DEPARTMENT OF THE INTERIOR
Ray Lyman Wilbur, Secretary

U. S. GEOLOGICAL SURVEY
George Otis Smith, Director

Water-Supply Paper 600

GEOLOGY AND GROUND-WATER RESOURCES OF CENTRAL AND SOUTHERN ROSEBUD COUNTY MONTANA

BY

B. COLEMAN RENICK

WITH CHEMICAL ANALYSES OF THE WATERS

BY

H. B. RIFFENBURG

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1929

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
U. S. GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
35 CENTS PER COPY

CONTENTS

ILLUSTRATIONS

INSERT

ABSTRACT

In the northwest corner of the area covered by this report the Claggett, Judith River, and Bearpaw formations of the Montana group (Upper Cretaceous), named in ascending order, crop out. These formations are about 450, 300, and 950 feet thick, respectively. The Bearpaw shale is overlain without observable stratigraphic hiatus by the fresh-water Lance formation (Tertiary?) age, which has a total thickness of about 925 feet. In the upper part of the Lance formation there are thin unworkable coal beds. Overlying the Lance is the Fort Union formation (Tertiary), which consists of the dark-colored Lebo shale member at the base (100 to 300 feet thick) and a younger light-colored member known as the Tongue River member (1,680 feet thick), made up of alternating beds of sandstone, shale, and coal. Many of these beds of coal are workable. In most of central and southern Rosebud County either the Lance formation or the Fort Union lies at the surface. Terrace gravel of Tertiary and Pleistocene age is present on many of the higher hills. Adjacent to the streams, especially the larger ones, there are belts of alluvium consisting of gravel, sand, and clay which are derived from the consolidated rocks and from the terrace gravel.

The most pronounced structural feature in this region is the Porcupine dome, the southern nose of which is exposed in the northwest corner of the area shown on the map. There are minor folds on the flanks of the dome. South of the Porcupine dome is a southeastern prolongation of the Bull Mountain syncline. Along the flanks of the syncline and in the vicinity of Hopsonville there are faults of slight displacement. It is probable that the faulting was coincident with the deformation that resulted in the uplift of the Porcupine dome.

The chief water-bearing formations in this area are the sandstone and coal beds of the Lance formation and the sandstone, coal, and clinker beds of the Fort Union formation. A supply of water can generally be had where the Lance and Fort Union formations are thick enough to extend below the water table. In the Lance and Fort Union formations and probably also in the underlying Cretaceous formations water from shallow depths (that is, less than perhaps 125 feet) contains considerable calcium and magnesium and is therefore hard, but the water from greater depths contains only small amounts of calcium and magnesium and is therefore soft. This natural softening with increase in depth is due to the fact that as the water gradually percolates downward and moves laterally, the silicate minerals in the rocks exchange their sodium for the calcium and magnesium in the water. The soft water from the Lance and Fort Union formations, which is a sodium bicarbonate water, is generally satisfactory for domestic purposes, although in many places not entirely satisfactory for cooking; but it foams when used in boilers and is unfit for irrigation, as it produces a hard crust of black alkali on the surface of the land. The hard water from shallow depths in the areas of Lance and Fort Union rocks is generally potable, satisfactory for irrigation, and usable for most domestic purposes, but it contains a considerable amount of scale-forming constituents.

The Colorado, Claggett, Judith River, and Bearpaw formations consist chiefly of highly mineralized shales that yield either no water or only very meager supplies of poor water. The Judith River formation contains some beds of water-bearing sandstone. Where these sandstones are not covered by the mineralized shale of the Judith River or Bearpaw formations they yield water of good quality, which is satisfactory for domestic use, for stock, and for irrigation. Such water generally contains less dissolved mineral matter than the water in the Lance and Fort Union formations. The Kootenai (?) formation contains water-bearing sandstones, but, so far as known, the water in these sandstones is highly mineralized and generally unsatisfactory for all uses.

In much of the area where the Pleistocene and older terrace gravel is present it is of sufficient thickness to extend below the water table and will yield considerable supplies of water. This water contains less dissolved mineral matter than the water from any other formation in the region and is satisfactory for domestic use, stock, and irrigation but is somewhat hard and contains an appreciable amount of scale-forming ingredients.

The alluvium along the Yellowstone River, the Tongue River, and the other streams in the region of Lance and Fort Union rocks yields hard water to shallow dug or bored wells. Such water is generally satisfactory for stock, for drinking, and for irrigation but is rather hard for domestic use and is generally unsatisfactory for industrial uses because of the relatively large amount of scale-forming constituents that it contains.

Flowing artesian wells along the flood plain of the Yellowstone River in the eastern part of the area derive their water from the Lance formation; those along the flood plain of the Tongue River in the vicinity of Ashland and Birney derive their water from the Fort Union formation. The water from all the artesian wells in both areas is soft. It is probable that flowing wells may be obtained by drilling into the Tongue River member at some places along the flood plain of the Tongue River between Ashland and Birney, but it is not feasible to predict exactly where such flows may be obtained.

Many of the flowing wells along the Yellowstone and Tongue Rivers yield some hydrocarbon gas, mostly methane derived from the coal and carbonaceous material in the Lance and Fort Union formations. In places there is evidence that the methane reduces the sulphate in the ground water, with the resulting formation of hydrogen sulphide and carbonate or bicarbonate.

GEOLOGY AND GROUND-WATER RESOURCES OF CENTRAL AND SOUTHERN ROSEBUD COUNTY, MONTANA

By B. Coleman Renick

INTRODUCTION

LOCATION AND EXTENT OF AREA

The area considered in this report is in southeastern Montana and includes all of Rosebud County south of T. 9 N. (See fig. 1.) It covers about 3,000 square miles and in 1920 had a population of 8,002.

Forsyth, with a population of 1,838 in 1920, is the county seat and largest town. Rosebud, with a population of 445, and Ashland, with 160, are the next largest. The eastern part of the Northern Cheyenne Indian Reservation is in the southern part of Rosebud County. Lame Deer, where the Indian agency is located, is the largest village within the reservation in this county.

FIELD WORK

The field work upon which this report is based was carried on between July 10 and October 10, 1923. The part of the area between the Yellowstone River and the Northern Cheyenne Indian Reservation and west of the line between Rs. 41 and 42 E. was mapped by plane table, with special reference to the coal beds, by a Geological Survey party under C. E. Dobbin; T. 1 N., Rs. 42 and 43 E., T. 1 S., Rs. 42, 43, and 44 E., and a considerable area along Tongue River were mapped by the same method by N. W. Bass and assistants. A strip of country along the east flank of the Porcupine dome had formerly been mapped in detail by C. F. Bowen.[1] The remainder of the area described in this report was mapped by the writer, whose survey was of the detailed reconnaissance type.

ACKNOWLEDGMENTS

Grateful acknowledgments for advice, suggestions, and review of the manuscript are due to O. E. Meinzer, geologist in charge of the division of ground water, under whose direction the work was done.

[1] Bowen, C. F., Gradations from Continental to Marine Conditions of Deposition in Central Montana during the Eagle and Judith River Epochs: U. S. Geol. Survey Prof. Paper 125, pp. 11–21, 1921.

While the ground-water investigation was being carried on, C. E. Dobbin and N. W. Bass were engaged in mapping the coal-bearing formations in a part of the area covered in this report, and they

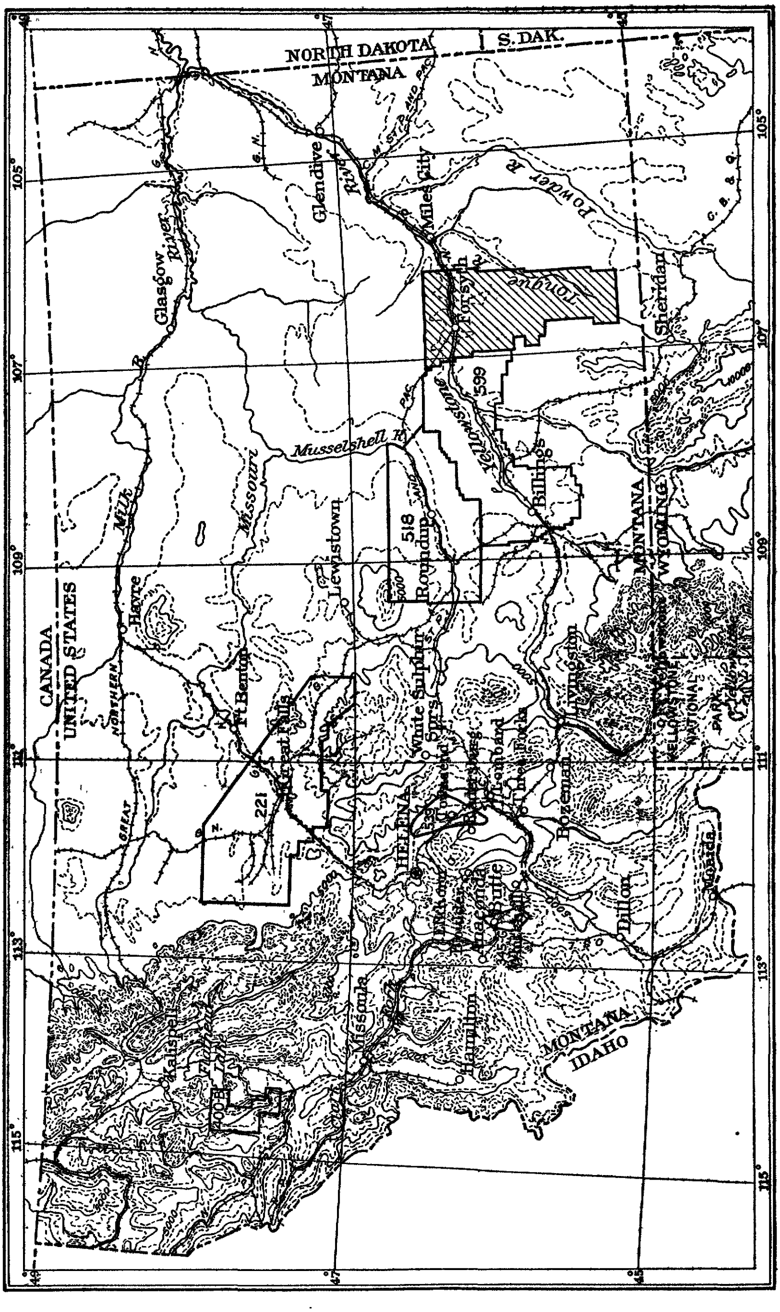


FIGURE 1.—Topographic index map of central and southern Montana showing location of area covered by this report (shaded area) and other water-supply papers of United States Geological Survey (indicated by outlined areas with numbers)

