the Missouri River.

Knechtel (1942) discussed the profound changes in drainage which have occurred as a result of continental glaciation in this part of Montana.

CLIMATE

The climate of the Fort Belknap Indian Reservation is typical of the semiarid Great Plains region. Yearly precipitation averages 10 inches at Dodson, 12 inches at Harlem, 15 inches at Hays, and 16 inches at St. Paul's Mission. No data are available for the central plain between the Milk River valley and the Little Rocky Mountains, but the average precipitation at Cleveland, 12 miles west of Wild Horse Butte, where the topography is similar, is about 14 inches. Undoubtedly the higher areas of the Little Rocky Mountains receive more precipitation, particularly snow, than Hays or St. Paul's Mission. About half the annual precipitation is concentrated in short but intense rainstorms in May, June, and July. During the warm period from June through August, there are about 40 days having rainfall of 0.01 inch or greater. In 1 year out of 5, however, the warm-season rainfall is less than 75 percent of the average, which ranges from 8 to 10 inches. The average annual snowfall is 30–40 inches, and the ground is covered with snow 80–90 days per year. The first snow generally falls between October 1 and 16, and snow falls on about 40 days through the winter.

Temperatures generally range from below zero in winter to the mid-nineties in summer. In Harlem, the average temperature in January is 12°F but ranges from about −13° to 26°. During the winter, the temperature is continuously below freezing for about 65 days, although a warming trend has been noted in recent years. The average temperature in July is about 70°. Similar temperatures are observed in Hays, although they are slightly lower in the summer. The comparatively high daytime temperatures in the summer are tempered by low humidity and relatively cool nights. The average relative humidity at 2:00 p.m. in January is 65–70 percent. In April it is 50 percent, in July, 35–40 percent, and in October, 45–50 percent.

The last killing frost generally is between May 21 and June 1, and the first killing frost is between September 1 and 11. The growing season thus ranges from 90 to 110 days. In 3 or 4 years out of 20, however, the dates of these frosts are likely to be 10 or more days earlier or later than the average dates given above. During the warm season, hail falls on about 2 days. Thunderstorms are far more frequent, 20–30 per year. About 140 days per year are clear of clouds.

TRANSPORTATION, COMMERCE, AND AGRICULTURE

Most of the inhabited parts of the reservation are served by all-weather roads. The only paved roads are U.S. Highway 2, which follows the south side of the Milk River valley through the reservation from the Fort Belknap Agency to Dodson, and State Highway 376, which connects the agency and Hays. Graveled all-weather roads interconnect Landusky, Lodgepole, and Zortman and also interlace the Milk River valley. Other roads on the reservation are passable tracks in dry weather and slippery mires when wet.

Cross-country movement by vehicle across most of the central plain is possible during dry weather, although frequent detours are necessary to avoid steep-walled gullies, and movement in some places is slow due to irregular ground surface. Even when the soil is dry in the Milk River valley, off-the-road movement is limited by the extensive network of irrigation canals and ditches, as well as dense vegetation, plowed fields, and marshy areas.

The principal activity of the residents of the reservation is stock raising. The irrigated lands of the Milk River valley provide fair crops of alfalfa and other winter forage crops for livestock, and in summer the stock thrive on the exceptionally nutritious short grass which grows abundantly all over the central plains. Irrigated wheat and small grain farming has been moderately successful in the Milk River valley, but only small tracts have been sown for dryland farming.

VEGETATION

Trees and other natural vegetation grow abundantly only along the banks of the river, in uncultivated parts of the Milk River valley, and in parts of the Little Rocky Mountains. In 1937 a severe fire burned off much of the timber in the mountains inside the reservation and little has been replanted. Dense brush has grown up to replace the trees. Unburned areas in the mountains are well forested, and south of the reservation, wooded areas are protected as part of the Lewis and Clark National Forest.

Some of the cuestas and hogbacks north of the Little Rocky Mountains support substantial growths of lodgepole pine, which favor the soils developed from certain rocks, especially the arkosic sandstone of the Kootenai Formation, the brittle siliceous Mowry Shale, and the sandstone of the Judith River Formation.

The angular unconformity between the terrace deposits and underlying bedrock formations is marked in many places by a line of brushy vegetation—its permanence and density depending on the amount of water seeping from the unconformity.

Only short grass grows abundantly on the central plain, but thick brush is concentrated in places along intermittent stream courses.

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

Sedimentary, igneous, and metamorphic rocks, ranging in age from Precambrian to Recent, are exposed on the Fort Belknap Indian Reservation. A summary of the rock formations and their water-bearing properties is given in table 1.

SUBSURFACE DATA

Relatively little drilling for oil has been done on the Fort Belknap Reservation. Formation-top logs are available for six oil tests, two of them just west of the reservation boundary, and lithologic data for two of these oil tests are available. The locations of the six oil-test holes are plotted on plate 1 and in figure 3. Montana Gas Corp.-Pochler 1 oil test (hole 1, fig. 3) was drilled to a depth of 925 feet in the center of the SW¼ sec. 17, T. 30 N., R. 22 E. It reached the Judith River Formation at 70 feet and bottomed in igneous rock.

The Fred Munger-John Siert Farm 1 oil test (hole 2, fig. 3) was drilled 4,890 feet deep in the S½SE¼SW¼ sec. 20, T. 29 N., R. 22 E. This hole began in glacial till, passed into the Judith River Formation at 80 feet, and bottomed in Mission Canyon Limestone at 4,890 feet.

Mobil Producing F–11–151 oil test (hole 3, fig. 3) was drilled to a depth of 4,154 feet in the NE¼NW¼NW¼ sec. 15, T. 30 N., R. 25 E. The hole started in Bearpaw Shale and finished in Mission Canyon Limestone.

Phillips Petroleum 1 Gros oil test (hole 4, fig. 3) was drilled in the NW¼NW¼ sec. 11, T. 31 N., R. 22 E. It started in Bearpaw Shale and bottomed in Mission Canyon Limestone at 4,192 feet.

Phillips Petroleum 1-A Savoy oil test (hole 5, fig. 3) was drilled in the center of the NW¼SW¼ sec. 26, T. 31 N., R. 24 E. The hole began in the Judith River Formation and bottomed in Devonian rocks at 4,902 feet.

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TABLE 1.—*Rocks of the Fort Belknap Indian Reservation and their water-bearing properties*

Age		Stratigraphic unit		Approximate thickness (ft)	Lithologic characteristics	Water supply
Sedimentary rocks						
Quaternary		Alluvium		0–90	Sand, silt, and clay and some gravel; near Little Rocky Mountains contains much limestone gravel.	Moderate quantities fair to good quality water in Milk River valley and major intermittent streams; yields poor in minor tributary valleys; moderate to large quantities good water near Little Rocky Mountains.
Quaternary		Glacial deposits		0–100	Gravel, sand, silt, and clay intermixed, in places reworked to form sand and gravel lenses and beds.	Moderate quantities of good quality water available from sand and gravel lenses. Where intermixed, yields are poor or no water is available.
Tertiary		Terrace deposits		0–50	Gravel, limestone pebbles and cobbles; some silt and sand.	Small quantities of good water may be available to wells in the central parts of large terrace areas.
Cretaceous	Late	Montana Group	Bearpaw Shale	0–1,100	Shale, dark-blue-gray; some bentonite.	May yield very small quantities of poor water to some wells.
Cretaceous	Late	Montana Group	Judith River Formation	380	Sandstone, fine-grained; siltstone and shale; some coal beds.	Yields moderate to large quantities of poor to good water from many wells. Water under artesian pressure in some places.
Cretaceous	Late	Montana Group	Claggett Shale	500	Shale, dark-gray, highly concretionary.	Yields very little or no water to wells.
Cretaceous	Late	Montana Group	Eagle Sandstone	270	Sandstone and shale interbedded at base; upper part mostly shale; sandstone decreases to east.	Massive sandstone of lower part yields small to moderate quantities of poor to fair quality water to wells, some under artesian pressure.
Cretaceous	Late	Colorado Group	Warm Creek Shale	1,000	Shale, blue-gray, highly concretionary. Thin calcareous sandstone 150 feet from base.	Yields very little or no water to wells; calcareous sandstone is potential poor aquifer.
Cretaceous	Early	Colorado Group	Mowry Shale	70	Shale, gray, brittle, siliceous.	Yields no water to wells.
Cretaceous	Early	Thermopolis Shale		610	Shale, dark-blue-gray; many small ferruginous concretions; some sandstone lenses in lower half.	Yields no water to wells; thin sandstone near base is potential poor aquifer.
Cretaceous	Early	Kootenai Formation		190	Sandstone, tan-buff massive, coarse, arkosic; interbedded with shale.	Sandstone yields moderate quantities of good quality water to wells, generally under artesian pressure, deeply buried in most of reservation.
Late and Middle Jurassic		Ellis Group		380	Shale, gray; lower third argillaceous limestone.	Lower third may yield small to moderate quantities of fair quality water to wells, springs issue from base.
Mississippian	Late	Madison Group	Mission Canyon Limestone	330	Limestone, light-gray and buff, massive, very resistant; weathers cavernously.	Should yield large quantities of good quality water to wells drilled into caverns, fissures, and fractures; very deeply buried in most of reservation.
Mississippian	Early	Madison Group	Lodgepole Limestone	560	Limestone, dark-gray, thin-bedded; in places colored red from thin shale partings.	Should yield moderate to large quantities of good quality water to wells penetrating fissures and joints; very deeply buried in most places.
Devonian, Ordovician, and Cambrian		Undifferentiated		2,000	Limestone, dolomitic limestone, and shale.	Should yield moderate to large quantities of good quality water to wells penetrating fissures and joints; very deeply buried outside Little Rocky Mountains.

TABLE 1.—*Rocks of the Fort Belknap Indian Reservation and their water-bearing properties*—Continued

Age	Stratigraphic unit	Approximate thickness (ft)	Lithologic characteristics	Water supply
Igneous and metamorphic rocks				
Tertiary			Syenite porphyry and related igneous rocks.	Large quantities of good water available from fractures in shonkinite at Snake Butte and at other buttes. Some water may be available from fault zones and fractures in Little Rocky Mountains.
Precambrian			Biotite and hornblende schist, gneiss, quartzite.	Some water may be available from fracture and fault zones in Little Rocky Mountains.

Phillips Petroleum 1 Fort Belknap "A" (hole 6, fig. 3) was drilled in the SW¼NW¼ sec. 3, T. 28 N., R. 23 E., between Peoples Creek and Twin Buttes. The hole began in the Judith River Formation and bottomed in Cambrian rocks at 7,074 feet.

Figure 3 has been taken from a larger map by Erdmann and Koskinen (1953). The configuration of the contours at the base of the Thermopolis Shale, as originally drawn by the authors, has been changed to conform with the information on formation tops from the six oil-test holes drilled on or near the reservation. The general structural interpretation has not been changed basically, however.

CAMBRIAN, ORDOVICIAN, AND DEVONIAN SYSTEMS

A considerable thickness of sedimentary rocks of Cambrian, Ordovician, and Devonian age is exposed in the core of the Little Rocky Mountains. The oldest formation of Cambrian age is the Flathead Sandstone, about 50 feet thick, which nonconformably overlies Precambrian metamorphic rocks. About 900 feet of unnamed greenish-gray shale and 60 feet of shale, dolomite, and intraformational conglomerate of the Dry Creek Shale complete the Cambrian section. The Ordovician System is represented by about 450 feet of Bighorn Limestone and dolomitic limestone. Unconformably above the Bighorn lies about 500 feet of Jefferson Limestone, of Late Devonian age. All these formations crop out only within the Little Rocky Mountains, where they are mapped (pl. 1) with the Mississippian Madison Group. Rader (1953) discussed the Ordovician, Silurian, and Devonian stratigraphy of this region and made a detailed stratigraphic section of Ordovician and Devonian rocks in Browns Gulch, secs. 11 and 14, T. 26 N., R. 24 E.

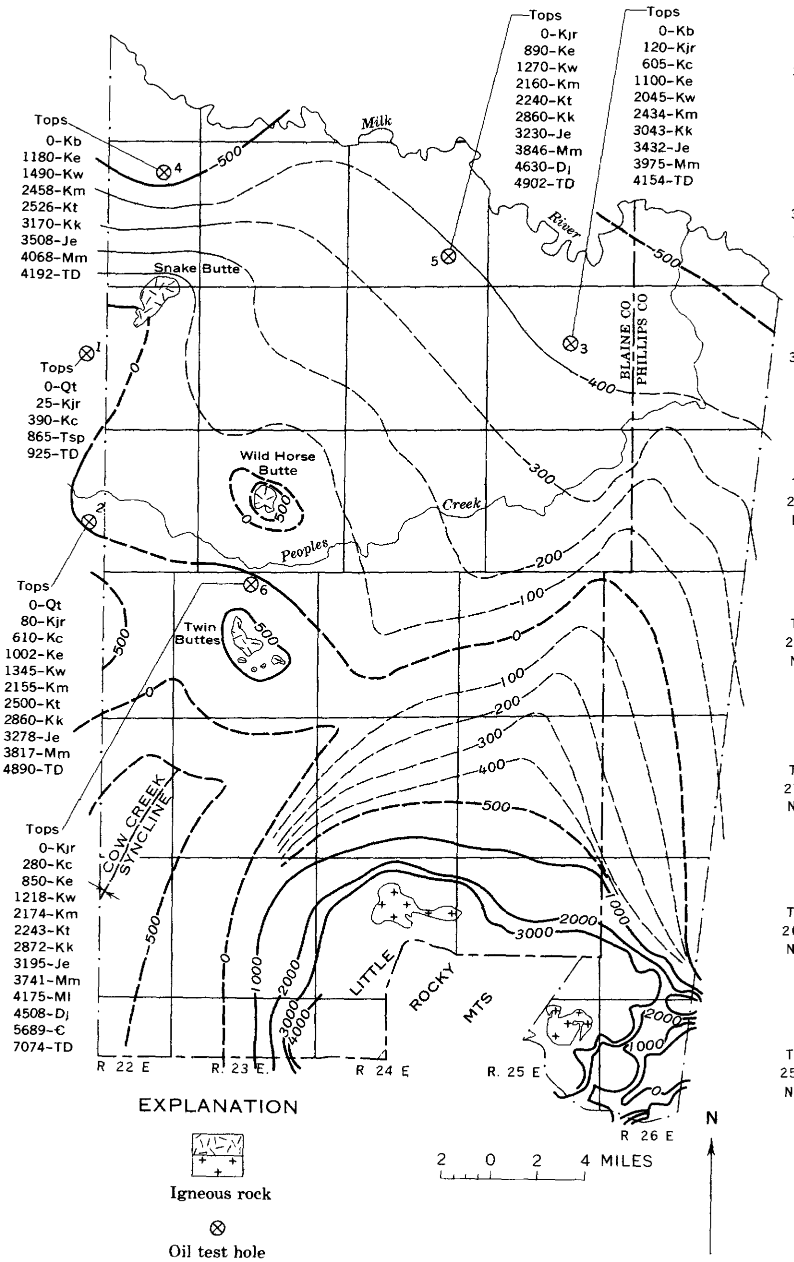

FIGURE 3.—Structure-contour map of the Fort Belknap Indian Reservation. Contours are drawn at the base of the Thermopolis Shale; they are dashed where control is less accurate. Contour interval is 100 feet; datum is mean sea level. Depths to formation tops in oil test holes were modified from Erdmann and Koskinen, 1953. Hole 1—Montana Gas Corp.-Pochler 1; Hole 2—Fred Munger-John Siert Farm 1; Hole 3—Mobil Producing F-11-151; Hole 4—Phillips Petroleum 1 Gros; Hole 5—Phillips Petroleum 1-A Savoy; Hole 6—Phillips Petroleum 1 Fort Belknap "A." Qt, glacial till; Tsp, syenite porphyry; Kb, Bearpaw Shale; Kjr, Judith River Formation; Kc, Claggett Shale; Ke, Eagle Sandstone; Kw, Warm Creek Shale; Km, Mowry Shale; Kt, Thermopolis Shale; Kk, Kootenai Formation; Je, Ellis Group; Mm, Mission Canyon Limestone; Ml, Lodgepole Limestone; Dj, Jefferson Limestone; Є, Cambrian rocks; TD, total depth of test hole.