have cooperated by freely furnishing all information at their disposal. The data for that part of the map (pl. 1) covering the area studied by Dobbin and Bass were taken directly from their maps, and the section of Eocene (?) rocks shown in Plate 2 has been taken from Dobbin's report. To W. T. Thom, jr., and Mr. Dobbin the writer is indebted for profitable discussions in regard to the geology of the area. Acknowledgments are due to H. B. Riffenburg for the analysis of 106 samples of water, to Margaret D. Foster for the analyses of certain of the alkalies and soluble material from the rock samples, to Norah Dowell Stearns for the tests of water-bearing properties of certain rocks in this area, and to O. E. Meinzer for the statements in the text in regard to the interpretation of these properties (pp. 35 to 38). C. S. Ross kindly rendered help in connection with the petrologic examination of thin sections of the rocks. For the analysis of the 10 samples of gas from the artesian wells thanks are due to G. W. Jones, of the Pittsburgh experiment station of the United States Bureau of Mines, who has made use of them in his own investigations. The Northern Pacific Railway cooperated by furnishing 11 water analyses.

The work was materially advanced by the hospitality and readiness with which the residents throughout the region cooperated by furnishing information regarding ground water. Especially worthy of mention is the assistance rendered by C. B. Taber, county surveyor, who, besides furnishing the original base map from which the geologic and hydrologic map has been prepared, put every facility at the writer's disposal for furthering the work. A. C. Terrell, division engineer of the Northern Pacific Railway, has aided in numerous ways. J. A. Weaver and L. R. Nash, well drillers, have kindly furnished well logs and certain data pertaining to drilling.

PHYSICAL FEATURES AND DRAINAGE

Rosebud County is within the physiographic province known as the Great Plains, Forsyth being 217 miles by railroad east of Livingston, Mont., which is at the foot of the Rocky Mountains. The surface is far from being a plain, however, as some parts are rough and much dissected, and the area contains very pronounced features of relief. The Wolf Mountains, which extend into the southwestern part of the county, form the most pronounced topographic feature. These mountains stand 800 to 1,000 feet above the adjoining country and consist of relatively flat-lying beds of the Fort Union formation. The upland of the Northern Cheyenne Indian Reservation, in the southern part of the area, represents a great thickness of nearly flat-lying Fort Union sedimentary beds. This upland has been deeply dissected by the Tongue River and its tributaries. The structural uplift known as the Porcupine dome extends into the northwest corner of the area. The easily eroded Colorado shale occurs in the center of the topographic depression that marks the dome, and the more resistant Judith River formation forms the rim.

The altitude in the central and southern parts of Rosebud County ranges from about 2,425 feet above sea level on the Yellowstone River at the eastern margin of the area mapped to about 4,780 feet at the top of the Wolf Mountains, giving a maximum relief of about 2,355 feet. The summit of the divide between the Tongue River and Lame Deer Creek, a tributary to Rosebud Creek, is at approximately the same altitude as the top of the Wolf Mountains.

The Yellowstone River, which flows eastward, is the largest stream in the region. A gaging station for measuring the discharge of this river was maintained by the United States Geological Survey at the highway bridge at Forsyth. The results of the measurements from 1921 to 1923 are tabulated below. No measurements were made in January and February.

Mean monthly discharge, in second-feet, of Yellowstone River at Forsyth, Mont., 1921–1923

Year	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1921					[a] 10, 600	5, 190	4, 320	3, 640	[b] 3, 750	
1922	[c] 9, 880	6, 350	14, 400	43, 300	16, 400	7, 490	5, 080	3, 370	4, 170	[d] 2, 980
1923	[e] 11, 900	6, 460	16, 600	38, 000	26, 600	9, 040	8, 280			

[a] 16 days. [b] 19 days. [c] 11 days. [d] 5 days. [e] 7 days.

The principal tributaries to the Yellowstone River from the north are Porcupine, Little Porcupine, Horse, and Sand Creeks, and the smaller Bull and Wilson Creeks. South of the river, Armells and Rosebud Creeks are the largest; others are Hay, Reservation, Smith, Slaughter House, Sweeney, Coal, Iron Jaw, and Graveyard Creeks. The minor creeks are intermittent in their lower courses. The Tongue River, which flows across the southeast corner of Rosebud County and empties into the Yellowstone at Miles City, has a considerable number of tributaries, among the largest of which are Otter, Odell, Cook, and Hanging Woman Creeks.

Generally the streams are bordered by belts of alluvium of considerable width, adjacent to which there are bluffs several hundred feet high at most places in the areas where the rocks are sufficiently resistant to have withstood erosion.

On the whole the topographic features are expressive of the differences in type of rock structure and in resistance to erosion. Because the variations in topography are in large measure correlated with the different geologic formations they are described for each formation in other sections of this report.

TRANSPORTATION

The northern part of the county is crossed by two transcontinental railroads—the Northern Pacific,[2] which runs on the south side of the Yellowstone River, and the Chicago, Milwaukee, St. Paul & Pacific, which runs on the north side. Forsyth, on the Yellowstone, is about 45 miles west of Miles City by railroad and about 100 miles east of Billings.

During the course of the field work the Northern Pacific Railway Co. was engaged in building a short line, which has since been completed, from the Yellowstone River up Armells Creek to the northern part of T. 1 N., R. 42 E., on the East Fork of that creek, where the company plans to develop a new coal field by stripping operations. At the same time an independent corporation was engaged in grading along the Tongue River for a projected railroad between Miles City, Mont., and Sheridan, Wyo., which, if completed, will tap the coal fields along the Tongue River in the southern part of Rosebud County. The coal resources of the area shown on Plate 1 have been mapped and described in detail by Dobbin.[3]

There are good automobile highways on both sides of the Yellowstone River, and several good graded roads lead from the river toward the north and the south. From Forsyth a good graded road leads southward along Rosebud Creek to a point near the mouth of Greenleaf Creek, where it forks, one fork leading to Lame Deer and points in the Northern Cheyenne Indian Reservation and the other fork connecting with the Tongue River road. Along the Tongue River there is a much traveled road which leads northeastward to Miles City and a secondary road which leads southwestward to Sheridan, Wyo. Other secondary roads and trails that in dry weather are easily traveled by automobile lead to the more remote parts of the area.

CLIMATE AND VEGETATION[4]

This part of Montana is semiarid and is characterized by warm summers and cold winters. The mean winter temperature is 17.4° F., the mean summer temperature 70° F., and the mean annual temperature 44.3° F.

The average annual precipitation at Forsyth is 13.6 inches, but in the Wolf Mountains and the Northern Cheyenne Indian Reservation, in the southern part of the county, where the altitude is

---

[2] For a brief account of the geology, agriculture, and history of the country adjacent to this railroad, see Campbell, M. R., and others, Guidebook of the Western United States, Part A, The Northern Pacific Route: U. S. Geol. Survey Bull. 611, pp. 71–76, 1915.

[3] Dobbin, C. E., The Forsyth Coal Field, Mont.: U. S. Geol. Survey Bull. 812–A (in press).

[4] A. E. Aldous, of the United States Geological Survey, has kindly furnished the information relating to vegetation contained in this section.

more than 2,000 feet greater than at Forsyth, the average is probably 4 to 6 inches more and the vegetation approaches a type characteristic of mountain regions. In the parts of the county where there are no noteworthy differences in the annual precipitation the differences in natural vegetation are due mainly to the differences in the soil.

The heavy clay soil derived from the Cretaceous shale northwest of the Yellowstone River supports grama grass (*Bouteloua gracilis*), wheat grass (*Agropyron smithii*), and black sage (*Artemisia tridentata*), with a scattering growth of prickly pear (*Opuntia missouriensis*), gum weed (*Grindelia subalpina*), and plantain (*Plantago major*). The same type of soil is found in the badlands along the Yellowstone in eastern Montana, but greasewood (*Sarcobatus vermiculatus*), shad scale (*Atriplex canescens*), and rabbit brush (*Chrysothamnus graveolens*) largely replace the black sage, and the stand of vegetation is also more sparse.

The soil of the terraces of Pleistocene gravel adjacent to the Yellowstone, such as the bench just south of Forsyth, is a very friable sandy loam. It supports a vegetation consisting of grama grass, with a little nigger wool (*Carex filifolia*) and a scattering of wild alfalfa (*Psoralea tenuiflora*) and June grass (*Koeleria cristata*).