Devonian rocks were penetrated at 4,508 feet beneath the surface in one oil test (hole 6, fig. 3) and at 4,630 feet in another (hole 5, fig. 3). Cambrian rocks were reached in only one oil-test hole, at 5,689 feet, in the Phillips Petroleum 1 Fort Belknap "A" oil test (hole 6, fig. 3).

None of the Cambrian, Ordovician, or Devonian rocks yield water to wells within the reservation. The limestone and dolomite of these older formations probably contain ground water of good quality in large quantities in caverns, fissures, and fractures, and it should be under high artesian pressure where the formations are buried. Outside the Little Rocky Mountains, however, they are overlain by a thick sequence of younger rocks, which include several good aquifers, and as the older rocks lie at great depth, it is unlikely that they will ever be a major source of ground water on the reservation.

MISSISSIPPIAN SYSTEM

MADISON GROUP

An angular unconformity separates the Madison Group, of Mississippian age, from the overlying formations of Mesozoic age. The Madison was named by Peale (1893) for its conspicuous outcrops in the Madison Range of southwestern Montana. Collier and Cathcart (1922, p. 173) called the Madison a group and designated the upper part the Mission Canyon Limestone and the lower the Lodgepole Limestone. Nordquist (1953) summarized Mississippian stratigraphy in north-central Montana.

The type section of the Mission Canyon Limestone is in Mission Canyon, 5 miles south of Hays, in sec. 32, T. 26 N., R. 24 E., on the Fort Belknap Reservation. The Mission Canyon is a massive white to light-buff crystalline to fragmental limestone, here about 330 feet thick. An additional 150 feet had been removed by erosion before deposition of the Jurassic sedimentary rocks began. The Mission Canyon is conspicuously exposed in the Little Rocky Mountains, where it forms the massive resistant white limestone "wall," which encircles the central core of the mountains. It also caps several of the small domes in the southeast corner of the reservation.

The Lodgepole Limestone consists of about 800 feet of thin-bedded light- to dark-gray limestone, in many places stained a distinctive red from thin intercalations of red shale. Its type section is in Lodgepole Canyon, 5 miles south of Lodgepole.

In five oil tests in the central and northern part of the reservation, the top of the Mission Canyon was penetrated at 3,741–4,068 feet beneath the surface. (See fig. 3, holes 2–6.)

No water wells on the reservation are known to tap the Madison Group. Water of good quality probably could be obtained in great abundance and under considerable artesian pressure from solution cavities, fissures, and fractures in the limestone, where it lies at depth. In most of the reservation, however, the Madison Group lies below economical drilling depth and is at least 200 feet deeper than the base of the Kootenai Formation, which should yield moderate supplies of water to wells. Near the flanks of the Little Rocky Mountains, substantial supplies of water from the Madison Group could be obtained at shallow depths, probably 500–1,000 feet, if wells were close enough to the base of the Madison "wall," possibly within the outcrop area of the Ellis Group.

JURASSIC SYSTEM

ELLIS GROUP

The Ellis Group, of Middle and Late Jurassic age, was named by Peale (1893) for exposures near Fort Ellis, near Bozeman, Mont. The Ellis has group rank in Montana and is subdivided into the Swift, Rierdon, and Piper (or Sawtooth) Formations. This subdivision has been recognized but not been mapped in the Little Rocky Mountain area. The Ellis conformably underlies the Kootenai Formation of Early Cretaceous age. A profound angular unconformity exists between the Ellis and the underlying Mission Canyon Limestone, of Mississippian age.

The Ellis crops out in a narrow belt around the north flank of the Little Rocky Mountains and in small areas in the southeast corner of the reservation. Exposures are not numerous, and, as it is less resistant to weathering than the overlying Kootenai and underlying Mission Canyon, it generally forms a valley between these formations. Where the formations dip steeply, debris from the Mission Canyon generally completely obscures the Ellis.

Knechtel (1959) divided the Ellis into the Swift Formation and the underlying Rierdon Formation. The Swift is mostly light- to dark-gray shale and contains calcareous concretions. In the upper part it has some glauconitic sandstone beds, and in the lower part silicified *Belemnites* are abundant and distinctive. The Swift is about 240 feet thick. About 50 feet of it is well exposed in the NE¼ sec. 18, T. 26 N., R. 25 E.

The Rierdon, about 140 feet thick, consists of light- to dark-gray clayey limestone, which weathers to white or light buff. The limestone commonly weathers into rounded pebble-sized fragments, which cover the outcrop surface. A thin sandstone bed marks the base of this formation.

Beneath the surface of the central plain, the top of the Ellis was penetrated at depths of 3,195–3,508 feet in five oil tests (holes 2–6, fig. 3).

No water wells on the reservation are drilled into the Ellis, although the Rierdon probably would be a fair aquifer and would contain water under high artesian pressure, where overlain by other rocks. In most of the reservation, however, the Ellis not only lies below economic drilling depths but is overlain by the aquifers of the Kootenai Formation, which generally will yield moderate supplies of water of good quality. If the water issuing from Big Warm and Little Warm Springs is typical of the Ellis, water from the Ellis may be more mineralized and warmer than water from younger formations. These springs issue from the base of the Ellis in the SW¼ sec. 24, T. 26 N., R. 25 E., and flow perennially at about 5 cfs.

CRETACEOUS SYSTEM

KOOTENAI FORMATION

The name Kootenai was suggested by Sir William Dawson from a Canadian Indian tribe inhabiting the region in which Dawson (1885) discovered sandstone, shale, conglomerate, and coal beds of lowest Cretaceous age. On the Fort Belknap Reservation, the Kootenai Formation is conformable with the overlying Thermopolis Shale and conformable to the underlying Ellis Group of Jurassic age. The Kootenai is of continental origin, and, as mapped herein, includes all beds below the thick dark-blue shale of the Thermopolis through the massive coarse arkosic sandstone bed above the gray shale of the Ellis.

The Kootenai crops out as one or two prominent hogbacks around the north flank of the Little Rocky Mountains and in smaller areas in the southeast corner of the reservation. Knechtel (1944) subdivided the Kootenai into three members: an upper coarse arkosic sandstone, 25 feet thick; a middle maroon, green, and gray shale, 85 feet thick; and a basal unit of alternating gray shale and thick beds of tan coarse arkosic sandstone, 80 feet thick. The sandstone beds around the north flank of the Little Rocky Mountains contain lenses of pebble conglomerate and display excellent crossbedding. Southwest of Lodgepole, in sec. 7, T. 26 N., R. 25 E., the Kootenai was measured and found to be 341 feet thick; the increase over Knechtel's figure is almost entirely due to thickening of the middle variegated shale member.

In the five oil-test holes that penetrated the Kootenai on the reservation, the top of the formation was at depths of 2,860–3,170 feet beneath the surface. (See fig. 3, holes 2–6.)

The coarse arkosic sandstone beds of the Kootenai are excellent aquifers. In most of the reservation, however, the Kootenai is buried under more than 2,000 feet of younger sedimentary rocks, far too deep for economic water-well drilling. Only around the north flank of the Little Rocky Mountains is the Kootenai near the surface, and in this area, water of good quality is obtained under artesian pressure from at least two wells. Well 26–24–20cc, 260 feet deep, flows about 0.5 gpm (gallons per minute), and well 26–24–30dd, 191 feet deep, flows 4 gpm. The best sites for drilling wells into this formation generally are near the contact of the Kootenai with the overlying Thermopolis Shale. Yields from properly constructed wells should be sufficient for domestic and moderate stock requirements. The water from well 26–24–30dd is of fair to good quality, as shown by the following analysis, in parts per million, by the Montana State Board of Health:

Sodium	76
Calcium	106
Magnesium	60
Sulphate	299
Chloride	24
Bicarbonate	405
Hardness	511
pH	6.8

COLORADO GROUP

The Colorado Group, of Cretaceous age, was named by Hayden (1876, p. 45) for exposures at the base of the Front Range in Colorado. Collier and Cathcart (1922, p. 172) divided the Colorado into three mappable formations south of the Little Rocky Mountains. From the bottom, these formations are the Thermopolis Shale, Mowry Shale, and Warm Creek Shale. The Thermopolis has since been removed from the Colorado Group (Reeside, 1944). The Mowry and Thermopolis Shales have been designated as Early Cretaceous on the basis of fossils. Only the Warm Creek Shale is considered (Cobban and Reeside, 1951) to be of Late Cretaceous age. Collier and Cathcart (1922, p. 172) considered the Mosby to be a member of the Warm Creek Shale in this area, and Knechtel (1944) tentatively correlated several sandy layers in the lower part of the Thermopolis to strata of the Blackleaf Formation in areas farther west in Montana. The highest layer occurs near the horizon of the Muddy Sandstone Member of the Thermopolis in Wyoming. Correlation within the Colorado Group in Montana and adjacent regions was discussed at length by Cobban (1951).

The Colorado Group is conformable with the overlying Eagle Sandstone of the Montana Group. In parts of Montana, a gradational sequence of sandstone and shale between the Colorado and the Eagle is called the Telegraph Creek Formation, but this formation is not recognized in the Little Rocky Mountains area. The underlying Kootenai Formation is also conformable with the Thermopolis Shale.

THERMOPOLIS SHALE

The Thermopolis Shale was named by Lupton (1916, p. 168) for dark marine shale exposed near Thermopolis, Wyo. The Thermopolis conformably overlies the Kootenai Formation and conformably underlies the Mowry Shale of the Colorado Group. Knechtel (1944) tentatively correlated the lower 270–300 feet of the Thermopolis with the Blackleaf Formation. At the top of the Blackleaf equivalent he identified the Muddy (?) equivalent, about 25 feet of fine-grained sandstone, containing polished chert pebbles. Knechtel (1959) named this prominent sandy unit the Cyprian Sandstone Member of the Thermopolis Shale. The Cyprian thins toward the east. The remainder of the formation consists almost exclusively of dark blue-gray marine shale containing numerous beds of heavy reddish-brown ferruginous limestone concretions. Total thickness of the Thermopolis is about 600 feet.

The Thermopolis is relatively nonresistant to weathering, and for this reason good exposures are scarce, although the outcrop area is a fairly wide band around the north flank of the Little Rocky Mountains. The Thermopolis also crops out in small areas in the southeast corner of the reservation. Except for low ridges overlying the concretionary beds and thin sandstone beds, the Thermopolis outcrop area is generally marked by a gentle slope or a swale between the Mowry ridge and the topmost Kootenai sandstone bed.

The top of the Thermopolis was penetrated at depths of 2,240–2,526 feet in four oil tests (holes 2, 4–6, fig. 3) drilled in the central and northern parts of the reservation.

On the whole, the Thermopolis is relatively impermeable. The Cyprian and other discontinuous thin sandstone beds and lenses may yield small quantities of water of poor quality to carefully constructed wells. Where possible, however, drilling should continue to the Kootenai sandstone aquifers. No wells are known to obtain water from the Thermopolis on the reservation.

MOWRY SHALE

The distinctive Mowry Shale, of Early Cretaceous age, was named by Darton (1904) for exposures along Mowry Creek, northwest of Buffalo, Wyo. In the Little Rocky Mountains area, the Mowry underlies the Warm Creek Shale and overlies the Thermopolis Shale and is conformable to both.

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The Mowry is a light-gray brittle siliceous shale, weathering to light orange brown and white, and it contains abundant fish scales. It is 70 feet thick, and, where exposed, generally forms a conspicuous white ridge supporting a good stand of lodgepole pine. The Mowry is an excellent marker bed, and its outcrop is traceable around the north flank of the Little Rocky Mountains from the southwest to the southeast corners of the reservation.

The top of the Mowry was penetrated at depths of 2,155–2,458 feet below the surface in five oil tests (holes 2–6, fig. 3) drilled in the central and northern parts of the reservation.

The Mowry probably is not a good aquifer. Its lithologic character indicates a low permeability. No wells are known to yield water from the Mowry on the reservation.

WARM CREEK SHALE

The Warm Creek Shale, of Late Cretaceous age, is the upper formation of the Colorado Group. It is overlain conformably by the Eagle Sandstone of the Montana Group, also of Late Cretaceous age, and underlain conformably by the Mowry Shale, of Early Cretaceous age. The type locality for the Warm Creek Shale is along Big Warm Spring and Little Warm Spring Creeks, on the Fort Belknap Indian Reservation, where the formation was described and named by Collier and Cathcart (1922, p. 172, footnote). No outcrop was specified as the type section, but fair exposures can be found in secs. 13 and 14, T. 26 N., R. 25 E. As defined by Collier and Cathcart, the Warm Creek included an upper shale member, the Mosby Sandstone Member, and a lower shale member.

The Warm Creek Shale crops out in a fairly wide band around the north flank of the Little Rocky Mountains, in the structurally complex southeast corner of the reservation, and in a few poor exposures around Wild Horse Butte. As almost the entire thickness is shale, outcrops are limited to vertical walls of recently cut gullies. The Mosby Sandstone Member, however, commonly forms a ridge. The surface expression of the Warm Creek is thus two sparsely vegetated smooth-sloping valleys between the Mosby ridge and the more resistant overlying and underlying formations.

The lower member of the Warm Creek Shale is 300–350 feet thick and consists of bluish-gray marine shale. Shale beds in the lowest 40 feet contain many small dense iron-rich concretions, which weather to a dark red brown or black. There are also some bentonite beds as much as 2 feet thick. Knechtel (1944) found a 2-foot sandstone bed about 150 feet above the base of the member, which he tentatively correlated with the Phillips sand of economic usage in the Bowdoin dome area.

Gries (1953, p. 102) found an 11-foot unfossiliferous salt-and-pepper sandstone at the same stratigraphic position.

The Mosby Sandstone Member was named by Lupton and Lee (1921, p. 263) for exposures near Mosby Post Office, Mont. The Mosby is about 45 feet thick and consists of a lower 3-foot bed of calcareous sandstone that contains abundant gastropods, 35 feet of gray calcareous shale, and 7 feet of light-gray granular fossiliferous limestone. Knechtel (1944) mapped the Mosby as having a range in thickness of 0–25 feet of calcareous sandstone and numerous lenses of fossiliferous limestone. It generally caps a ridge between broad grassy valleys of the upper and lower members of the Warm Creek Shale. In sec. 17, T. 26 N., R. 25 E., 6 feet of fine-grained light-gray slightly calcareous platy sandstone containing lenses and thin beds of gastropod-rich light-gray limestone is exposed on a ridgetop parallel to the mountain front. East of this outcrop, near the Phillips County line, 5–10 feet of light-bluish-gray shale lies between the upper and lower beds of the Mosby.

The upper member of the Warm Creek Shale is 750 feet thick and consists of soft gray shale. Large calcareous concretions showing septarian and cone-in-cone structure are numerous. Knechtel measured 835 feet of the upper member of the Warm Creek south of the Little Rockies (1944), and Collier and Cathcart (1922) measured 775 feet of the upper member.

The top of the Warm Creek Shale was penetrated at depths of 1,218–2,045 feet beneath the surface in five oil tests (holes 2–6, fig. 3) in the central and northern parts of the reservation.

With the exception of the Mosby Sandstone Member, the entire sequence of Warm Creek Shale is relatively impermeable and is not likely to be a potential source of water to wells. Small quantities of water of poor to fair quality probably are available under artesian conditions from the Mosby in most places where it is near the surface. Stock drink from a small spring that issues from the Mosby in sec. 16, T. 26 N., R. 25 E. No wells are known to obtain water from the Warm Creek Shale on the reservation.

MONTANA GROUP

The Montana Group, of Late Cretaceous age, was named by Eldridge (1889, p. 93) for its extensive development in Montana. It includes, from bottom to top, the Eagle, Claggett, Judith River, and Bearpaw Formations. On the Fort Belknap Indian Reservation, it overlies the Colorado Group conformably and is overlain unconformably by terrace deposits, glacial till, glaciofluvial deposits, and alluvium, all of Tertiary and Quaternary age. The Bearpaw and Judith River Formations underlie most of the central plains of the reservation, where they are concealed under different thicknesses of surficial deposits. If the surficial deposits were stripped away, these two formations would be exposed in about 90 percent of the reservation, including almost all the land outside the Little Rocky Mountains.

EAGLE SANDSTONE

The oldest formation in the Montana Group is the Eagle Sandstone, of Late Cretaceous age. The formation was named by Weed (1899) for exposures along Eagle Creek, near Fort Benton, Mont. It conformably overlies the Warm Creek Shale of the Colorado Group and conformably underlies the Claggett Shale of the Montana Group. The Eagle is subdivided into two members, an unnamed upper shale member and the Virgelle Sandstone Member, which was described and named by Stebinger (1914, p. 62) for exposures near Virgelle, Mont.

In the western part of the reservation, the Virgelle Sandstone Member is a yellow to buff massive fine- to medium-grained resistant sandstone and interbedded siltstone and shale. Some thick sandstone layers are crossbedded. Toward the east, the proportion of sandstone in the member decreases, and near the Phillips County line only a few sandstone beds, a few feet thick, remain. Near Lodgepole, massive sandstone interbedded with shale totals about 125 feet in thickness. The Virgelle typically forms vertical cliffs. It is commonly jointed, and weathering at joint corners forms subrounded shapes, which are distinctive. To the east, however, where the massive sandstone has thinned to a few feet, the Virgelle forms gentle slopes broken at short intervals by small sandstone ridges.

The upper shale member is about 50 feet thick and consists of light-gray and tan shale and siltstone. Near its top is a thin bed of highly polished chert fragments, which is taken as the contact with the overlying Claggett Shale. The upper shale member generally forms gentle slopes between more resistant siltstone beds.

The outcrop area of the Eagle is limited to a narrow band, generally half a mile or less wide, around the north flank of the Little Rocky Mountains, a thin poorly exposed band around Wild Horse Butte, and exposures in the southeast corner of the reservation. Good exposures may be found along the Lodgepole-Hays road, in sec. 26, T. 26 N., R. 23 E., sec. 5, T. 26 N., R. 24 E., and sec. 6, T. 26 N., R. 25 E.

In the Mobil Producing F–11–151 oil test (hole 3, fig. 3) the Eagle Sandstone was penetrated from 1,100 to 2,045 feet below the surface. The rocks in this interval consist of interbedded sandstone, silstone, shale, and mudstone and a few limestone beds in the lower part, which become bentonitic and fossiliferous toward the base. In the Phillips Petroleum 1 Gros oil test (hole 4, fig. 3), the Eagle was penetrated at 1,180 feet and was 310 feet thick; it included silty green shale and tight clayey siltstone. The depth to the top of the Eagle in three other oil tests (holes 2, 5, and 6, fig. 3) ranged from 850 to 1,002 feet.

In the western part of the reservation, the massive sandstone beds of the Virgelle should be fair to good aquifers. Outside the foothills of the Little Rocky Mountains, however, the Virgelle is below economic drilling depths, and water from it at these depths is likely to be highly mineralized. Around the Little Rocky Mountains, yields of water of poor to fair quality, probably under artesian pressure, can be obtained from wells tapping the Virgelle. Wells should be drilled near the contact of the Eagle with the overlying Claggett Shale, or in the outcrop area of the upper shale member of the Eagle, to penetrate as great a thickness of Virgelle as possible. The water may be under sufficient artesian pressure to flow from wells.

Several wells near the Little Rocky Mountains obtain water from the Virgelle. Well 26–23–12ac, depth unknown, flows 0.4 gpm; well 26–23–14da, drilled 290 feet through alluvium and possibly part of the Claggett Shale to the Eagle, flows 1 gpm; well 26–24–6cd, depth unknown, flows 1 gpm; and in well 26–25–6dd2, depth 83 feet, water rises to within 15 feet of the surface. Water from these wells contains moderate to large concentrations of sulfate and iron.

CLAGGETT SHALE

The Claggett Shale was named by Hatcher and Stanton (1903) for exposures near Fort Claggett, at the mouth of the Judith River. It is about 400 feet thick on the Fort Belknap Reservation and lies conformably between the Judith River Formation and the Eagle Sandstone.

On the reservation, the Claggett is best exposed in an outcrop belt a quarter to three-quarters of a mile wide around the north flank of the Little Rocky Mountains. It also is exposed in sec. 23, T. 26 N., R. 22 E., near Suction Creek, where it has been faulted to the surface. Other small outcrop areas, mostly covered with glacial deposits, are near Twin Buttes and Wild Horse Butte; along Three Mile Creek in sec. 13, T. 31 N., R. 23 E., where the Claggett has been uplifted by faulting; in sec. 25, T. 31 N., R. 24 E., also exposed by faulting; and in the structurally complex southeast corner of the reservation.

The Claggett Shale consists largely of dark-gray clay shale, which weathers to brownish gray, interbedded with thin buff-colored sandstone. Near the base are a few bentonite beds. There are many large round fossiliferous calcareous concretions and aggregates of cone-in-cone structure in the formation, especially in the upper part. The number and thickness of sandstone beds increases toward the top, and determining the contact with the overlying Judith River Formation is difficult in places. On the reservation, the contact is just below a massive buff sandstone bed about 4 feet thick, which generally is exposed at the base of the Judith River hogback.

The Claggett is best exposed in steep-walled recently cut gullies, where slopewash and slump have not covered the shale. It forms gentle slopes and smooth broad valleys. In fresh exposures, the more resistant concretions and aggregates of cone-in-cone structure cap small mounds and ridges on slopes.

In the Montana Gas Corp.-Pochler 1 oil test (hole 1, fig. 3), Claggett was penetrated from 390 to 865 feet beneath the surface. The rocks in this interval consist of 130 feet of gray shale and 345 feet of dark shale. In the Mobil Refining F–11–151 oil test (hole 3, fig. 3), Claggett was penetrated at a depth of 605–1,100 feet below the surface. The rocks in this interval were described as gray bentonitic lignitic shale and interbedded sand, siltstone, and bentonite in the lower part. The depth to the top of the Claggett in other oil-test holes ranged from 280 feet (hole 6, fig. 3) to 610 feet (hole 2, fig. 3).

The highly impermeable marine shale of the Claggett is not an aquifer, and water from the few thin sandstone beds is likely to be of very poor quality and insufficient for most needs. Wells in the Claggett outcrop area should penetrate the underlying Eagle Sandstone to obtain adequate water supplies. No wells are known to yield water from the Claggett on the Fort Belknap Reservation.

JUDITH RIVER FORMATION

The Judith River Formation was named by Hayden in 1871 from exposures first studied by him in 1854 near the confluence of the Judith and Missouri Rivers. The age and position of the formation were long in controversy, until Stanton and Hatcher (1905) and Bowen (1915) settled the problem conclusively. Stanton and Hatcher (1905, p. 14–31) gave an excellent summary of the previous work and opinions of such pioneer geologists and paleontologists as Meek, Hayden, Leidy, Cope, Dana, Dawson, and many others who studied the Judith River Formation.

The Judith River Formation is composed predominantly of light-tan to light-gray fine- to medium-grained sandstone, which weathers to buff and light orange brown, lesser amounts of siltstone, some light-gray shale and claystone, and local thin beds of lignitic coal of poor grade. The sandstone beds are highly lenticular and virtually untraceable away from their outcrops. Individual beds may be several tens of feet thick and pinch out completely several hundred yards away. On the whole, however, the formation presents a massive appearance and is extremely resistant to weathering.

The Judith River Formation is perhaps the second most widespread bedrock formation in this area, second only to the overlying Bearpaw Shale. It is exposed along the low bluffs bordering the Milk River valley and extends to the southeast and southwest corners of the reservation. Much of its outcrop area, however, is concealed under the ground moraine that mantles most of the central plain. In this part of the reservation, sections as thick as 30 feet have been exposed where streams have cut through the overlying till; these sections may be found along White Bear, Three Mile, Fifteen Mile, and Peoples Creeks, in the northern part of the central plain. About 1 mile southwest of Fort Belknap Agency, erosion has proceeded far enough to produce a small area of badlands topography, where as much as 50 feet of Judith River, including a coal bed, are exposed. Smaller outcrops of Judith River sandstone extend along the low cliffs bordering the Milk River valley from White Bear Creek east to the reservation line.

The best exposures of the Judith River, however, may be found along the so-called Judith River Ridge, a hogback that parallels the north side of the Little Rocky Mountains. A typical, although incomplete, section has been exposed by the action of Big Warm Spring Creek in cutting its gorge through the Judith River Ridge in sec. 1, T. 26 N., R. 25 E. and is given below:

Section in SE¼ sec. 1, T. 26 N., R. 25 E., along Big Warm Spring Creek

	Feet
Recent or Pleistocene:	
21. Gravel, pebble and cobble (limestone), much fresher and lighter in color than unit 19	3
Pleistocene:	
20. Glacial till, slightly pebbly, medium-gray-green	2
Pleistocene or Pliocene:	
19. Gravel, pebble and cobble (limestone), light- to medium-yellow-brown	3
Unconformity.	
Upper Cretaceous:	
Montana Group:	
Judith River Formation:	
18. Sandstone, slightly clayey, light-gray, cliff-forming; weathers brown	6
17. Clay light-gray	2
16. Siltstone, light-gray blocky, cliff-forming, hard; weathers red brown; thickens to west	2
15. Siltstone, very clayey; interbedded with silty light-gray to light-gray-green slope-forming clay	26

Upper Cretaceous—Continued	
Montana Group—Continued	
Judith River Formation—Continued	*Feet*
14. Siltstone, clayey, tan; cliff-forming; weathers light orange brown; thinly banded on weathered surface	2
13. Clay, light-gray; interbedded with thin beds of clayey light-gray siltstone that weathers tan to buff	4
12. Sandstone, light-gray to tan, fine- to medium-grained, cliff-forming; granular and conglomeratic in places; iron stained where weathered; crossbedded on a small scale	9
11. Clay, silty, light-gray, slope-forming; interbedded with a 1-foot layer of clayey siltstone 1 foot above base	8
10. Siltstone, very clayey, medium-gray to brown, massive cliff-forming; weathers light orange yellow and dark red brown; includes zones of thin contorted bedding	6
9. Clay, silty in places; includes fragments of medium-gray to violet carbonaceous material; iron stained on surface	6
8. Shale, carbonaceous, medium- to dark-gray	6
7. Sandstone, light-gray, fine- to medium-grained, arkosic, massive; pink hue where weathered; weathered surface of upper three-fourths shows thin wavy beds; crossbedded in part. Gentle slope on upper foot	9
6. Shale, carbonaceous, dark-gray, slightly silty; weathers light gray; top less carbonaceous and lighter in color	1
5. Siltstone, clayey, light-gray, massive; weathers to light orange brown; weathered surface shows wavy thin beds; contains a 1-foot clay bed about a foot from base	6
4. Clay, medium-gray, very silty in places; contains carbonized wood and iron concretions in places; iron stained where weathered	4
3. Clay, medium-gray; same as unit 1	1
2. Siltstone, light-gray, dense; weathers to light orange brown; contains two orange-brown iron-stained zones at top and in middle of unit; weathered surface shows wavy very thin beds	2
1. Clay, medium-gray; weathers light gray; poorly exposed	1
Total thickness of the Judith River Formation	101

In the southwest corner of the reservation, low-angle thrust faulting has caused a repetition of the Judith River outcrop.

All six oil-test holes in the north and central parts of the reservation either began in or passed through the Judith River Formation. In hole 1, figure 3, it was penetrated at a depth of 25–390 feet. In hole 2, figure 3, it was penetrated from 80 to 610 feet. In hole 3, figure 3, it was penetrated from 120 to 605 feet, where it was described as being white and gray calcareous lignitic sandstone, becoming shaly at 320 feet, and having a few white silt and lignite beds in the lower part. The Judith River was not recorded in hole 4, figure 3, but in holes 5 and 6, it was at the surface to 890 and 280 feet, respectively.

The Judith River Formation is the most important bedrock aquifer on the reservation. Its sandstone beds are fair to good aquifers, yielding slightly to moderately alkaline water in quantities generally sufficient for domestic and stock use. Its widespread distribution at the surface and under the relatively impermeable Bearpaw Shale and glacial till make it the most accessible bedrock aquifer in most of the reservation. Yields from individual sandstone beds are likely to be small, however, and for this reason wells are generally drilled to depths of more than 100 feet, to penetrate several aquifers. Wells in the outcrop area of the Bearpaw Shale must penetrate as much as 700 feet of shale before reaching aquifers in the Judith River. Water from the Judith River, where it is beneath the Bearpaw, is likely to be of poorer quality than water from the Judith River near the surface. In much of the reservation, the geologic structure favors artesian conditions, and some wells drilled into the Judith River may flow or have a relatively high static water level. In other areas, water-table conditions may prevail, and water levels in Judith River wells may be relatively deep.