The type of vegetation most common in the region, particularly south of the rough country adjacent to the Yellowstone, is a mixed stand of grama grass, nigger wool, and wheat grass. This type is found on the rolling lands that have a sandy loam or sandy clay loam soil. On the stream bottoms that have a rather heavy clay soil which receives additional moisture from the flood waters a very good stand of wheat grass is produced; the lighter bottom lands that have a sandy loam or sandy clay loam soil support grama grass and valley sage (*Artemisia nana*) in addition to the wheat grass, but the valley sage is usually the least abundant.

In the area of red clinkers (see pp. 22 and 23), in the southern part of the county, bunch grass (*Andropogon scoparius*) and triple awn (*Aristida longiseta*) are the dominant species, with a small amount of sand grass (*Calamovilfa longifolia*). There are also small patches of prostrate juniper (*Juniperus* sp.) growing on the slopes of these hills.

Cottonwood trees and various shrubs form rather dense thickets along the Yellowstone and Tongue Rivers. The shrubs include willows, buffalo berry (*Shepherdia argentea*), wild rose, and squaw berry (*Rhus trilobata*). These shrubs are found also along the main drainage channels. Yellow pine trees are found scattered over the burned shale buttes in the southern part of the area and in open stands in the Custer National Forest. A very good stand of merchantable yellow pine is found on the divide between the Rosebud and Tongue Rivers, in the Northern Cheyenne Indian Reservation, which is about 1,800 feet above the Tongue River and receives the maximum rainfall of the area.

Between the mountainous part of the area, with its highland type of vegetation, and the lower open country, with its plains type, there is a transition belt within which grow the main species of each environment, including grama grass, wheat grass, wild geranium (*Geranium* sp.), yarrow (*Achillea millefolium*), lupine (*Lupinus* sp.), blue grasses (*Poa* sp.), asters, senecios, pentstemons, fescues (*Festuca* sp.), also aspen (*Populus tremuloides*) and scattering shrubs, mainly wild rose, buck brush (*Symphoricarpos occidentalis*), choke cherry (*Prunus demissa*), and service berry (*Amelanchier alnifolia*).

AGRICULTURE

Although Rosebud County possesses considerable potential wealth in its undeveloped coal reserves, its chief industry at the present time is agriculture. Almost all of the country is well adapted to grazing, and large numbers of both cattle and sheep are raised. Most of the flood plain of the Yellowstone River has been reclaimed by irrigation (see p. 61), also considerable strips along the Tongue River and Rosebud Creek. The alluvium-filled valleys of the Tongue River, Rosebud Creek, Armells Creek, and Sweeney Creek in places are capable of growing good crops of hay without irrigation. Wheat, rye, oats, barley, corn, alfalfa, and sugar beets are the principal agricultural products of Rosebud County. The sugar-beet fields are confined almost entirely to the irrigated tracts on the Yellowstone River that are near railroads. Dry farming has been undertaken by a considerable number of people, but owing to droughts and the ravages of grasshoppers and other pests the results on the whole have been rather discouraging.

HISTORY [5]

Lewis and Clark, on their westward journey to the Pacific in 1804, crossed Montana north of Rosebud County, but on their return in 1806 the party divided, and Captain Clark traveled down the Yellowstone River across the present Rosebud County, while Captain Lewis returned by way of the Missouri, the two parties uniting at the mouth of the Little Knife River, N. Dak.

Perhaps the most widely known chapter in the history of Rosebud County is the story of General Custer's great battle with the Indians on the Little Horn River, June 25, 1876. About 1875 considerable disturbance arose among the Indians, led by Sitting Bull and his warlike Sioux. Because of their menacing attitude the Government detailed General Gibbon from Fort Ellis, near Bozeman, Mont.,

[5] Much of the material contained in this section has been obtained from Stout, Tom, Montana, Its Story and Biography, 3 vols., Am. Hist. Soc., 1921.

General Crook from Fort Fetterman, near Douglas, Wyo., and General Terry from Fort Abraham Lincoln, near Mandan, N. Dak., to cooperate in restoring order. General Crook, though a great Indian fighter, was defeated by the Indians in a battle on the headwaters of Rosebud Creek on June 17, 1876. He endeavored to warn Generals Terry and Gibbon, but his scouts failed to get in touch with them, and Terry and Gibbon met at the mouth of Rosebud Creek unaware of Crook's defeat and of the great number of Indians. Custer, who commanded the Seventh Cavalry under Terry, was ordered to proceed up Rosebud Creek, scouts having reported an Indian village between this creek and the Wolf Mountains. In the meantime Terry and Gibbon were moving up the Big Horn River, expecting to join Custer in the vicinity of the reported village and engage the Indians at that place. Custer followed close on the trail of the Indians, who in the meantime had moved westward to the Little Horn River, where he found them assembled in a large camp. On June 25 Custer decided to attack this host of warriors under Sitting Bull without waiting for Terry and Gibbon. Major Reno, with a detachment of troops, was ordered to proceed down to the river and dislodge them from their encampment, Custer apparently intending to attack from the foothills to the east at the same time. Reno failed in his endeavor and was forced to retreat to a position in the near-by hills, where with skirmishing he held out until the commands of Terry and Gibbon arrived. Custer's entire detachment of 265 men was wiped out. Only a single Indian scout escaped. But the valor of the defense is well known. Terry and Crook continued the campaign against the Indians, and by December, 1876, most of the rebellious tribes had been subdued and concentrated in the agencies.

Among the Indians prominent in the history of this region are the Northern Cheyenne,[6] whose reservation borders the Tongue River in the southern part of Rosebud County. The Cheyenne Indians belong to the great Algonquian family. When first mentioned by the French, in 1680, they were living in northwestern Minnesota. Later, under pressure from the Sioux, who were themselves retiring before the Chippewa, they migrated into North Dakota and from there westward toward the Missouri River. There they were opposed by the Sutaio, a people speaking a closely related dialect. After a period of hostility the two tribes made an alliance and the Sutaio were in time assimilated by the Cheyenne. Some time later the Cheyenne crossed the Missouri below the entrance of the Cannonball River and settled in the Black Hills about the head of the Cheyenne River, S. Dak., where they were found by Lewis and Clark in 1804. They

[6] For further information see Handbook of American Indians: U. S. Bur. Am. Ethnology Bull. 30, 1907.

were constantly pressed westward and southward by the hostile Sioux and settled next near the headwaters of the Platte River, where they came into conflict with the Kiowa, whom the Cheyenne, in turn, forced farther south. The Cheyenne tribe made their first treaty with the Government in 1825. In consequence of the building of Bent's Fort on the upper Arkansas in Colorado in 1832 the tribe split. One group moved south and made permanent headquarters on the Arkansas, while the other group remained between the North Platte and Yellowstone Rivers. This separation was made permanent by the treaty of Fort Laramie, in 1851, and the two tribes were designated Southern and Northern Cheyenne. During the next 25 years the Northern Cheyenne were involved in numerous wars and skirmishes with enemy tribes and with the whites. In 1876 the Northern Cheyenne joined the Sioux under Sitting Bull and took part in the Custer massacre. Later in the same year Mackenzie administered a disastrous defeat to the Northern Cheyenne, which resulted in their surrender. In the winter of 1878–79 a band under Little Wolf, Wild Hog, and Dull Knife attempted to escape from Fort Reno. In the pursuit many Indians and whites were killed. The captives were confined to Fort Robinson, Nebr., from which another escape was attempted. In this second dash for freedom Little Wolf and some followers managed to escape to the north. Realizing that provision must be made for this tribe, the Government, in 1886, established the Tongue River Northern Cheyenne Indian Reservation. (See p. 126.)

STRATIGRAPHY

GENERAL FEATURES

F. B. Meek and F. V. Hayden were the pioneer geologists of Montana, an area which was included in Nebraska Territory when they began their studies in the early fifties. Between 1857 and 1883 these men made many contributions to the geologic knowledge of the northwestern United States.[7]

The geologic section in Rosebud County includes Upper Cretaceous and Tertiary strata and is therefore involved in the Lance problem, or the determination of the position of the boundary between the deposits of the Mesozoic and Cenozoic eras. It is beyond the scope of this report to attempt to discuss this problem here. Thom and Dobbin,[8] after study extending over a number of field seasons, have discussed in detail the correlation of the Cretaceous and Eocene beds in eastern Montana and the Dakotas. The papers of Stanton and

[7] See Nickles, J. M., Geologic Literature on North America, 1785–1918, Part 1, Bibliography: U. S. Geol. Survey Bull. 746, pp. 469–472, 732–735, 1923.

[8] Thom, W. T., jr., and Dobbin, C. E., Stratigraphy of the Cretaceous-Eocene Transition Beds in Eastern Montana and the Dakotas: Geol. Soc. America Bull., vol. 35, pp. 481–506, 1924.

Hatcher[9] and of Bowen[10] on the Upper Cretaceous and those of Stone and Calvert[11] and of Thom and Dobbin[12] on the Tertiary are all of especial interest in connection with this problem.

The facts concerning the beds in Rosebud County are as follows: (1) The Montana group of the Upper Cretaceous series is marine; (2) all the strata of the Lance and Fort Union formations, which lie above the Montana group, are of fresh-water origin; (3) the upper fresh-water deposits (Lance and Fort Union formations), most of which are coal bearing, rest on the marine Upper Cretaceous rocks without the slightest suggestion of a structural unconformity and with no evidence of an erosional break of greater magnitude than occurs within the formations themselves. In conformity with the long-established classification of the United States Geological Survey, the Montana group is here mapped as Cretaceous, the Lance formation as Tertiary (?), and the Fort Union formation as Tertiary.

The areas covered by the exposed rocks described in the following pages are shown on Plate 1.

UNEXPOSED ROCKS

KOOTENAI (?) FORMATION

The rocks now known as the Kootenai formation were originally called "Kootanie series" by William Dawson[13] and were later referred to as "Kootanie series" and "Kootanie formation," indiscriminately, by G. M. Dawson.[14] They are in part correlative with the Fuson shale and Lakota sandstone in the Black Hills to the southeast and the Cloverly formation near the Big Horn Mountains.[15] The Dakota sandstone may possibly be represented in the top of this formation or in basal sandy beds of the Colorado shale. The rocks here designated Kootenai (?) formation are not exposed at the surface in the area mapped but have been penetrated in drilling for oil in near-by areas. They are doubtless of fresh-water origin and are

[9] Stanton, T. W., and Hatcher, J. B., Geology and Paleontology of the Judith River Beds, with a Chapter on the Fossil Plants by F. H. Knowlton: U. S. Geol. Survey Bull. 257, 1905.

[10] Bowen, C. F., The Stratigraphy of the Montana Group, with Special Reference to the Position and Age of the Judith River Formation in North-Central Montana: U. S. Geol. Survey Prof. Paper 90, 95–153, 1915; Gradations from Continental to Marine Conditions of Deposition in Central Montana during the Eagle and Judith River Epochs: U. S. Geol. Survey Prof. Paper 125, pp. 11–21, 1921.

[11] Stone, R. W., and Calvert, W. R., Stratigraphic Relations of the Livingston Formation, Montana: Econ. Geology, vol. 5, pp. 551–557, 652–669, 741–764, 1910.

[12] Thom, W. T., jr., and Dobbin, C. E., op. cit.

[13] Dawson, William, On the Mesozoic Floras of the Rocky Mountain Region: Roy. Soc. Canada Trans., vol. 3, sec. 4, pp. 1–22, 1885.

[14] Dawson, G. M., On the Earlier Cretaceous Rocks of the Northwestern Portion of the Dominion of Canada: Am. Jour. Sci., 3d ser., vol. 38, pp. 120–127, 1889.

[15] Thom, W. T., jr., Oil and Gas Prospects in the Crow Indian Reservation, Mont.: U. S. Geol. Survey Bull. 736, p. 40, 1922.

Generalized table of geologic formations in central and southern Rosebud County, Mont.

	System	Series	Group and formation	Member	Approximate maximum thickness (feet)	Lithologic character	Water supply
Exposed	Quaternary.	Recent.				Mostly silt, sand, clay, and gravel. Along Yellowstone River and some of its tributaries beds of coarse well-rounded gravel interbedded with the finer material are common. The gravel beds are mostly rehandled material from the older terrace-gravel deposits.	The alluvium that contains coarse gravel yields considerable water to shallow dug or bored wells, but the finer material is either not water bearing or yields meager supplies. The largest yields are obtained from the alluvial gravel along Yellowstone and Tongue Rivers. The water from the alluvium is everywhere hard but varies considerably in the amount of mineral matter. Within the irrigated tracts the water in shallow wells is with local exceptions very highly mineralized and nonpotable.
		Pleistocene.	Terrace deposits.		70	Well-rounded pebbles and cobbles of many kinds of igneous, sedimentary, and metamorphic rocks, derived mostly from the Rocky Mountains; embedded in a matrix of silt and sand. They lie along Yellowstone River 150 to 350 feet above the stream.	Where these deposits are sufficiently thick they will yield considerable supplies of palatable water, which, though hard, contains less dissolved mineral matter than most of the ground water in Rosebud County. Water from these deposits is satisfactory for all domestic and stock uses and for irrigation. Springs occur at many places.
	Tertiary.	Pliocene (?). Miocene (?). Oligocene(?).	Terrace deposits.		60	Consist of the same types of material as the Pleistocene terraces. It is probable that the successively higher terraces found southward from those of Pleistocene age along the Yellowstone are respectively of Pliocene, Miocene, and Oligocene age.	Where the gravels are sufficiently thick they yield abundant supplies of water, which is hard but potable, being similar in quality to that in the Pleistocene gravels. Springs occur at many places.
		Eocene.	Fort Union formation.	Tongue River member.	1,680	Sandstone, shale, and coal. In the lower part the sandstone and shale are generally white to light gray with a tint of yellow; in the higher part they are mostly yellow to buff. Much of the coal has been burned along the outcrop, producing red to lavender clinker beds over most of southern Rosebud County.	The sandstone and coal beds furnish the water supplies; the shale is not water bearing. The water from shallow wells is hard, but the water from the deeper drilled wells is soft. Both the shallow and the deep water is potable. The shallow ground water is satisfactory for domestic purposes and for irrigation but will form scale in boilers; the deeper water is satisfactory for domestic purposes but is unfit for irrigation and often foams in boilers. At several localities along Tongue River there are artesian wells that obtain their water from this member. The coal, clinker beds, and sandstone yield hard but potable water to springs at many places.
				Lebo shale member.	300	Dark carbonaceous shale with a considerable amount of arkosic sandstone and lignite.	The sandstone in this member yields water similar in quality to that in the Tongue River member, but not in such great quantity because it is less pervious. The shale is either not water bearing or yields water that is highly mineralized.
	Tertiary (?).	Eocene (?).	Lance formation.	Tullock member.	250	Alternating beds of yellowish-gray to buff sandstone and shale with thin but persistent beds of coal and carbonaceous material. At the top is a sandstone which resists erosion and gives rise to a well-developed rim rock.	The sandstone furnishes considerable supplies of water. The water from shallow wells is hard, but that from deeper sources is soft. The hard water, even if not entirely satisfactory, can generally be utilized for domestic uses and drinking and is always satisfactory for irrigation. The deeper soft water is always potable and satisfactory for domestic uses but is unfit for irrigation and causes foaming in steam boilers. The Lance strata crop out in the most densely populated part of Rosebud County and for this reason are the chief source of water supplies in the county. Along Yellowstone River in the eastern part of the county there are artesian wells which obtain their water from the Lance sandstones. Springs yielding water from the sandstone and coal beds occur at some places; such water is always hard but potable and varies in degree of mineralization.
				Hell Creek member.	675	At the base of this member is a massive cliff-making arkosic sandstone. Above this are interbedded shale and lenticular sandstone. These beds grade through light yellow, light buff, and gray.	
	Cretaceous.	Upper Cretaceous.	Montana group: Bearpaw shale.		950	Dark-gray, dark-brown, and black fissile marine shales containing numerous concretionary bands, which abound in invertebrate fossils. Locally thin beds of bentonite. Near the top a few feet of unconsolidated sand.	Generally not water bearing. Meager supplies of highly mineralized water have been obtained in some places.
			Montana group: Judith River formation.		300	Contains three lithologic units—a sandstone member at the top 30 feet thick, a sandstone member at the bottom about 100 feet thick, and a shale member 165 feet thick between. Marine in Rosebud County.	The sandstone members, especially the lower one, yield considerable water, but where the sandstone is covered with shale (Bearpaw or Judith River) the mineralized shale above causes a high mineralization in the water, which makes it unfit for most uses. Wells in the sandstone at places where it is not covered by shale yield potable but hard water, which contains relatively little mineral matter.
			Montana group: Claggett shale.		475	Mostly dark-gray and dark-brown shale; locally a small amount of sandy shale. Limestone beds as much as 2 feet thick are present. The contact with the underlying Colorado shale is not distinct.	Generally not water bearing but locally yields relatively small supplies of hard, highly mineralized water, which is generally nonpotable but at some places can be used for drinking.
			Colorado shale.		2,500	Dark-gray to black fissile shale containing thin calcareous concretionary bands, which abound in marine vertebrate fossils. Thin beds of sand in places. Marine in Rosebud County. Only the upper part exposed.	Generally not water bearing but locally yields meager supplies of highly mineralized, hard water.
Not exposed		Lower Cretaceous.	Kootenai (?) formation.		350 (?)	Not exposed in Rosebud County. Probably consists of sandstone and sandy shale interbedded with variegated shale. Also possibly contains very coarse sandstone or conglomerate. The Dakota sandstone may be represented in the top of this formation or in sandy beds in the basal part of the Colorado shale.	Yields highly mineralized brackish water.

probably made up of sandstone and sandy shale, possibly also very coarse sandstone or conglomerate, interbedded with red and variegated shale. Their thickness is probably 300 to 400 feet. These beds yield oil at Cat Creek and elsewhere in Montana. Sandstones of the Kootenai are believed to have been reached in drilling for oil in the center of the Porcupine dome, about 10 miles north of the area shown on Plate 1.

EXPOSED ROCKS

CRETACEOUS SYSTEM

UPPER CRETACEOUS SERIES

COLORADO SHALE

Only the upper few hundred feet of the Colorado shale, which is 2,200 to 2,500 feet thick in Rosebud County, is exposed in the area mapped, but the entire thickness has been penetrated in drilling for oil 10 to 15 miles to the north, near the center of the Porcupine Dome, and also in the well drilled at Vananda by the Chicago, Milwaukee, St. Paul & Pacific Railway. (See p. 72.) Where penetrated by these wells the strata are made up chiefly of dark-gray to black fissile shale but contain a few thin beds of sandstone, limestone, and fossiliferous calcareous concretionary bands. They are marine and are doubtless equivalent to both the Benton and Niobrara formations to the east. The Colorado shale is easily eroded and when wet becomes plastic and sticky and gives rise to "gumbo."