Many wells have been drilled through the alluvium of the Milk River valley into the underlying Judith River Formation. In the northwest corner of the reservation, well 32–22–21db, 255 feet deep, flows 1.2 gpm from sandstone at a depth of 236–255 feet. Well 32–22–16cd, 233 feet deep, taps a sandstone sequence 166–233 feet deep. Its static water level is about 15 feet beneath the surface. Farther to the east, the Geological Survey drilled a test well, 31–24–16bb, 145 feet deep; it was a flowing well, and the head was about half a foot above the land surface. Well 31–24–10ad flowed 7 gpm before it was deepened and the flow lost. At the edge of the large bedrock "island" in the Milk River valley near the Blaine-Phillips County line, well 31–25–24ba yields water for domestic and stock use from a sandstone bed of the Judith River Formation. The well is about 135 feet deep, and the static water level is about 15 feet beneath the surface. Well 31–24–17da, about 85 feet deep, probably passes into the Judith about 30 feet below the surface. It has a static water level about 2 feet below the surface.

On the central plains, several flowing wells have been drilled into the Judith River Formation. On the Hays-Harlem road, well 29–23–35cc, depth unknown, flows about 17 gpm of moderately alkaline water. Well 29–23–35cb flows about 150 gpm. A well south of Twin Buttes, 27–23–16d, 112 feet deep, reportedly flows 20 gpm. Near the site of the old Hays Subagency, well 27–23–36cc, depth unknown, flows about 75 gpm. Near the Milk River valley, well 31–23–4cal, 75 feet deep, has a static water level of 36 feet. Water from this well probably is not under artesian pressure.

Several wells drilled into the Judith River are not used because of their highly alkaline water. Water from deep wells at Fort Belknap Agency is of rather poor quality, and the wells are used only in emergencies. Fort Belknap Agency obtains its regular water supply from the Milk River.

The apparently increasing alkalinity of water from wells tapping the Judith River and those tapping only alluvium may be due to highly alkaline zones in the Judith River and the alluvium. The alkalinity also may be due to intermixing of water from the overlying and underlying shale formations, which contain large amounts of gypsiferous material. Other factors, such as the availability of treated Milk River water at the Fort Belknap Agency, may have influenced the abandonment of water wells. Most wells that penetrate the Judith River Formation and that are now used have been drilled comparatively recently; and all those not in use are relatively old wells.

BEARPAW SHALE

Perhaps the most extensive but least exposed of all formations on the Fort Belknap Reservation is the Bearpaw Shale, of the Montana Group. The Bearpaw, of Late Cretaceous age, was named by Hatcher and Stanton (1903) from exposures in the Bearpaw Mountains. On the reservation, the Bearpaw is uncomformably overlain by terrace deposits of Tertiary and Quaternary age and by glacial deposits of Quaternary age. It is comformably underlain by the Judith River Formation. No sedimentary bedrock formation younger than the Bearpaw is exposed on the reservation. In the standard section for north-central Montana, the Bearpaw underlies the Fox Hills Sandstone, also of Late Cretaceous age.

No complete and few incomplete sections of the Bearpaw are exposed in this area. Over wide areas in the central plain it is covered by as much as 80 feet of glacial deposits. It is relatively soft, and exposures in recent gullies soon slump or are covered by slopewash.

In its outcrop area, the Bearpaw forms gentle slopes and rounded hills. Its surface is generally dessication cracked and supports only sparse vegetation. When wet it forms a gumbo mud, capable of immobilizing almost any wheeled vehicle.

The Bearpaw has a total thickness of 600–700 feet in this area and is composed of dark-gray fissile marine shale, some thin beds of bentonite, and numerous calcareous concretions. Bedding is difficult to distinguish. About 400 feet above the base of the formation, Gries (1953, p. 105) found a series of intermittent limestone masses. Bowen (1915, p. 102) mentioned a bed of brackish-water shells at the base of the Bearpaw. This may correlate with thin beds of oyster shells in the same stratigraphic position in the NE¼ sec. 9, T. 30 N., R. 25 E.

On the reservation, the Bearpaw is mapped extensively over the glaciated central plain and into the southwest and southeast corners. It is poorly exposed, however, and best outcrops may be found in vertical gully walls and streambeds, where, at best, only a few feet are exposed.

No wells are known to obtain water from the Bearpaw Shale on the reservation. This marine shale is highly impermeable, and water from it probably would be of poor quality. Wells in the Bearpaw outcrop area tapping the Judith River Formation would have to be about 800 feet deep to obtain adequate quantities of water.

TERTIARY AND QUATERNARY SYSTEMS

TERRACE DEPOSITS

Terrace deposits of wide extent unconformably overlie bedrock around the north flank of the Little Rocky Mountains. These deposits are predominantly pebbles and cobbles and minor amounts of sand derived from the Madison and older limestone formations exposed in the Little Rocky Mountains. A thin soil zone has developed on the terraces. The largest terrace areas are west of the Little Rocky Mountains, in T. 25 N., Rs. 22 and 23 E., and T. 26 N., R. 23 E., and north of Lodgepole, in secs. 16, 21, 28, 30, and 33, T. 27 N., R. 25 E. Smaller terrace areas may be found on almost every ridge or hill around the north flank of the Little Rocky Mountains. Terraces of the western area have been severely dissected by streams, and a complexly crenulated outcrop pattern results on the geologic map (pl. 1). North of the Little Rocky Mountains, the terraces have been overridden by continental glaciers in the Pleistocene Epoch, and the terrace deposits have been mixed in part into the glacial till. Glacial action has destroyed the normally very flat surfaces, and just a few miles north of the southern limit of glacial advance the surfaces cannot be recognized under the till.

Thickness of the terrace deposits ranges from a few feet to perhaps 50 feet at the most. The deposits were laid down on a highly irregular erosion surface on the older bedrock, and relief of 10 feet or so on this surface can be seen in roadcuts west of Hays. The degree of rounding of the terrace gravel differs considerably. Some of the pebbles and cobbles, more properly termed fragments, evidently were derived from limestone exposures at no great distance from their site of deposition, as they show little or no signs of abrasion. Limestone pebbles and cobbles in terrace deposits progressively farther from the mountains show greater degrees of rounding.

The highest terrace is at an altitude of about 4,000 feet, where it bevels the upturned wall of Mission Canyon Limestone. This surface dips rather steeply away from the mountains, perhaps 350 feet for the first mile or so, and then flattens considerably, to about 10 feet per mile. Representative of this surface are the large terrace north of Longepole, the high terrace in the area west of Hays, and many smaller remnants at approximately this level. Alden (1932, p. 19–20) correlated this terrace with the Flaxville Formation of northeastern Montana, of Miocene or Pliocene age.

About 200 feet lower than the highest terrace are extensive lower terraces that also are underlain by gravel and sand derived from the Little Rocky Mountains. These lower terraces are well developed in the area around Beaver Creek, in the southeast corner of the reservation: in secs. 19 and 20, T. 26 N., R. 26 E.; in sec. 16, T. 26 N., R. 25 E., east of Lodgepole Creek; in secs. 1, 2, and 3 of T. 26 N., R. 24 E., between the Hays-Lodgepole road and the Madison "wall;" in secs. 24 and 25, T. 26 N., R. 23 E., west of Peoples Creek; and in large areas of T. 25 N., Rs. 22 and 23 E., and in the southernmost tier of sections of T. 26 N., R. 23 E. Lithologically, these terrace deposits are practically identical to the highest terrace deposits. Alden (1932, p. 45–46) dated this surface as early and middle Pleistocene, and correlated it with his No. 2 terrace throughout Montana.

About 300 feet below this intermediate level (Alden's No. 2), terraces of small extent are developed along some streams. The terraces along Suction Creek, in secs. 23, 24, and 26, T. 26 N., R. 22 E., and sec. 19, T. 26 N., R. 23 E., as well as small patches in other areas, belong to this level (Alden's No. 3).

The contact between terrace deposits and underlying truncated bedrock is commonly marked by a line of denser vegetation, denoting a seep or intermittent spring. In general, however, the comparatively high altitude of the terraces, their relative thinness, and their acute dissection, particularly west of Hays, preclude the existence of large supplies of ground water in the terrace gravels.

No wells are known to have been drilled into the terraces. The best localities for obtaining water from this source probably would be near the center of sec. 12, T. 25 N., R. 22 E.; the NE¼ sec. 8, or the NW¼ sec. 9, T. 25 N., R. 23 E.; the NW¼ sec. 15, T. 26 N., R. 23 E.; and perhaps the SW¼ sec. 33, T. 26 N., R. 26 E. Ground water probably forms a thin lenslike body within the terrace gravel where it overlies relatively impermeable bedrock, such as the Bearpaw and Claggett Shales and the Colorado Group. (See fig. 4.) The greatest saturated thickness of gravel in such a lens most likely would be near the center of the terrace area. If the underlying formation is relatively permeable, water will percolate through the gravel and the permeable formation and down to the regional water table. Such areas may be favorable for drilling much deeper wells.

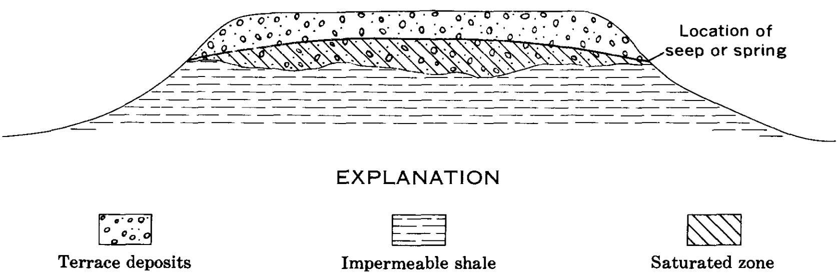

FIGURE 4.—Schematic section through terrace, showing lens of ground water in terrace gravel perched on aquiclude.

GLACIAL DEPOSITS

Most of the area north of the Little Rocky Mountains is covered by a blanket of unconsolidated clay, silt, sand, and gravel deposited by the most recent advance of continental glaciation during the Pleistocene Epoch. Calhoun (1906, p. 53) and Alden (1932, p. 95) date this advance as the Wisconsin Glaciation. Glacial deposits overlie the Montana Group and terrace deposits of Tertiary and Quaternary age with angular unconformity and are overlain unconformably by Recent alluvium. They are 100 feet thick in places, but commonly range in thickness from 20 to 80 feet. Only the southern limit of the glacial deposits has been mapped on plate 1. South of this limit, which marks the end moraine of the latest glaciation, there are only erratic boulders and pebbles and small glaciolacustrine and glaciofluvial deposits. In sec. 28, T. 27 N., R. 25 E., the limit indicates the position to which glacial ice overrode the highest terrace.

There are several types of glacial deposits in the area. Most predominant is the yellowish-brown unstratified heterogeneous mixture of clay, silt, sand, gravel, and boulders termed "till." Most of the ground moraine and the elongate linear drumlins described by Lemke (1958) are composed of till. Its distribution and thickness are irregular, and its surface is uneven and hummocky, marked by numerous swales, closed undrained depressions, and the elongate linear drumlins. Relief of the ground-moraine surface generally does not exceed 25 feet. Major intermittent streams of the central plain have cut through the till in many places along their courses and exposed the underlying Cretaceous bedrock. The till is remarkably resistant—forming nearly vertical banks, where cut by stream action. Because of its heterogeneity and poor sorting, till is rather impermeable and generally does not contain appreciable quantities of water. No wells on the reservation are known to obtain ground water from till.

In places, glacial melt water has sorted out and carried away most of the fine-grained constituents of the till, leaving behind relatively well sorted and permeable glaciofluvial sand and gravel deposits. Near the south edge of the Milk River valley, a belt of low hills, composed largely of glaciofluvial deposits, extends from the Fort Belknap Agency east to about sec. 17, T. 31 N., R. 24 E. These glaciofluvial deposits may extend a slight distance to the north, underneath the Milk River alluvium. If so, moderate quantities of water of good quality probably can be obtained from wells drilled through the alluvium into the glaciofluvial deposits. Such wells should be drilled near the south edge of the Milk River valley. (See fig. 5.)

Numerous lenses and other small deposits of glaciofluvial sand and gravel are probably scattered throughout the thick till blanket covering the central plain. Their extent, thickness, and vertical position within the till are unpredictable. Some glaciofluvial deposits probably are associated with the large outwash plains in the east-central part of the reservation, and some possibly have been formed near the terminal moraine. The glacial melt-water channels also may contain small thin deposits of sand or gravel which might yield small quantities of water to wells.

Large areas in the southeast quarter of T. 29 N., R. 24 E., in T. 29 N., R. 25 E., in the northern half of T. 28 N., R. 25 E., and in adjacent townships, mapped as alluvium on plate 1, probably represent glacial-outwash plains or the sites of glacial lakes. Much of the fine-grained material washed from till by melt-water streams accumulated here as glaciofluvial and glaciolacustrine deposits. Within this area, in the NE¼ sec. 20, T. 29 N., R. 25 E., Alden (1932, p. 107 and pl. 40A) found about 10 feet of stratified clay overlying till. Thin deposits of

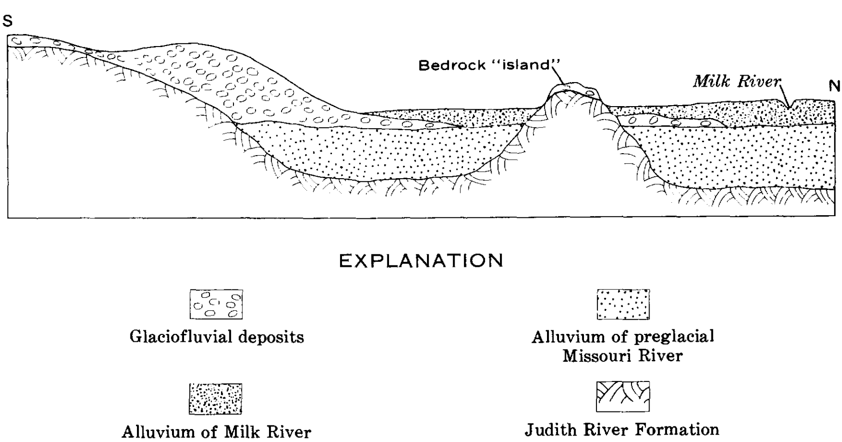

FIGURE 5.—Schematic section through the Milk River valley showing relations between the Judith River Formation, alluvium of the preglacial Missouri River, glaciofluvial deposits, and Recent alluvium of the Milk River.

fine clay, just south of the southern limit of ground moraine, as mapped on plate 1, presumably also are glaciolacustrine deposits. The clay and silt of glaciolacustrine deposits are relatively impermeable and probably do not contain much water. No wells are known to yield water from these deposits on the reservation.