West and northwest of Rosebud County the top of the Colorado shale is marked by a massive cliff-making sandstone known as the Eagle sandstone, but in this area there is no well-marked sandstone at that horizon, except, possibly, in Yellowstone Valley. It is likely, however, that detailed work will reveal the horizon of the Eagle sandstone. The pinching out of the Eagle toward the east is due to a seaward thinning of the sand beds that formed this sandstone, as shown by Stebinger [16] and Bowen.[17] (See pl. 2.)

MONTANA GROUP

Claggett shale.—The name Claggett formation, for Fort Claggett, near Judith, was applied by Stanton and Hatcher [18] to the strata above the Eagle sandstone and below the Judith River formation.

---

[16] Stebinger, Eugene, The Montana Group of Northwestern Montana: U. S. Geol. Survey Prof. Paper 90, p. 67, 1914.

[17] Bowen, C. F., Gradations from Continental to Marine Conditions of Deposition in Central Montana during the Eagle and Judith River Epochs: U. S. Geol. Survey Prof. Paper 125, pp. 11–21, 1921.

[18] Stanton, T. W., and Hatcher, J. B., op. cit., p. 13.

According to Heald,[19] the Claggett shale in the Ingomar dome, which is about 12 miles northwest of the northwest corner of this area, is about 435 feet thick, and what is considered to be the equivalent of the Eagle sandstone is about 50 feet thick. In the area described in this report the total thickness of the Claggett shale, including any beds that may represent the time equivalent of the Eagle sandstone, is about 475 feet. It is possible that as a result of further paleontologic studies the heavy sandstone at the bottom of the Judith River formation may be included in the Claggett formation. Most of the Claggett formation is shale, and much of it, especially the lower part, is similar to the Colorado shale. Limestone beds as much as 3 feet thick are present in the Claggett, and in its upper part there are well-marked beds of sandy shale. The Claggett shale, like the Colorado, is easily eroded, in contrast with the overlying massive sandstone, which has been referred to the base of the Judith River formation.

Judith River formation.—The Judith River formation[20] in this part of Rosebud County is marine and is divisible into three distinct lithologic units—an upper and a lower sandstone and a middle member of shale. The section of the Judith River formation given below was measured in the bluff southwest of Vananda, but it does not represent the entire thickness of the Judith River formation, which is probably about 300 feet, because in this bluff some of the top sandstone has been removed by erosion and the bottom of the section lacks a few feet of reaching the top of the Claggett formation.

The upper sandstone averages about 30 feet in thickness and is thin bedded. On the south and east sides of the Porcupine dome it forms well-developed hogbacks, owing to the ease with which the overlying Bearpaw shale and underlying shale of the Judith River are eroded. The middle shale member is dark gray to dark brown and is not essentially different lithologically from the Bearpaw or Claggett shales; like these shales it contains numerous fossiliferous calcareous concretionary beds.

[19] Heald, K. C., The Geology of the Ingomar Anticline, Treasure and Rosebud Counties, Mont.: U. S. Geol. Survey Bull. 786, p. 17, 1926.

[20] Hayden, F. V., Geology of the Missouri Valley: U. S. Geol. Survey Terr. Fourth Ann. Rept., p. 97, 1871. Stanton, T. W., and Hatcher, J. B., op. cit., pp. 33–34.

Section of the Judith River formation in bluff on line between the SE. ¼ sec. 9 and the NE. ¼ sec. 16, T. 7 N., R. 38 E.

Member	Description	Thickness (feet)	Total thickness of each member (feet)
Upper sandstone	Interbedded thin laminated gray sandstone and sand	18	[a] 18
Middle shale	Light-colored sandy shale	45	163
	Dark-gray to dark-brown shale	60	
	Lime concretion zone	.5	
	Dark-gray and dark-brown shale	33	
	Light-brown to buff sandy shale	7	
	Sandstone	1.5	
	Dark-brown and gray shale	16	
Lower sandstone	Massive to thin-bedded sandstone	2.5	[b] 98.5
	Light-yellow sand	6	
	Thin laminated gray to white sandstone	2	
	White to light-yellow medium to fine grained massive sandstone; some layers stained with limonite and hematite.	88	

[a] The top of this member has been removed by erosion. Its average thickness throughout the area is about 30 feet.
[b] The top of the Claggett is probably within 10 feet of the bottom of this section.

The lower sandstone (pl. 3) is generally a white to light-gray heavy cliff-making sandstone. Because of its relative resistance to erosion it forms a pronounced rim around the southern and western edge of the Porcupine dome, and the depression below this escarpment is occupied by the easily eroded Colorado and Claggett shales. Bowen[21] has shown that the Judith River formation, which is marine in this longitude, is transitional into the coal-bearing fresh-water Judith River to the northwest along the Musselshell River, and he has given the following description[22] based on petrographic examination of both the fresh-water and marine types:

As revealed by a study of thin sections the sandstones of both the fresh-water and marine facies of the formation are as similar in microscopic appearance as they are in outward physical appearance. They are arkosic and consist of angular, subangular, and rounded grains of orthoclase, plagioclase, quartz, and black chert, with small amounts of muscovite and biotite, inclosed in a matrix or cement of calcite, which is more or less stained with iron oxide. Grains of limestone are numerous in one specimen of fresh-water origin and are rather well rounded; but they are not observed in any of the other specimens examined. A rather surprising feature is the slight alteration of a considerable proportion of the feldspar. Many of the grains, especially of the plagioclase variety, are perfectly fresh and clear and show no sign of kaolinization. In the sections examined the calcite constitutes 50 per cent or more of the bulk of the rock; of the granular material feldspar is in general the most abundant, followed by black chert and quartz, which vary in amount, in some specimens the one and in some the other predominating. Another interesting feature is the small proportion of well-rounded grains. The grains of chert and quartz are subangular to rounded, whereas those of feldspar are predominantly angular and give to the thin sections the appearance of being made up largely of angular to subangular fragments. This marked angularity does

[21] Bowen, C. F., op. cit., pp. 11–21. [22] Idem, pp. 15–16.

not accord well with the highly assorted condition of the material, which is remarkably uniform in size and free from silt or fine particles. This highly assorted condition suggests considerable agitation, either by waves or by currents, whereas the angularity of the grains suggests but a moderate amount of abrasion. It is probably to be attributed to the cleavage of the feldspar and the smallness of the grains rather than to the amount of abrasion of the particles. The texture is fine and varies somewhat in the different specimens, the grains ranging from about 0.075 to 0.2 millimeter in average diameter.

Bearpaw shale.—The Bearpaw shale[23] takes its name from the Bearpaw Mountains, in north-central Montana. This shale, which is approximately 950 feet thick in Rosebud County,[24] rests conformably on the Judith River formation and is equivalent only to the upper part of the Pierre shale in eastern Montana. The Bearpaw is a dark-gray to chocolate-colored marine shale containing numerous brown calcareous concretionary bands, many of which contain an abundance of marine invertebrate fossils. At the top of the Bearpaw shale there is 20 to 30 feet of unconsolidated sand and sandy shale which apparently represents a transition phase into the heavy sandstone at the base of the overlying Lance formation.

The topographic expression of the Bearpaw shale is in marked contrast to that of the overlying Lance formation. The easily eroded Bearpaw shale is conducive to an undulating topography, but the topography of the overlying Lance formation, with its numerous firm sandstone members, is much rougher. The sandstone at the base of the Lance formation gives rise to a loose soil that supports trees; the compact clay of the Bearpaw areas is almost without exception destitute of tree growth. Owing to this fact the contact at many places is easily recognized.

Near the mouth of Armells Creek, in sec. 23, T. 6 N., R. 39 E., the upper contact of the Bearpaw is freshly exposed by a recent railroad cut in which it is clearly shown that there is a gradation into Lance sandstone above, without any suggestion of stratigraphic hiatus.

Thin sections cut from representative samples of the Bearpaw shale show that the mineral constituents are too fine grained for identification.