ALLUVIUM AND COLLUVIUM

Alluvium is extensively deposited in the Milk River valley, along the flood plains of the intermittent streams crossing the central plain, and where streams debouch from the central core of the Little Rocky Mountains.

In the Milk River valley, Recent alluvium consists of discontinuous lenses and beds of fine-grained sand, silt, sandy clay, and clay, which thinly cover Pleistocene glaciofluvial deposits and till, or older alluvium deposited by the preglacial Missouri River. The Recent alluvium probably has no greater thickness than in the natural levee of the Milk River, where it probably does not exceed 25 or 30 feet. Near the south margin of the valley, it is much thinner.

The Recent alluvium is composed predominantly of fine-grained materials and includes a high content of soluble alkaline substances; consequently, the permeability of the alluvium is low, yields to wells are small, and the ground water obtained is of poor to fair quality. Many shallow wells dug or drilled into the Recent alluvium have been abandoned because of the alkalinity of the water. The water table is generally within 25 feet of the surface near the Milk River and is shallower in places farther from the river. The water table is generally 10 or more feet lower in the natural levee than in the southern margin of the valley. The difference is due to the rise of the land surface toward the natural levee, as the water table is very nearly level.

Underlying an unknown and probably quite variable thickness of Pleistocene glaciofluvial materials and till, which may not be present in much of the Milk River valley, is the older alluvium deposited by the preglacial Missouri River. Its thickness is also quite variable but probably does not exceed 60 feet, and it may also be absent in places. It is predominantly sand and has some gravel and lesser amounts of intermixed clay and silt.

Several wells tap the alluvium of the preglacial Missouri River. Well 31–23–2bb, 75 feet deep; well 31–24–7bd, 83 feet deep; and well 31–24–8aa, 78 feet deep; all have static water levels from 3 to 4 feet beneath the surface. Well 31–25–25ad, near the Phillips-Blaine County line, 63 feet deep, has a static water level of about 5 feet. The uniformity of water levels suggests that water in the older alluvium may be under artesian pressure, as the older alluvium is capped by less permeable deposits (till or Recent alluvium) and may have a lateral hydraulic connection with the lower aquifers of the Judith River Formation, which are under considerable hydraulic head. (See fig. 5.) Water from wells drilled into the older alluvium is of about the same quality, or poorer, than water from the Recent alluvium.

On the central plain, relatively thin deposits of alluvium are mapped along major intermittent streams. Where contemporary streams occupy glacial melt-water channels, some of this alluvium actually may be a glaciofluvial deposit. In general, the alluvium, which does not usually exceed 25 feet in thickness, has been derived from the till or the underlying Judith River and Bearpaw Formations. Consequently it is composed predominantly of relatively impermeable fine-grained sand, silt, sandy clay, and clay, and lesser amounts of gravel and coarse sand. Small quantities of water of poor to fair quality probably are available to shallow wells in this alluvium in the larger stream valleys. Only one well, 31–23–18dd, that was inventoried, obtained water from this source.

Near the base of the Little Rocky Mountains, streams such as Lodgepole Creek and the South Fork of Peoples Creek have filled wide channels with limestone gravel and sand derived from the nearby mountains. In the summer and fall, long stretches of these creeks have no flow, and the underflow is restricted to only a part of the gravel, which is of small width and saturated thickness. Wells such as 26–25–8bd, which taps this underflow, yield large quantities of water of good quality and with little drawdown. Selecting sites for such wells is difficult, however, as the location of the underflow is difficult to predict.

Hays is on alluvial limestone gravel of the South Fork of Peoples Creek. The water table is close to the surface in the town, and wells only a few feet deep yield adequate supplies of water of good quality throughout the year. Upstream, however, the water table is at greater depth—16 feet in well 26–24–30bdl, half a mile south of Hays, and 71 feet in well 26–24–30dd, 1 mile southeast of Hays. During the summer, the South Fork flows at Hays and in the gorge cut into the Mission Canyon Limestone, but the streambed is dry between these points. A possible explanation is that the South Fork has carved its valley much deeper into the relatively soft Mesozoic rocks, which underlie Hays, than into the adjacent hard Mission Canyon Limestone and that subsequently a cycle of deposition filled this valley to grade with the base of the South Fork gorge in the Little Rocky Mountains. The valley was filled with relatively coarse limestone gravel, which is highly porous and permeable. Water issuing from the gorge passes directly into and through the gravel, flows along the gravel-bedrock surface, and reappears at the land surface where the gravel becomes thinner near Hays.

An alternative hypothesis is that erosion did not completely remove the relatively resistant siliceous Mowry Shale and left a ridge, now buried under gravel, downstream from Hays. This ridge forms a ground-water dam, and ground water accumulates behind it up to the top of the dam. This creates a ground-water reservoir under Hays. The ground water eventually overflows the dam and continues as underflow down the valley of South Fork. Both hypotheses assume that the thickness of the gravel increases toward the mountains and that the slope of the water table in the gravel is less than the slope of the valley floor except very close to the moutains. Situations similar to this possibly exist in Lodgepole Creek and in the beds of other major streams issuing from the Little Rocky Mountains.

In places, extensive deposits of colluvium have been mapped with the alluvium. This material is, in general, poorly sorted sand, silt, clay, and pebbles and was deposited by slump, sheetwash, and gravity and is not a potential source of ground water in this area.

IGNEOUS AND METAMORPHIC ROCKS

PRECAMBRIAN METAMORPHIC ROCKS

Metamorphic rocks are exposed only in the core of the Little Rocky Mountains in relatively small areas in sec. 16, T. 25 N., R. 24 E.; secs. 13, 14 and 27, T. 26 N., R. 24 E.; and secs. 2, 10, 11, and 12, T. 25 N., R. 25 E. According to Dyson (1939, p. 202) and Weed and Pirsson (1896, p. 404), the metamorphic rocks of the Little Rocky Mountains consist of fine-grained black amphibole schist, finely banded white gneiss, pink granite-gneiss having sheared and elongate feldspar crystals, mica and garnet schist, and interbedded hornblende schist and white quartzite.

None of the metamorphic rocks yield water to wells on the reservation, although fissures, fractures, and fault zones in metamorphic rocks are a possible source of moderate quantities of water of good quality. Petrologic details of these rocks are given by the authors cited above.

TERTIARY SYENITE PORPHYRY

In the Tertiary Period, a large mass of syenite porphyry intruded the Precambrian metamorphic basement rocks and overlying sedimentary rocks in this area and uplifted an area about 10 miles in diameter into a dome. Subsequent erosion has stripped away much of the sedimentary cover, leaving large areas of the syenite porphyry exposed, mostly in secs. 9, 10, 13–16, 27, and 34, T. 26 N., R. 24 E.; sec. 16, T. 25 N., R. 24 E.; and secs. 1, 2, 10–12, and 15, T. 25 N., R. 25 E. Smaller intrusions occurred at Twin Buttes, Wild Horse Butte, and Snake Butte at the same time.

The most common variety of the syenite porphyry has a very fine grained light- to dark-gray groundmass of feldspar having large phenocrysts of orthoclase and plagioclase. Tinguaite, a variety of phonolite, has been described by Weed and Pirsson (1896, p. 419) from a locality near Landusky, and it may occur at the contact between the syenite intrusive and the intruded consolidated sedimentary rocks on the reservation. Tinguaite is a dark-green dense fissile aphanitic syenite. The igneous rock that forms the laccolithic sill at Snake Butte is called shonkinite. It is a very dark gray to black medium-grained syenite containing feldspar and ferromagnesian minerals, of which the most abundant is augite (Cathcart, quoted by Knechtel, 1942, p. 920). Columnar jointing is extremely well developed in the shonkinite at Snake Butte.

The igneous rocks of the Fort Belknap Indian Reservation are not a major source of water, although moderate quantities of water of good quality probably could be obtained from fractures, fissures, and fault zones in them. No wells tap these rocks on the reservation. However, large springs of good water issue from the bases of Twin Buttes, Wild Horse Butte, and Snake Butte. Although the catchment area for precipitation onto these buttes is small, enough water apparently percolates through joints and fissures to supply the springs. The springs are perennial and discharge as much as 150 gpm.

Ground-water conditions at Snake Butte are shown in figure 6. The large springs at the base of the sill discharge from a ground-water lens that has formed in the well-developed columnar joint system of the shonkinite, which otherwise is impermeable. Recharge is from precipitation, which percolates down the joint system to the ground-water lens. The water cannot percolate in large quantities through the impermeable "baked" shale of the underlying Bearpaw Shale, so it accumulates as a lens and discharges through openings around the base of the sill.

GEOLOGIC STRUCTURE

The dominant structural feature of the Fort Belknap Reservation is the uplift that created the Little Rocky Mountains. Over most of the reservation, the uplift tilted the previously flat-lying sedimentary rocks. Near the Little Rocky Mountains and the outlying minor intrusions of Twin Buttes, Wild Horse Butte, and Snake Butte, dips are visibly steep at the surface and generally are oriented away from the center of the intrusion. In the central plain, south of the seventh standard parallel north, the uplift tilted the sedimentary rocks to dips of 80–100 feet per mile, generally to the northeast or northwest. North of the seventh standard parallel, dips are gentler, about 40 feet per mile, and generally are to the northeast.

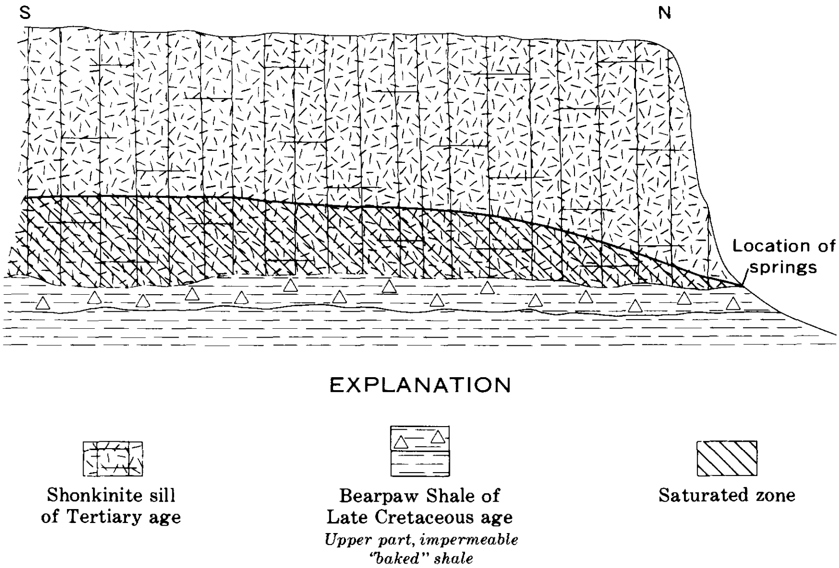

FIGURE 6.—Schematic section through part of Snake Butte, showing lens of ground water (diagonal pattern) perched in joint system above aquiclude.

Two major structural features are not immediately visible at the surface. A gentle anticline trends northeastward from the Little Rocky Mountains to the northwest corner of T. 29 N., R. 26 E., and the Cow Creek syncline trends and plunges to the southwest of Twin Buttes. (See fig. 3.)

THE LITTLE ROCKY MOUNTAINS AND SUBORDINATE TRAPDOOR DOMES

The large mass of syenite porphyry that was intruded into what is now the Little Rocky Mountains area was emplaced in early Tertiary time in the form of a laccolith between the metamorphic rocks and the overlying sedimentary rocks. In places, however, the porphyry did not reach the sedimentary rocks, and roof pendants of metamorphic rocks were formed. Throughout most of the dome, the upper surface of the intrusion was concordant to the base of the sedimentary rocks, but in some places the syenite porphyry cuts through the Paleozoic and Mesozoic rocks discordantly; in fact, some dike offshoots of the main intrusive body intersect formations as young as the Kootenai. Most of the sedimentary rocks that were uplifted over the central part of the dome have been eroded, and the underlying intrusive and metamorphic rocks have been exposed. (See fig. 7.)

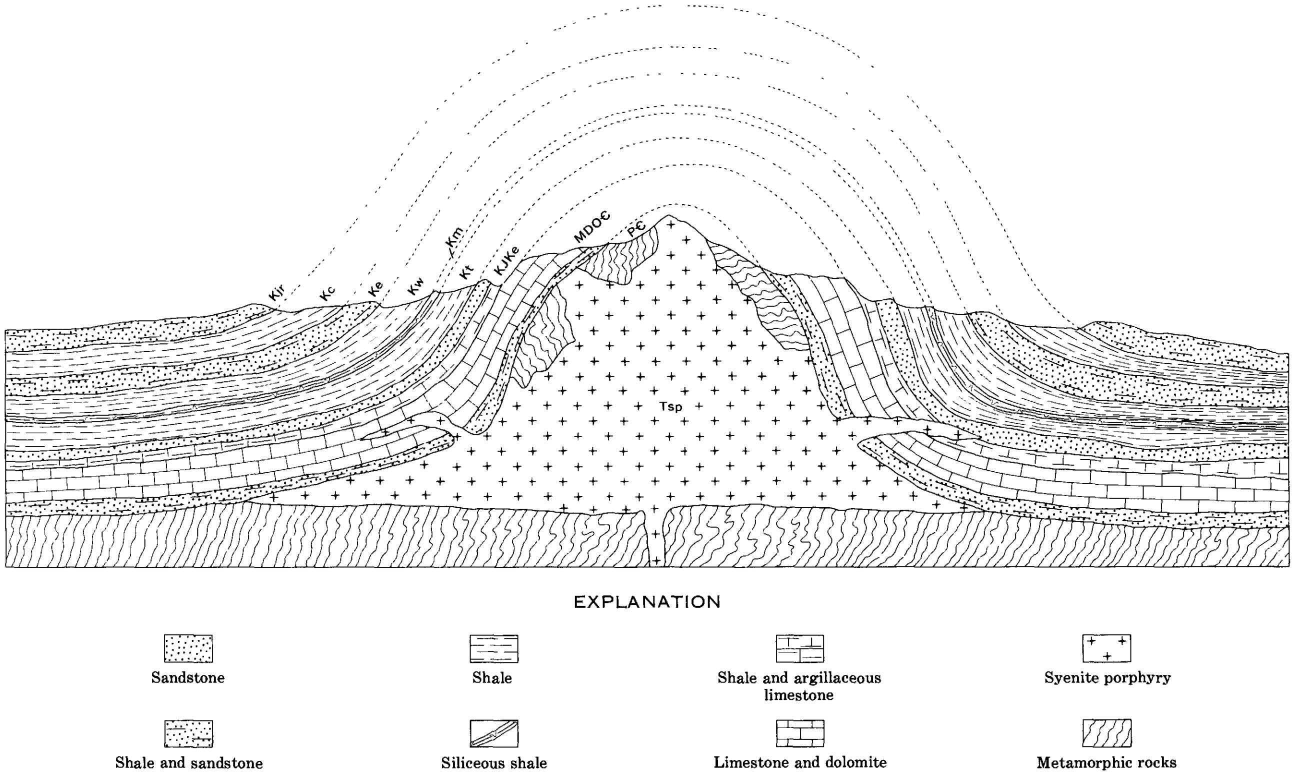

FIGURE 7.—Schematic section through the Little Rocky Mountains, showing the laccolithic intrusion of syenite porphyry and the doming of the sedimentary rocks. Tsp, syenite porphyry; Kjr, Judith River Formation; Kc, Claggett Shale; Ke, Eagle Sandstone; Kw, Warm Creek Shale; Km, Mowry Shale; Kt, Thermopolis Shale; KJke, Kootenai Formation and Ellis Group; MDO€, limestone and sandstone of Mississippian to Cambrian age; and p€, Precambrian rocks.