TERTIARY (?) SYSTEM

EOCENE (?) SERIES

LANCE FORMATION

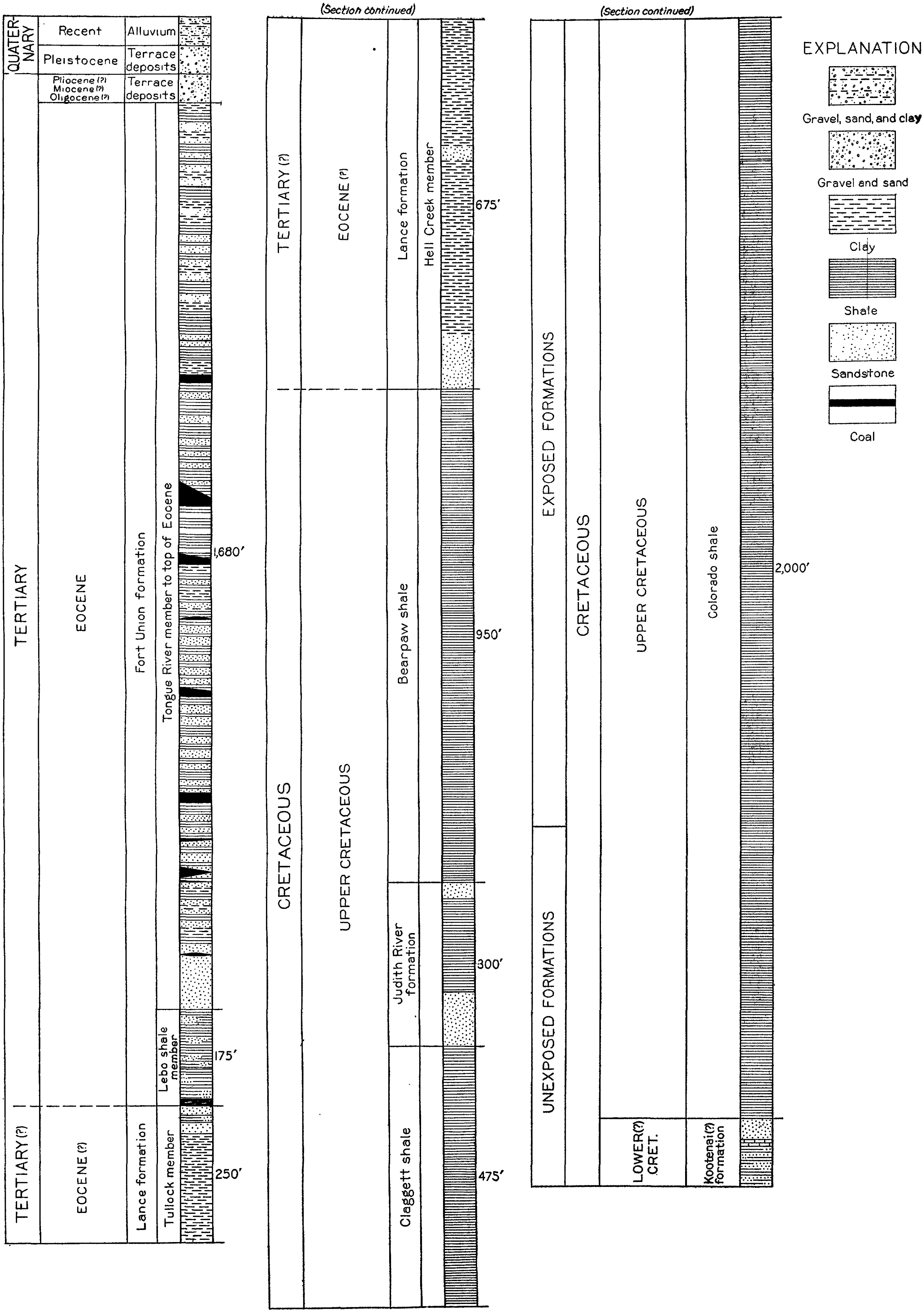
The name Lance formation, as defined by Stanton,[25] is an abbreviation of the "Lance Creek beds"[26] of Hatcher. This formation,

[23] Stanton, T. W., and Hatcher, J. B., Science, new ser., vol. 18, p. 216, 1903.

[24] Bowen, C. F., op. cit., pp. 11–21.

[25] Stanton, T. W., The Fox Hills Sandstone and Lance Formation ("*Ceratops* Beds") in South Dakota, North Dakota, and Eastern Wyoming: Am. Jour. Sci., 4th ser., vol. 30, pp. 172–188, 1910.

[26] Hatcher, J. B., Relative Age of the Lance Creek (*Ceratops*) Beds of Converse County, Wyo., the Judith River Beds of Montana, and the Belly River Beds of Canada: Am. Geologist, vol. 31, p. 369, 1903.



GENERALIZED COLUMNAR SECTION OF THE ROCKS EXPOSED IN CENTRAL AND SOUTHERN MONTANA

PHOTOMICROGRAPH OF THIN SECTION SHOWING TEXTURE AND MINERALS OF BASAL SANDSTONE OF JUDITH RIVER FORMATION

A. SANDSTONE IN HELL CREEK MEMBER OF LANCE FORMATION, NE. ¼ SEC. 28, T. 6 N., R. 40 E.

Showing gradation from massive sandstone into sandy shale

B. VALLEY OF ALDERSON CREEK IN NORTHERN CHEYENNE INDIAN RESERVATION, ABOUT 5 MILES WEST OF LAME DEER

Showing typical topography of the forest-covered Tongue River member of the Fort Union formation in the Cheyenne Reservation which is a fresh-water deposit, has been divided into an upper coal-bearing member about 250 feet thick known as the Tullock member[27] and a lower non coal-bearing member about 675 feet thick known as the Hell Creek member.[28] Though separated into these two members, the local lithologic differences between the members are not striking.

It is difficult to determine positively the exact position of the boundary between the Bearpaw shale and the Lance formation, but the natural lithologic boundary is between the sand or sandy shale at the top of the Bearpaw and the overlying cliff-making sandstone, which is regarded as the base of the Lance formation but which may possibly be in part correlative with the Fox Hills sandstone of the Glendive region, assumed to be the top of the Montana group. The question of this boundary is discussed in detail by Thom and Dobbin.[29] (See fig. 2.)

Above the persistent sandstone at the bottom of the Lance formation there are other sandstone beds, many of which are markedly lenticular, grading from massive coherent sandstone into nonindurated sandy shale within a few feet. (See pl. 4, *A*.) Interbedded with the sandstones are shale beds and at a few places carbonaceous seams. The shale and sandstone are light yellow, light buff, and gray, with a faint greenish tint evident on close inspection. The Hell Creek member in most places contains disseminated carbonaceous material and locally a considerable amount of black organic matter. A thin persistent coal bed has been mapped[30] as the top of the Hell Creek member, but in many places there is no easily recognizable boundary line.

Conglomerate beds are rare in the Hell Creek member and are not confined to its base. They probably represent channel deposits, as they are very local. There is a good exposure of conglomerate in the SW. ¼ sec. 31, T. 8 N., R. 41 E. The conglomerate is usually interbedded with sandstone and may aggregate 50 feet in thickness. The pebbles and cobbles are as a rule fairly well rounded. They consist of sandstone in a matrix of sand, and the largest are several inches in diameter.

The Tullock member consists of yellowish-gray to buff sandstone and shale and, unlike the underlying Hell Creek member, contains a number of thin but persistent coal beds which are usually not workable. Calcareous shale bands are also present. At the top of

---

[27] Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek Coal Field, Mont.: U. S. Geol. Survey Bull. 749, p. 19, 1924. Dobbin, C. E., Geology of the Forsyth Coal Field, Mont.: U. S. Geol. Survey Bull. 812–A (in press).

[28] Brown, Barnum, The Hell Creek Beds of the Upper Cretaceous of Montana: Am. Mus. Nat. Hist. Bull., vol. 23, pp. 823–845, 1907.

[29] Thom, W. T., jr., and Dobbin, C. E., Stratigraphy of the Cretaceous Eocene Transition Beds in Eastern Montana and the Dakotas: Geol. Soc. America Bull., vol. 35, pp. 481–506, 1924.

[30] Rogers, G. S., and Lee, Wallace, op. cit. Dobbin, C. E., op. cit.

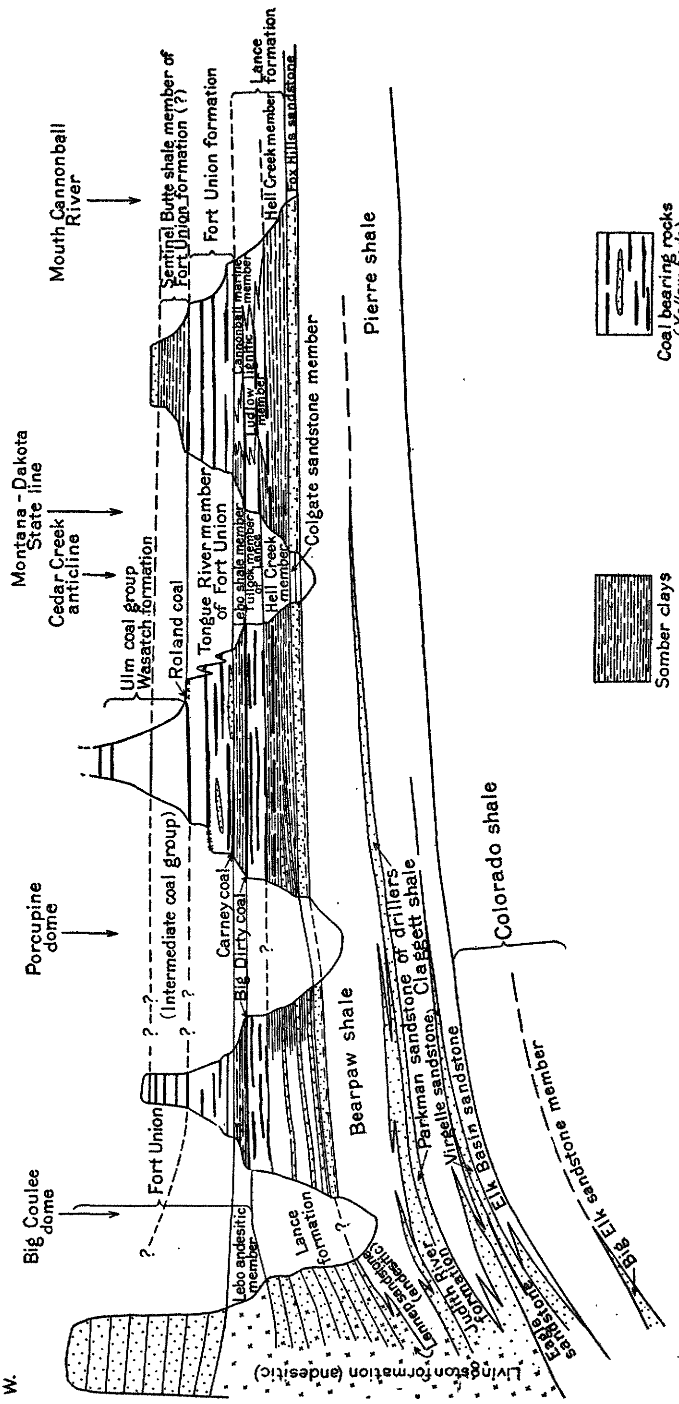


FIGURE 2.—Succession and interrelations of late Cretaceous and early Eocene formations of eastern Montana and the Dakotas. (After Thom and Dobbin.)

the Tullock member there is a relatively thin sandstone which is present throughout the region. This sandstone forms a well-developed flat-topped escarpment, below which there are usually steep cliffs of Tullock strata, and the underlying Hell Creek beds are generally eroded into a semibadland topography, so that as a whole the surface in the area of Lance strata is extremely rough.