The sedimentary rocks adjacent to the dome were steeply tilted, in places to vertical dips, by the intrusion. The degree of tilting decreases outward from the mountains. Differential erosion of the upturned sedimentary rocks has produced the steeply dipping limestone "wall" of the Mission Canyon and Lodgepole Limestones, the less steeply dipping hogbacks of the Kootenai and Mowry Formations, and the gently dipping cuestas of the Eagle and Judith River Formations. Dips flatten to just a few degrees within a few miles of the mountains.

In plan, the Little Rocky Mountains dome is not regular. The outcrop bands of the sedimentary rocks around the base of the mountains are bulged outward in several places, creating what are in effect very steeply plunging synclines and anticlines. The axial planes of these very short (in plan) structural features radiate from the central part of the dome, and the features disappear only a few miles from the Mission Canyon wall. The largest structural features formed in this way are a syncline east of Hays, in the N½ sec. 29, T. 26 N., R. 24 E.; a syncline south of Lodgepole, in the NE¼ sec. 19, T. 26 N., R. 25 E.; a syncline that has associated high-angle faulting in the N½ sec. 29, T. 26 N., R. 25 E.; and a syncline starting in the SE¼ sec. 36, T. 26 N., R. 25 E., and trending southeast into the NE¼ sec. 1, T. 25 N., R. 25 E.

The complex structural features in the southeast corner of the reservation were mapped in detail by Knechtel (1944). This small area (approximately the northwest quarter of T. 25 N., R. 26 E., and the northeast quarter of T. 25 N., R. 25 E.) typifies a belt of trapdoor domes that encloses the Little Rocky Mountains on the east and south. Knechtel described these features as follows:

> The subordinate domes * * * were formed by bodies of igneous rock which were punched upward into the sedimentary rocks. They range in diameter from 1½ to 3½ miles. Each is typically subcircular or subelliptical in plan and normally includes a hinged block that is raised on a nearly vertical fault of curved trace. The rock strata * * * are tilted up like a trapdoor which has opened along the fault and slopes down toward the opposite side of the block. The typical structure * * * is ordinarily more or less obscured by faulting within the block. The faults * * * have throws ranging from almost zero to several thousand feet; consequently the oldest rocks appearing at the surface in the blocks * * * range in age from Precambrian to upper Cretaceous.

MINOR INTRUSIONS ON THE CENTRAL PLAIN

Snake Butte is a sill that lies over hard baked Bearpaw Shale. The Bearpaw is the only formation that crops out around the butte. Twin Buttes and Wild Horse Butte probably are outliers from the main igneous body that formed the Little Rocky Mountains dome. They may be laccolithic but are probably small stocklike intrusive bodies. Part of the Claggett Shale was upturned and exposed around Twin

Buttes by the intrusion, but the Judith River, Claggett, Eagle, and Warm Creek Formations were tilted up by the intrusion at Wild Horse Butte. Most of the outcrops of these formations are covered by glacial deposits.

FAULTS

Two low-angle thrust faults, trending approximately N. 30° E., can be traced for about 9 miles in the southwest corner of the reservation before they are buried under glacial deposits. The displacement of these faults is not known, but it must be 400 feet or more along part of their trace, as rocks of the Claggett Shale have been thrust over Bearpaw Shale in one place (sec. 23, T. 26 N., R. 22 E.), and, over most of their traces, these faults have displaced Judith River against Bearpaw. The westernmost fault has two small bifurcations, in secs. 23 and 27, T. 26 N., R. 22 E. The faults are continuations of thrust faults originally mapped in the area between the Little Rockies and the Bearpaws by Reeves (1924a, 1946), who discussed their origin and mechanism at length.

A second low-angle thrust fault system has been traced from sec. 4, T. 31 N., R. 23 E., southeast to sec. 26, T. 30 N., R. 24 E., about 20 miles. This system is probably related to the thrust faults originating in the Bearpaws also. The displacement of the fault is not known, but it is probably much the same as that of the faults in the southwest corner of the reservation. For the most part, this fault displaces Judith River or Bearpaw strata against higher beds in the same formation, or Judith River against Bearpaw Shale.

Relatively high angle faults, displacing Claggett against Judith River and Judith River against Bearpaw, are mapped in the area a few miles south of the Milk River valley between Fort Belknap Agency and the mouth of White Bear Creek.

Within the Little Rocky Mountains, the contact between Tertiary syenite porphyry and Paleozoic sedimentary rocks is marked by faults of unknown type and displacement.

SUMMARY OF GEOLOGIC HISTORY

The oldest rocks exposed on the Fort Belknap Reservation are extensively metamorphosed sedimentary and igneous rocks of Precambrian age. Deciphering the geologic history represented by these rocks is beyond the scope of this report; it can be said, however, that during Precambrian time, huge thicknesses of sediments were deposited, buried, lithified, folded, metamorphosed, and elevated and were then leveled by erosion.

Upon this old erosional surface, basal sandstone and conglomerate (Flathead Sandstone) of Cambrian age were deposited. These were followed by finer grained sedimentary rocks representing relatively stable near-shore marine environments. Toward the end of the Cambrian, layers of calcareous sediments (limestone and dolomite) were more frequently deposited. However, ripple marks, mud cracks, and intraformational conglomerate suggest an alternating littoral and marine environment.

The Ordovician Period was marked by the uninterrupted but probably slow deposition of dolomitic limestone and dolomite (Bighorn Limestone) in a stable deep marine environment. Later in the Ordovician or during the Silurian Period, this area was uplifted, and an erosional surface was developed on the Bighorn Limestone. The uplift was not accompanied by significant folding, however, as the Devonian rocks (Jefferson Limestone) were deposited disconformably on the eroded Ordovician surface.

During the Devonian Period, clayey limestone, limestone, and calcareous shale were deposited during a second interval of relatively stable marine environment. The shore from which the land-derived part of these sedimentary rocks was transported apparently oscillated gradually during the course of this geologic period.

Deposition of calcareous sedimentary rocks continued, probably without interruption, into the Mississippian and possibly into the Pennsylvanian Period. At some time during these periods, however, this area was again uplifted, and this time uplift was accompanied by folding. A large thickness of the Mission Canyon Limestone, estimated at 150 feet, as well as all overlying sedimentray rocks were eroded away. The area may have been dry land during part or all of the Pennsylvanian, Permian, and Triassic Periods, as no sedimentary rocks of these ages are found in the Little Rocky Mountains area.

This area was submerged during the Jurassic Period, and sedimentation onto the eroded surface of the Mission Canyon Limestone was resumed. After deposition of a thin sandy basal unit, marly limestone, calcareous shale, and some sandstone were laid down in a near-shore marine environment.

During Cretaceous time, considerable quantities of sediment were deposited in this part of Montana. The sequence of formations from the Kootenai through the Bearpaw represents an alternation of the continental environment of deposition of sandstone and siltstone (Kootenai, Eagle, Judith River) with near-shore marine deposition of shale (Thermopolis, Colorado Group, Claggett, Bearpaw). The several thousand feet of sedimentary rocks of Cretaceous age probably represent detritus from an ancestral Rocky Mountain chain, which was being uplifted far to the west. Deposition continued uninterruptedly into the Paleocene Epoch, and the Hell Creek and younger formations, now stripped away, were laid down.

In the early part of the Tertiary Period, the same forces that created the Rocky Mountain chain acted to form small outlying mountain groups in the Great Plains area. Such features as the Highwood Mountains, the Little Belt Mountains, the Judith Mountains, and the Little Rocky Mountains were created by the intrusion or extrusion, or both, of relatively small amounts of igneous material through the Precambrian metamorphic rocks and into and under the overlying sedimentary rocks. The Little Rocky Mountains were domed up by syenite porphyry. Subsidiary intrusions formed the trapdoor domes south of the mountains, as well as Twin Buttes, Wild Horse Butte, and Snake Butte. Probably at this time, igneous rocks were being extruded to the west and forming what are now the Bearpaw Mountains.

Erosion attacked the domed sedimentary rocks over the core of the Little Rocky Mountains uplift and by the Pliocene Epoch had reduced the dome to a low mountain mass. Detritus from the erosion was deposited as an extensive terrace at least 3 miles wide around the base of the mountains. Several times during the Pliocene and possibly during the early Pleistocene, this part of the Great Plains was uplifted slightly, and erosion cut into the previously deposited terrace gravel. The resumption of sedimentation formed younger terraces at slightly lower levels.

During the continental glaciation of North America, at least two advances of the ice sheet covered most of the Fort Belknap Reservation, although the Little Rocky Mountains were not overridden. The glacial ice picked up rocks from the exposed bedrock and incorporated them with material brought from as far away as the Canadian Rockies. On recession of the ice front, this material was dropped all over the central plain, forming the hummocky undrained topography that characterizes much of the reservation. Advance of the ice sheet diverted the Missouri to its present course south of the Little Rocky Mountains and profoundly influenced the drainage system.

After the glacial epoch, streams issuing from the Little Rocky Mountains and Bearpaws deposited relatively thin layers of alluvium in glacial melt-water channels and newly cut stream channels. Streams were rejuvenated slightly after the glaciation, as they are slightly incised into their present flood plains.

Details of the geologic history of this region in the Devonian are presented by Sloss and Laird (1947) and Andrichuk (1951). Paleozoic sedimentation in the Montana area is discussed for each period by Sloss (1950). Reeves (1946) gave a summary of the geologic history of the Bearpaw Mountains area, and Calhoun (1906) and Alden (1932) discussed the glacial history and geomorphology in detail.

Excellent summary stratigraphic papers are given in the Guidebook to the Billings Geological Society's Fourth Annual Field Conference (Parker, 1953).

HYDROLOGY

Water is not normally stable in one condition or place. Water on the land surface, for example, may be removed by being transpired by plants or evaporated (conversion to vapor stage in the atmosphere). It may flow as runoff to lakes or streams (surface water), or it may percolate into or through the soil zone (soil water or ground water). The hydrologic cycle (fig. 8) is a summation of the various paths that water may take from one place and state to another.

OCCURRENCE OF GROUND WATER

Ground water occurs in pore spaces or openings between the particles that make up rocks, as well as in fissures, fractures, and caverns in the less porous rocks. The surface beneath which water occupies all openings in rock is termed the water table. Interstices are generally interconnected to some degree, permitting water to flow at different rates under the influence of gravity.

Some rocks have relatively large connected interstices capable of holding large amounts of ground water and permitting easy flow within the rock; these rocks are called aquifers. Others have very small and poorly connected interstices incapable of holding or transmitting easily the water within the rock; these rocks are termed aquicludes.

Water in the ground-water reservoir may be under water-table or artesian conditions. Water that rises above the base of a confining bed that is penetrated by a well is under artesian conditions. If the water rises above the land surface, the well will flow. The surface to which water will rise in a well is termed the piezometric surface. Water not confined under an aquiclude is said to be under water-table conditions.

RECHARGE

According to Meinzer (1923, p. 46), "* * * recharge * * * comprises the processes by which water is absorbed and is added to the zone of saturation. * * * [The term also is] * * * used to designate the quantity of water that is added to the zone of saturation." Where the water table is relatively stable from year to year, the amount of recharge is approximately equal to the amount of water discharged from the zone of saturation during the year. If the position of the water table is progressively lowered or raised through a period of several years, the change may be caused by climatic changes or by overpumping—

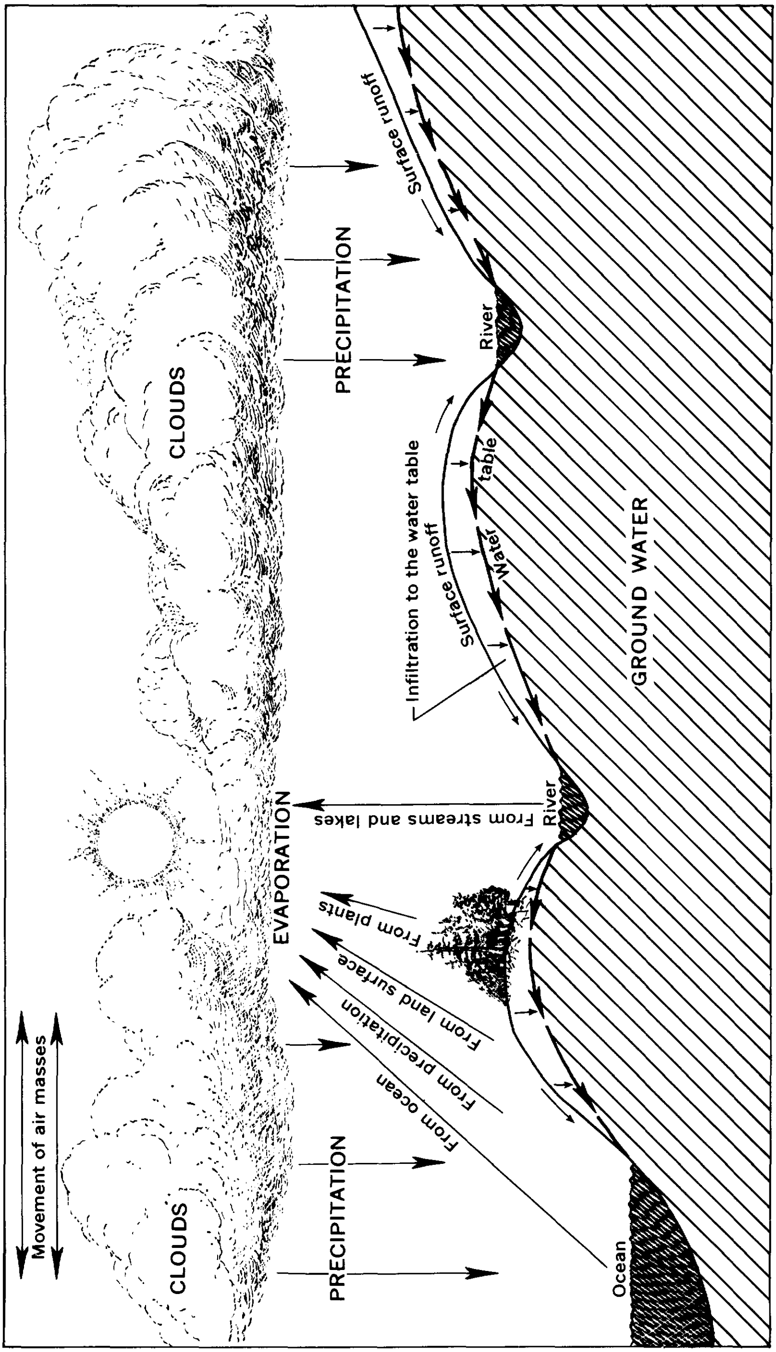

FIGURE 8.—The hydrologic cycle (modified from McGuinness, 1951).

withdrawal of more water from the ground-water reservoir by pumping from wells than is replaced by recharge. Thus, recharge is important economically as well as hydrologically.