Examination of thin sections of the sandstones of the Hell Creek and Tullock members showed that there was no essential difference in their mineral constituents, all of them being very arkosic.[31] They are made up of angular and subangular grains of quartz and fragments of volcanic rock. Many of these rock fragments contain a glassy groundmass, which is considerably altered. The quartz has been strained, doubtless before deposition, and as a result appears biaxial. For this reason it is extremely difficult to differentiate the quartz from the orthoclase that is also present in these rocks, but the thin sections show that the quartz is generally more angular than the orthoclase and that the orthoclase is more altered than the quartz. Examination of the crushed fragments in index of refraction liquids showed that orthoclase did not exceed 3 per cent of the sample and averaged about 1 per cent. In many slides a chertlike material, which may represent altered rock grains of sedimentary (?) origin, is conspicuous. (See pl. 5.) All slides of the Lance rocks contain a few grains of plagioclase, muscovite, biotite, and detrital calcite. Glauconite grains were also identified. An examination by heavy solution of one sample of sandstone showed that the Lance rocks contain garnet, pink and white zircon, and a pyroxene, probably augite.

The freshest material in the rock fragments consists of quartz and feldspar in a matrix of secondary material, mostly leverrierite and an allied mineral. Leverrierite and the allied species are described below by Clarence S. Ross. All thin sections contained some leverrierite, and some showed as much as 10 per cent. Secondary claylike material and calcite were present in all, and chlorite was also noted. These secondary minerals are derived from the alteration of the feldspars and rock fragments. It is problematical just how much secondary material would be obtained from thin sections made from drill cuttings.

---

[31] Most of the rock samples are incoherent, and it is very difficult to make thin sections from them. Clarence S. Ross (A Method of Preparing Thin Sections of Friable Rock: Am. Jour. Sci., 5th ser., vol. 7, pp. 483–485, 1924) has described a method for hardening the incoherent rock chips by first treating with bakelite in order to make them sufficiently coherent for grinding. Bakelite has a high index of refraction and appears isotropic through crossed nicols, as shown by observing the interstitial material in the thin sections shown in Plates 5 and 7.

BENTONITIC MATERIALS

By Clarence S. Ross

A group of clay minerals that are micaceous in habit and quite unlike kaolin have a very wide geologic distribution and may form in various ways, but bentonite is derived only from glassy volcanic ash.[32] The mineralogy of these clay minerals has been investigated by Larsen and Wherry[33] and by Ross and Shannon,[34] and that of the closely related group of hydrous iron silicates by Larsen and Steiger.[35]

The thin sections made from samples of sandstone from the Lance and Fort Union formations show that in many of the rock fragments the mineral grains have no characteristic outline and the nature of the original rock is not evident, but in others euhedral feldspar in a fine-grained groundmass indicates derivation from a volcanic rock. Some of the interstitial material in these rock grains is a secondary claylike aggregate, and at least part of it has the optical and physical properties of bentonitic material. Material of the same kind also forms a scant cement between mineral grains. In a former paper[36] this material was described as leverrierite. At that time the investigation of these minerals was incomplete, and the undifferentiated members of the group were all included under the name leverrierite.

In the section from which Plate 5, *A*, was made, a pale-brown material with a silvery luster forms rather definite masses between other grains. In thin section it is seen that these have a micaceous structure, but instead of being plates many of the grains are made up of groups of plates with random orientation or of fan-shaped or rudely radial aggregates of plates. The best of these plates give a negative optical figure with a small axial angle. The indices are 1.60 to 1.70, and the birefringence is about 0.03. In habit and general appearance and in all optical properties this brown material resembles bentonite, and the mineral probably is beidellite, or a member of the beidellite-nontronite isomorphous series.[37] The ferric iron content of this brown mineral is high, and in consequence the indices of refraction are high.

---

32 Larsen, E. S., and Wherry, E. T., Leverrierite from Colorado: Washington Acad. Sci. Jour., vol. 7, pp. 208–217, 1917.

33 Larsen, E. S., and Wherry, E. T., Beidellite, a New Mineral Name: Washington Acad. Sci. Jour., vol. 15, pp. 465–466, 1925.

34 Ross, C. S., and Shannon, E. V., The Chemical Composition and Optical Properties of Beidellite: Washington Acad. Sci. Jour., vol. 15, pp. 467–468, 1925; The Minerals of Bentonite and Related Clays and Their Physical Properties: Am. Ceramic Soc. Jour., vol. 9, pp. 77–96, 1926.

35 Larsen, E. S., and Steiger, George, Dehydration and Optical Studies of Alunogen, Nontronite, and Griffithite: Am. Jour. Sci., vol. 15, pp. 1–19, 1928.

36 Renick, B. C., Base Exchange in Ground Water by Silicates as Illustrated in Montana: U. S. Geol. Survey Water-Supply Paper 520, pp. 61–62, 1925.

37 Larsen, E. S., and Steiger, George, op. cit.

TERTIARY SYSTEM

EOCENE SERIES

FORT UNION FORMATION

The Fort Union formation as now defined has been discussed by Thom and Dobbin.[38] It is divisible into a lower, so-called somber member, known as the Lebo andesitic [39] or shale [40] member, and an upper, Tongue River member,[41] which corresponds to the Tongue River coal group [42] in the Sheridan coal field, Wyo.

Lebo shale member.—The Lebo shale member ranges from about 125 feet in thickness in the southwestern part of the area to 300 feet or more in the northeast corner; the average is about 175 feet. This member forms an easily recognizable lithologic unit. On account of its dark-gray or olive-drab color in most places, it is easily distinguished from the light-colored underlying Lance and overlying Tongue River rocks. At the base of this member there is a thick bed of impure lignite, known as the Big Dirty coal, which throughout the area lies conformably on the mesa-forming sandstone at the top of the Tullock member of the Lance formation. In many places there are 40 feet or less of strata transitional into the overlying Tongue River member. These transitional beds are lighter in color than the typical Lebo. The Lebo shale member is characteristically eroded into a badland topography. (See pl. 6, *A*.) In this area the Lebo member consists mostly of shale, but locally it contains a considerable amount of arkosic sandstone and carbonaceous bands consisting of liguite, bone, and black shale, which are fairly persistent at one or more horizons. The dark color of this shale is probably due to the presence of disseminated organic matter. The Lebo member contains numerous concretionary bands, mostly siliceous but some calcareous, as much as 12 inches in thickness. On weathering, these siliceous bands become stained at the surface with hematite and break up into roundish cobbles covered with the red iron oxide. Some of the chertlike bands on weathering become impregnated with iron in the form of limonite; these disintegrate into small angular fragments of light orange-colored or yellow-buff material, which covers many of the Lebo slopes. At some places carbonate bands give rise to a cone-in-cone texture.

---

[38] Thom, W. T., jr., and Dobbin, C. E., op. cit.

[39] Stone, R. W., and Calvert, W. R., Stratigraphic Relations of the Livingstone Formation, Montana: Econ. Geology, vol. 5, pp. 551–557, 652–669, 741–764, 1910. Woolsey, L. H., Richards, R. W., and Lupton, C. T., The Bull Mountain Coal Field, Musselshell and Yellowstone Counties, Mont.: U. S. Geol. Survey Bull. 647, 1917.

[40] Rogers, G. S., The Little Sheep Mountain Coal Field, Dawson, Custer, and Rosebud Counties, Mont.: U. S. Geol. Survey Bull. 531, pp. 159–172, 1913.

[41] Thom, W. T., jr., and Dobbin, C. E., op. cit.

[42] Taff, J. A., The Sheridan Coal Field, Wyo.: U. S. Geol. Survey Bull. 341, pp. 123–150, 1909.