Recharge to ground water on the Fort Belknap Indian Reservation, exclusive of recharge from irrigation in the Milk River valley, is thought to equal the discharge, estimated at 7,000 acre-feet per year (p. F53). Most recharge on the reservation occurs as direct percolation of precipitation into aquifers and as influent seepage into aquifers from intermittent streams. Recharge to the alluvium of the Milk River valley by percolation from applied irrigation water has not been evaluated. Study of incomplete hydrographs of wells in the Milk River valley indicates that the water table may rise by as much as 3 feet locally, and 1 foot generally, during the irrigation season. (See figs. 9 and 10.)

RUNOFF

Water leaves the reservation as surface-water runoff, ground-water discharge, and evapotranspiration. The Milk River, which with its four principal tributaries, drains most of the reservation, severely floods areas in its valley every few years. Flood peaks of 20,000 cfs. (1899) and 12,000 cfs (1952) have been recorded at Havre. On June 8, 1953, 7,780 cfs was gaged at Fort Belknap. At times, however, the river has been dry. The average discharge of the Milk River at Havre during the period 1899–1916 was 273 cfs. In 1916, the St. Mary's canal began operation, and from 1916 to 1922 the average discharge of the river was 336 cfs. Measured at Lohman, 13 miles downstream from Havre, the average yearly discharge for the period of usable record (1922–25, 1934–51) was 267 cfs. From 1954 to 1962, measured at Havre, the river has discharged an average of 423 cfs. Discharge records of the Milk River at Lohman and Havre are shown in tables 2 and 3.

The major drainageway for surface water across the reservation is Peoples Creek, a tributary of the Milk River. Its drainage area above the U.S. Geological Survey gaging station near Dodson is 670 square miles. The average yearly discharge for the period of record, 1951–62, is 25.1 cfs (18,170 acre-feet). The maximum daily discharge was 3,500 cfs and was recorded on March 30, 1952. (See table 4.)

The average annual rainfall over the Peoples Creek basin is about 13 inches (from Montana climatological data), or 465,000 acre-feet per year. The average yearly surface runoff from the basin is about 4 percent of the average annual precipitation on the basin. Assuming the same relation for the entire reservation, the annual precipitation is about 660,000 acre-feet and the runoff is 26,000 acre-feet.

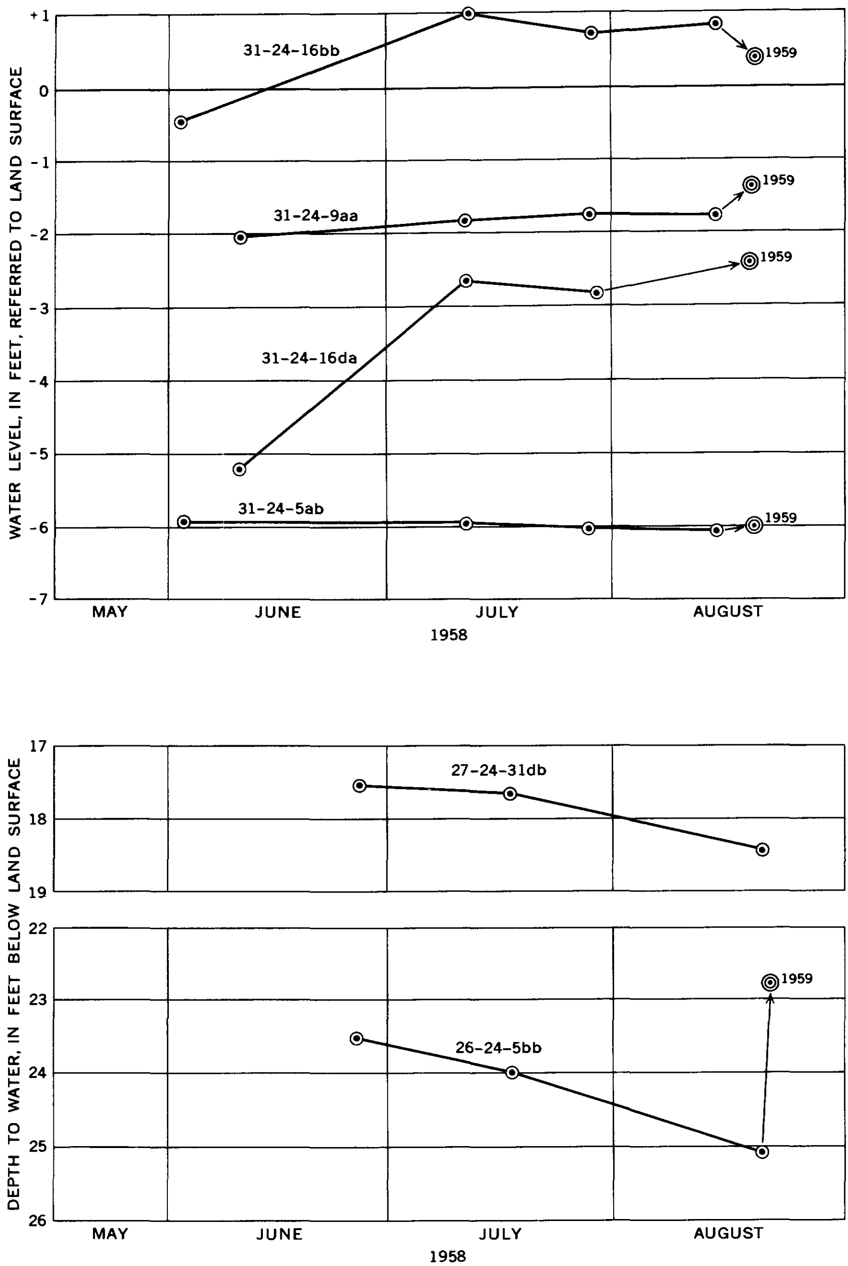

FIGURE 9.—Hydrographs of wells.

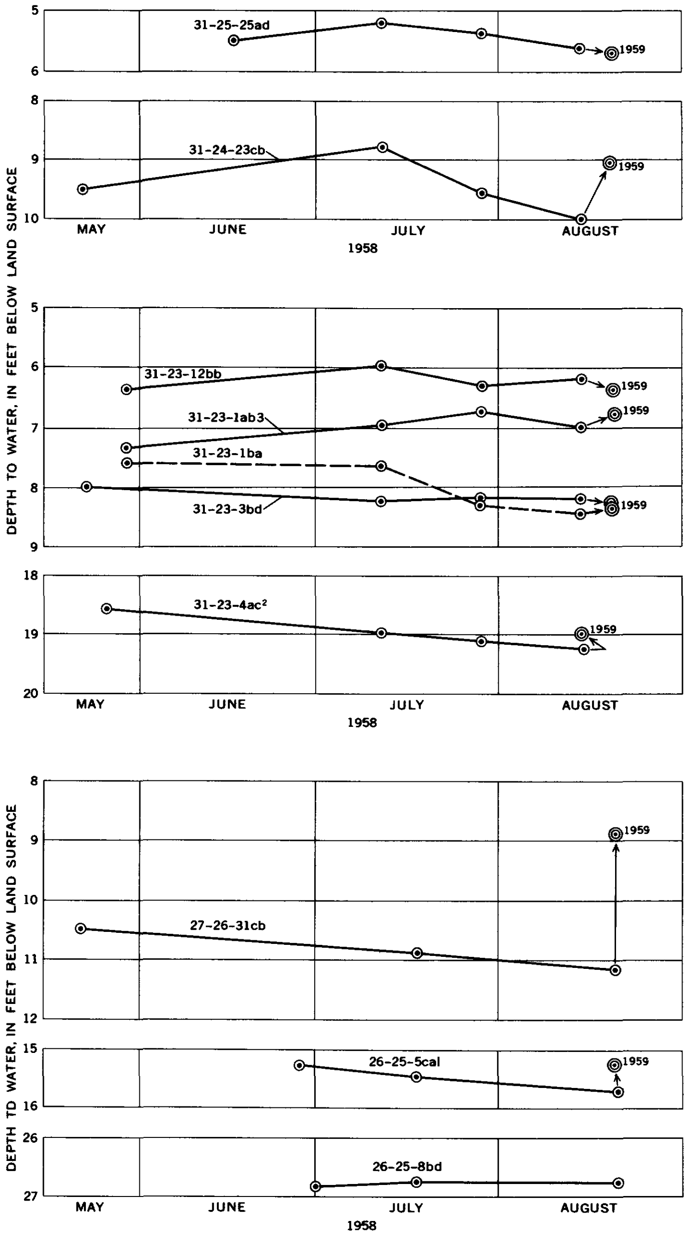

Figure 10.—Hydrographs of wells.

TABLE 2.—*Monthly and yearly mean, momentary maximum, and minimum day discharge (cfs) and runoff (thousands of acre-feet) of the Milk River at Lohman, Mont.*

[SE¼ sec. 20, T. 33 N., R. 18 E. Discharge: 1 cfs is about 449 gpm; flow regulated after 1939 by Fresno Dam, 30 miles above station. Data from U.S. Geol. Survey Water-Supply Papers 1209 and 1309]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The year	Momentary maximum		Minimum day	Runoff, in thousands of acre-feet
														Discharge	Date		
1918	----	----	----	----	----	----	----	----	172	252	240	82.2	----	----	----	----	----
1919	----	----	----	----	----	----	----	364	294	203	271	210	----	580	May 13	----	----
1920	----	----	----	----	----	----	----	1,150	497	395	307	67.7	----	----	----	----	----
1921	----	----	----	----	----	----	----	327	397	354	160	----	----	----	----	----	----
1923	90	15	5	5	5	170	422	223	1,240	1,070	360	197	317	3,270	June 23	----	230
1924	75.1	77.3	60	30	80	120	570	244	1,120	287	365	138	263	----	----	----	190
1925	38.4	30	20	10	15	600	1,300	756	802	306	350	353	382	3,290	Mar. 24	----	277
1926	384	99.7	61.4	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1934	----	----	----	----	----	----	385	542	787	460	413	120	----	1,760	June 12	----	----
1935	38.1	27.4	33.3	5.9	326	395	848	555	451	522	379	273	320	----	----	----	231.8
1936	15.8	5	5	3	1	417	499	251	486	387	394	50.3	210	2,260	Apr. 15	----	152.5
1937	18.5	9.24	2.06	.5	1	179	508	448	636	533	458	233	253	2,680	June 16	0	183.3
1938	43.7	1.3	.5	1	5	609	460	760	671	698	480	282	337	3,230	June 23	0	243.9
1939	13.6	77.9	59.4	37.3	20.0	748	179	487	631	498	325	40.8	262	3,450	Mar. 21	1.6	189.7
1940	.65	68.2	45.6	7.3	12.8	92.2	159	220	488	456	289	185	169	660	June 11	.1	122.6
1941	35.1	21.3	22.8	12.2	25.1	64.4	41.8	336	280	420	306	115	141	699	June 29	5	102.2
1942	35.7	23.6	21.1	23.7	23.9	72.0	136	369	666	408	551	477	235	1,340	July 29	11	169.9
1943	219	86.2	90.7	60.5	152	300	351	684	297	366	584	444	304	----	----	20	220.3
1944	202	50.6	54.5	54.8	47.6	89.9	134	453	246	287	290	148	172	556	July 26	15	125.2
1945	26.9	13.6	33.3	30.5	33.5	122	110	351	307	571	500	269	199	739	July 22	4	144
1946	56.5	38.6	40.3	41.5	47.4	75.2	249	523	430	461	493	220	224	664	Aug. 1	22	162.4
1947	70.9	25.7	75.6	44.4	58.6	611	936	648	716	615	501	255	381	----	----	15	276
1948	133	90.5	56.6	48.7	46.2	45.5	247	619	1,148	807	580	412	353	2,450	June 22	28	256.3
1949	406	71.4	39.5	32.3	34.7	72.7	417	582	483	620	480	326	299	----	----	25	216.3
1950	24.6	26.1	30.8	29.6	34.6	48.1	119	365	691	731	487	362	247	1,090	June 8	13	178.8
1951	51.5	28.5	40.3	30.7	43.4	146	599	945	747	877	805	644	415	1,440	May 20	15	300.5

TABLE 3.—*Monthly and yearly mean, momentary maximum, and minimum day discharge (cfs) and runoff (thousands of acre-feet) of the Milk River at Havre, Mont.*

[SW¼ sec. 4, T. 32 N., R. 16 E. from 1899 to 1922; SE¼SE¼ sec. 5, T. 32 N., R. 16 E. from 1955 to 1961. Discharge: 1 cfs is about 449 gpm. Data from U.S. Geol. Survey Water-Supply Papers 1309, 1389, 1439, 1509, 1559, 1629, 1709 and Surface Water Records of Montana, 1961, 1962]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The year	Momentary maximum		Minimum day	Runoff, in thousands of acre-feet
														Discharge	Date		
1898	---	---	---	---	---	---	---	1,220	1,354	162	113	53	---	---	---	0	---
1899	88	100	---	---	---	---	2,700	1,054	843	240	188	131	---	20,000	Apr. 12	---	---
1900	94	250	160	140	80	100	420	435	154	43	40	76	166	1,650	May 17	8	120.4
1901	186	100	110	60	90	670	205	648	553	184	28	56	241	2,540	May 4	11	175.4
1902	82	80	70	90	110	249	199	1,085	1,479	2,045	364	222	506	9,960	July 7	---	369
1903	204	200	150	150	130	240	996	1,079	975	445	378	164	426	4,120	May 30	---	308.9
1904	138	115	110	90	75	75	1,736	373	278	44	5	3	254	4,900	Apr. 7, 13	1	182.5
1905	19	35	25	5	5	146	59	61	35	54	21	0	39	366	July 29	0	28.3
1906	0	0	0	0	.6	30	94.6	119	935	101	5.2	2.8	107	4,150	June 8	0	77.1
1907	1.5	.5	0	0	250	700	1,210	458	822	397	61.6	127	334	3,750	Mar. 24	0	242
1908	81.8	72.5	90	80	60	150	295	330	2,190	527	177	124	346	11,000	June 9	---	251
1909	178	186	50	20	75	354	430	1,610	742	367	180	52.7	356	5,360	May 25	---	258
1910	73.6	70	40	40	50	1,060	197	167	103	15.3	0	9.0	153	1,860	Mar. 4, 5	0	111
1911	20.8	34.2	25	20	20	330	329	416	394	313	115	664	224	2,980	Sept. 7	---	162
1912	281	97	80	30	50	1,050	1,440	466	243	115	77.0	73.5	333	7,790	Mar. 29	---	242
1913	104	96.6	40	20	50	180	1,360	607	360	181	96.3	16.5	259	2,540	Apr. 15	7	187
1914	60.4	63.6	70	40	30	440	437	151	119	26.4	1.49	16.2	122	1,080	Mar. 14	0	88
1915	154	110	30	10	5	600	302	189	463	296	179	171	210	3,640	Mar. 24	---	152
1916	166	92.6	30	10	1,400	1,600	374	459	889	1,160	414	300	561	---	---	---	415
1917	277	140	70	35	30	350	2,570	1,150	792	360	332	300	534	8,090	Apr. 11	---	386
1918	73.3	148	56.9	780	327	2,110	600	261	233	324	258	98 0	442	9,150	Mar. 20	---	320
1919	30	30	20	5	5	5	263	415	350	283	301	206	160	686	May 13	---	116
1920	41.5	30	10	5	10	1,000	1,200	1,270	604	463	396	70.7	426	4,090	Apr. 22	---	310
1921	24.7	25.9	23.1	15.3	10	90	504	410	472	410	196	32.6	185	1,450	Apr. 6	---	134
1922	8.97	5	2	0	0	100	839	704	422	596	356	201	271	3,340	July 9	0	196
1923	94.5	18	---	---	---	150	423	---	---	---	---	---	---	---	---	---	---
1955	285	116	81.0	47.4	39.6	39.9	469	1,218	997	942	973	709	496	2,550	May 23	20	359.1
1956	268	56.9	36.3	41.1	40.5	81.9	330	634	1,029	1,066	943	649	433	1,280	July 19	20	314
1957	365	116	54.4	28.9	37.9	88.5	236	944	909	985	907	522	436	1,250	July 26	20	315.6
1958	200	56.1	48.3	56.9	58.6	138	476	1,053	840	1,024	794	631	451	1,390	May 21	30	326.2
1959	81.8	36.7	35.0	31.1	31.6	528	212	925	1,094	834	1,125	525	458	1,720	Aug. 1	20	331.8
1960	331	125	58.7	42.1	47.4	125	384	826	1,144	1,282	851	530	481	1,630	July 18	25	348.8
1961	150	37.4	41.0	43.1	48.3	45.3	149	846	727	873	601	357	329	1,280	July 15	30	238.2
1962	45.3	46.1	30.4	28.3	33.1	25.0	212	785	589	827	588	331	297	1,180	July 5	10	215.2

TABLE 4.—*Monthly and yearly mean, momentary maximum, and minimum day discharge (cfs), and runoff (thousands of acre-feet) of Peoples Creek, near Dodson, Mont.*

[N½ sec. 21, T. 30 N., R. 26 E. Discharge: 1 cfs is about 449 gpm. Data from U.S. Geol. Survey Water-Supply Papers 1209, 1239, 1279, 1309, 1339, 1389, 1439, 1509, 1559, 1629, 1709, and Surface Water Records of Montana, 1961, 1962]

Water year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	The year	Momentary maximum		Minimum day	Runoff, in thousands of acre-feet
														Discharge	Date		
1918	---	---	---	---	---	---	---	7.86	1.24	0	---	0	---	---	---	---	---
1919	---	---	---	---	---	---	40	10.9	1.57	6.75	0	0	---	---	---	---	---
1920	---	---	---	---	---	---	94.5	78.5	126	95.4	.19	0	---	---	---	---	---
1921	---	---	---	---	---	---	---	---	12.1	75.5	.39	.49	---	---	---	---	---
1922	1.97	3.98	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
1951	---	---	---	---	---	---	---	---	1.68	2.97	.35	1.95	---	---	---	---	---
1952	1.53	2.4	6.0	1.0	71.6	374	461	27.5	18.0	10.8	1.32	.16	80.9	3,500	Mar. 30	0	58.7
1953	1.42	.78	0	.13	.58	18.3	3.58	143	332	52.9	10.1	.70	47.0	934	June 5	0	34.0
1954	2.26	10.7	8.5	3.5	51.1	22.9	95.9	29.0	25.8	9.36	2.12	6.36	21.9	917	Apr. 6	0	15.9
1955	7.92	9.24	7.3	1.9	2.1	77.8	313	248	75.3	37.6	4.25	.91	65.6	1,280	Apr. 11	0	47.5
1956	1.38	1.92	0	0	0	27.0	25.1	7.58	2.10	2.06	.17	.08	5.70	100	Mar. 25	0	4.1
1957	.38	0	0	0	.71	32.5	25.2	14.9	5.51	.28	0	.72	6.72	156	Mar. 21	0	4.9
1958	.06	.31	.53	0	7.4	32.5	7.91	.34	.03	0	0	0	4.08	155	Mar. 25	0	3.0
1959	0	0	3.65	.34	0	155	23.8	6.37	12.7	5.0	0	1.64	17.6	434	Mar. 13	0	12.8
1960	2.45	.79	2.00	3.13	7.06	154	25.6	20.3	13.1	6.28	1.10	.69	19.9	1,500	Mar. 20	0	14.4
1961	.45	.07	0	0	0	2.32	1.19	6.58	3.45	0	0	0	1.18	177	May 31	0	.8
1962	0	0	0	.03	3.06	32.4	.57	13.1	8.50	12.1	.47	0	5.91	216	May 22	0	4.3

GROUND-WATER DISCHARGE

Much ground-water discharge occurs as subsurface seepage into the Milk River and the valley fill of the preglacial Missouri River. The preglacial Missouri valley is cut into the Judith River Formation for its entire length along the north boundary of the reservation. Well records (Alden, 1932, p. 67) and other subsurface data indicate that the maximum amount of fill is about 200 feet. Assuming that the Judith River Formation dips uniformly at 40 feet per mile to the north, that the formation has a coefficient of permeability of about 10 gallons per day per square foot, that flow through the Judith River is uniform and is due north, and that the hydraulic gradient is equal to the dip of the aquifer, Darcy's law may be used to compute the ground-water discharge into the Milk River. Darcy's law states that:

$$Qd=PIA$$

where Qd=discharge in gallons per day, P=coefficient of permeability, in gallons per day per square foot, I=the hydraulic gradient, in feet per foot, and A= the cross-section area, in square feet, through which discharge occurs. Substituting numerical values, the discharge is computed as about 3 million gpd, or about 3,500 acre-feet per year. As ground water flows toward the Milk River in only about half the reservation, it is probably safe to assume that about an equal amount of ground water flows out of the reservation to the west, east, and south through the Judith River Formation, for a total ground-water discharge of about 7,000 acre-feet per year from the reservation. The ground-water discharge due to flowing wells and discharge through other aquifers below the Judith River is considered negligible for these calculations. Because of the assumptions made and the lack of aquifer-test data, this calculation may be in considerable error and should be considered only as a rough approximation.

EVAPOTRANSPIRATION

Of the approximately 660,000 acre-feet of annual precipitation on the reservation, 4 percent, or about 26,000 acre-feet, runs off as surface water, and 1 percent, or about 7,000 acre-feet, is ground-water discharge. The remaining 627,000 acre-feet, or 95 percent of the precipitation, is evaporated or transpired. As vegetation on the Fort Belknap Reservation is sparse, except in the Milk River valley and near the Little Rocky Mountains, transpiration probably accounts for only a small percentage of the evaportranspiration.

According to Lee (1942, p. 317), very high rates of evaporation, expressed as percentages of total precipitation, are typical of those stream basins west of the 95th meridian in which the average annual precipitation is less than 15 inches. In the Red River basin, above Grand Forks, N. Dak., for example, the ratio of runoff to total precipitation for the period 1882 through 1934 ranges from 3.19 percent to 8.40 percent (Hoyt and others, 1936, p. 63). As total runoff plus evapotranspiration equals precipitation, the ratio of evapotranspiration to total precipitation in this basin ranges from 91.60 percent to 96.81 percent. Thus 95 percent for evapotranspiration is not unduly high for the Fort Belknap Reservation.

Several factors contribute to the high rate of evaporation, including the low gradient of the land surface and the drainage system (Peoples Creek has an average gradient of about 10 ft per mile); the low permeability of the glacial till overlying much of the recharge area, which hinders downward percolation; and the irregular surface of the ground moraine, which restricts rapid runoff. Large areas of hummocky topography are undrained or have local interior drainage. This undoubtedly contributes to the high evaporation rate as runoff collects in basins and lakes, which have relatively impermeable bottoms, and stands until evaporated. The low humidity and high temperatures during the summer, which are the months of greatest rainfall, also promote evaporation.

FLUCTUATIONS OF WATER LEVEL IN WELLS

Partial hydrographs showing the fluctuations of water level in observation wells on the reservation plotted from measurements made during the summers of 1958 and 1959 are shown in figures 9 and 10. Partial hydrographs of wells near the Little Rocky Mountains show a continuous lowering of water level during the summer or no significant change. Wells in the Milk River valley shows a marked rise in water level, however, near the end of June or early July. This rise undoubtedly is due to recharge from irrigation, which is intense in these months. Water levels in wells near the Little Rocky Mountains seemed to be higher in 1959 than in the corresponding period in 1958; about two-thirds of the wells in the Milk River valley had small rises in water level.

Water levels in all wells probably become lower until late fall or winter, when a slight rise accompanies the first winter precipitation. Levels then will become lower through the winter, as precipitation is frozen at the surface as snow or ice, until the spring thaw, when levels rise to a high point. Levels slowly lower through the summer, broken only by slight rises from summer rains and from irrigation in the Milk River valley.

THE INFLUENCE OF GEOLOGIC STRUCTURE ON GROUND WATER

The availability of ground water from an aquifer commonly is determined by the position and attitude of the aquifer, which are functions of the geologic structure in the area.

Flat-lying aquifers at the surface, as in aquifer A, in the left half of figure 11, generally contain water under water-table conditions. Well I taps the saturated zone in the lower half of aquifer A. Aquifer A is recharged by direct percolation of preciptation. Under aquifer A is aquiclude B, which perches water in aquifer A. Under aquiclude B is aquifer C, which may contain water under some confining pressure caused by the weight of the overlying rocks. Water in well II, therefore, may rise slightly above the bottom of aquiclude B. Well III has been drilled into aquiclude B and will not yield appreciable quantities of water from that formation; it may, however, yield water from the fault zone bordering the igneous rock.

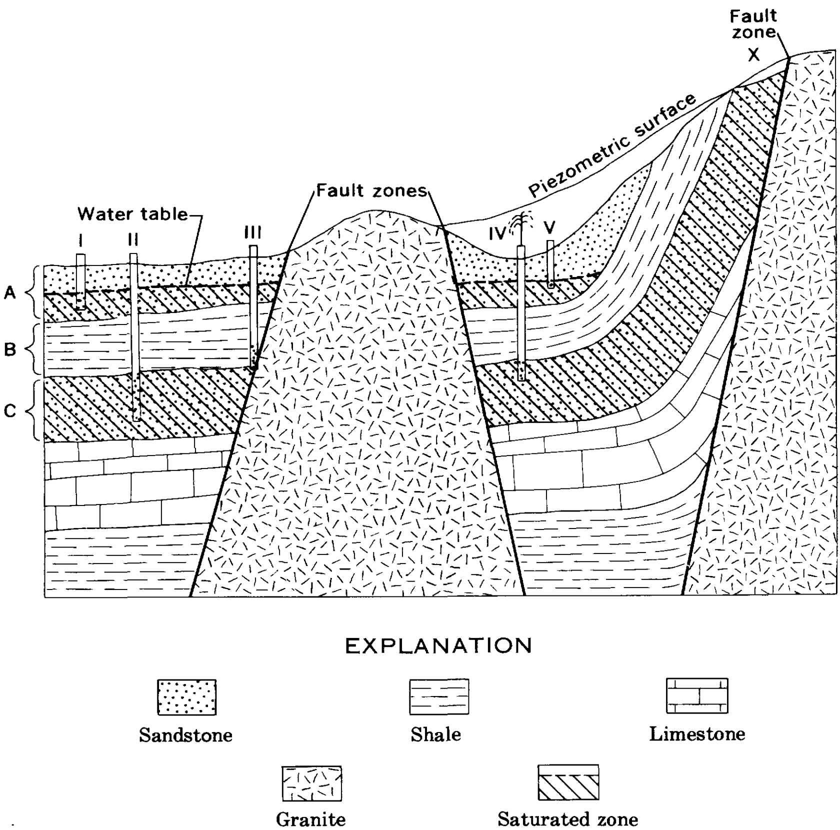

FIGURE 11.—Schematic section illustrating artesian and water-table conditions.

In the right half of figure 11, the same sequence of sedimentary rocks has been tilted upward by an intrusion. Parts of aquifers A and C are now higher than other parts of the same formations. This situation creates a hydraulic head within each confined aquifer, analogous to a water tower or standpipe in a tall building. When well IV penetrates aquifer C, at the same depth beneath the surface as well II, water will rise above the land surface to the height of the piezometric surface. Although the right half of aquifer A also has been tilted up, no hydraulic head has been created because aquifer A remains unconfined. Thus water in well V, which is drilled only into aquifer A, will stand at about the same depth as that in well I. Aquifer C is recharged by direct precipitation on the outcrop area at X.

Structural conditions in the bedrock formations on the Fort Belknap Indian Reservation are shown by the geologic cross sections as shown on plate 1, and figure 7. These indicate that the bedrock sequence has been uptilted around the Little Rocky Mountains, Twin Buttes, and Wild Horse Butte, creating hydraulic heads in the aquifers. Particularly good conditions for obtaining artesian wells exist between the Little Rocky Mountains and Twin Buttes, all around Twin Buttes, probably around Wild Horse Butte, and in the structural trough (Cow Creek syncline) west of the Little Rocky Mountains. Water in the uppermost bedrock aquifer, the Judith River Formation, is under water-table conditions in some places near the surface, but at depth it is confined beneath relatively impermeable rocks. Wells drilled into the outcrop areas of the other bedrock aquifers (the Eagle, Kootenai, and Ellis) will yield water under water-table conditions. However, if the well is drilled near the upper contacts of these formations or in the overlying aquiclude a short distance from the contact, it will probably yield water under artesian conditions. At a distance of a few miles from the outcrop area, however, the aquifer becomes too deep for economic drilling. For example, between the Little Rocky Mountains and Twin Buttes, the Eagle Sandstone, the next aquifer below the Judith River Formation, is about 800 feet beneath the surface.

Water in the alluvium, terrace deposits, and glacial deposits generally is under water-table conditions.

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