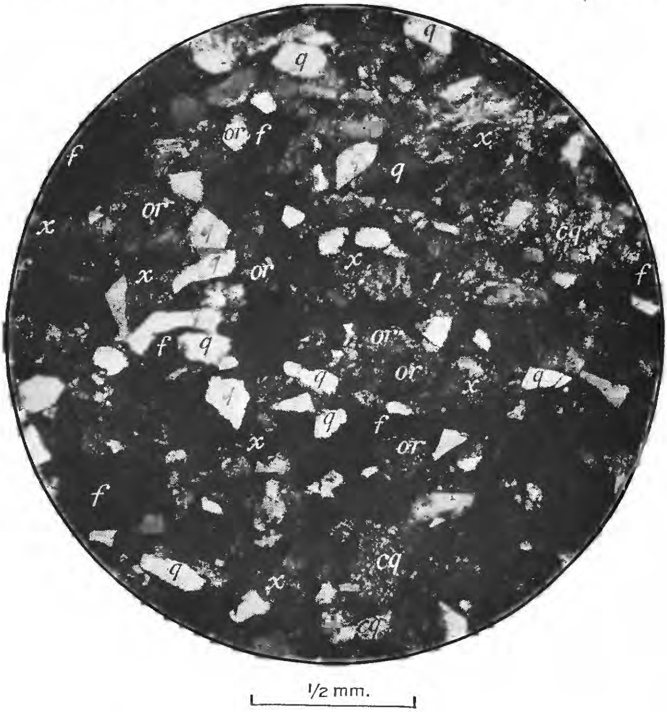
PLATE 5

Photomicrographs of Thin Sections Showing the Texture and Minerals of Sandstone from the Lance Formation

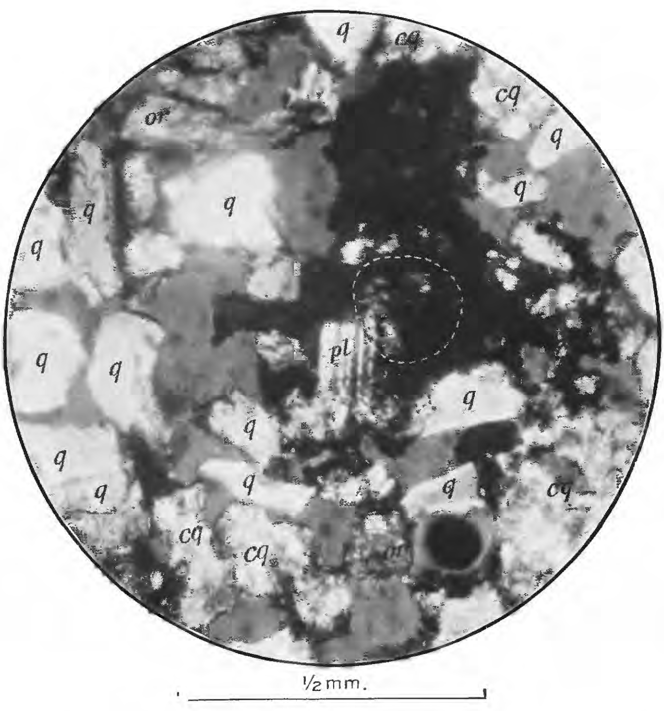
A. Sandstone from NE. ¼ sec. 7, T. 5 N., R. 41 E., nicols crossed.

B. Basal sandstone from NW. ¼ sec. 26, T. 6 N., R. 39 E., showing grains of altered igneous rock containing phenocrysts (also altered), nicols crossed.

cq, Chertlike material, in part possibly secondary, in part probably altered sedimentary rock grains; *f*, impure iron oxide, mostly limonite; *l*, bentonitic material; *m*, colorless mica; *or*, altered mineral grains, probably orthoclase; *pl*, plagioclase; *q*, quartz; *x*, impure claylike interstitial material, in some places containing small amounts of disseminated calcite, probably in considerable part bentonitic material.



A



B

PHOTOMICROGRAPHS OF THIN SECTIONS OF SANDSTONE FROM LANCE FORMATION

A. LEBO SHALE MEMBER OF THE FORT UNION FORMATION, SEC. 13, T. 7 N., R. 44 E.

Showing badland topography characteristic of this member

B. LAME DEER, NORTHERN CHEYENNE INDIAN RESERVATION

View looking east up Alderson Creek; Lame Deer Creek in the middle distance. The village is underlain with alluvium, much of which is disintegrated clinker from the rocks in the near-by upland which belong to the Tongue River member of the Fort Union formation. These beds of clinker gravel in the alluvium supply most of the inhabitants with hard but potable water

Microscopic examination of thin sections of the sandstone and shale facies of the Lebo member shows that the shale is too fine-textured for identifying individual mineral grains but that the sandstone consists of an aggregate of quartz, rock fragments with glassy groundmass, chertlike grains, orthoclase, plagioclase, calcite, chlorite, claylike material, and leverrierite and its allied mineral. (See pl. 7, *A*.) These constituents were found in approximately the same proportions and with the same relations as in the Lance formation and the Tongue River member. Owing to the similar mineral composition in underlying and overlying strata, it seems doubtful if petrologic methods will be of any considerable service in correlating the Lebo member in remote areas, as suggested by Rogers.[43]

Although only five thin sections of the Lebo member were examined, care was exercised in selecting the samples from which these sections were cut, in order that they might be representative of the member in Rosebud County. As these slides indicated that plagioclase was no more abundant in this member than in the Lance formation or the overlying Tongue River member, where plagioclase makes up less than 1 per cent of the rock, it is evident that the descriptive term "andesitic," which is appropriate elsewhere, is not applicable in Rosebud County.

The shale in this member is very incoherent and is easily eroded to a typical badland topography, which almost everywhere characterizes the Lebo member. The comparatively wide outcrop of the Lebo is due to the protection from erosion that is afforded by the top sandstone of the Lance formation, on which the Lebo rests.

Tongue River member.—The Tongue River member, or uppermost part of the Fort Union formation in this region, is light colored, forming a contrast to the olive-drab Lebo shale. Except for later gravel, which rests on the older rocks, the Tongue River strata are the youngest beds in the region. The maximum thickness as reported by Dobbin[44] is over 1,680 feet.

The Tongue River member is made up of shale, sandstone, sandy silt, and coal and constitutes the great productive coal-bearing group of rocks in this region. In the lower part of the member the sandstone and shale are generally white to light gray, with a tint of yellow. At several horizons there are heavy, massive sandstones. (See pl. 8, *A*.) The higher beds of the member, which are well exposed along the Tongue River in the vicinity of Birney, consist of alternating beds of buff shales, sandy silt, thin sandstone, and coal, and are darker in color than the beds in the lower 300 feet. Much of the coal has been burned along the outcrop, and in consequence

[43] Rogers, G. S., A Study in the Petrology of Sedimentary Rocks: Jour. Geology, vol. 21, pp. 715–727, 1913.
[44] Dobbin, C. E., op. cit.

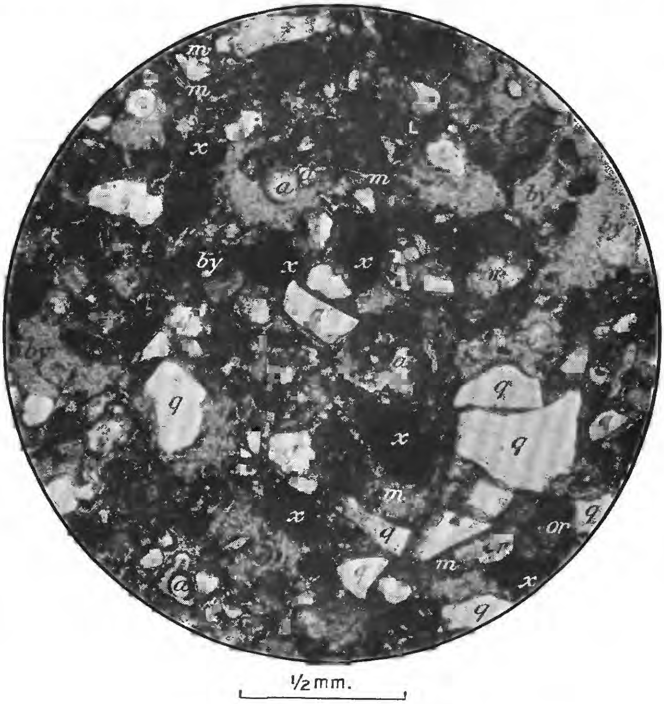
PLATE 7

Photomicrographs of Thin Sections Showing the Texture and Minerals of the Rocks in the Fort Union Formation

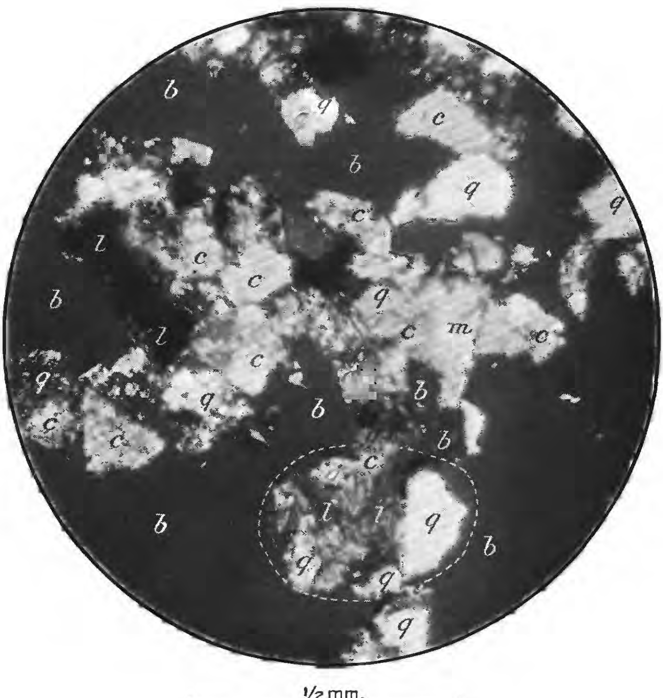
A. Lebo shale member, sandy facies, from NW. ¼ sec. 34, T. 8 N., R. 42 E.; one nicol.

B. Sandstone near base of lower light-colored member in NW. ¼ sec. 33, T. 2 N., R. 43 E.; nicols crossed. Section shows grains of altered igneous rock containing plates of bentonitic material.

a, Air hole; *b*, bakelite mounting; *by*, claylike material stained with bakelite; *c*, calcite; *cq*, chertlike material, in part possibly secondary, in part probably altered sedimentary rock grains; *l*, bentonitic material; *m*, colorless mica; *or*, altered mineral grains, probably orthoclase; *q*, quartz; *x*, impure claylike interstitial material, in some places containing small amounts of disseminated calcite, probably in considerable part bentonitic material.



A



B

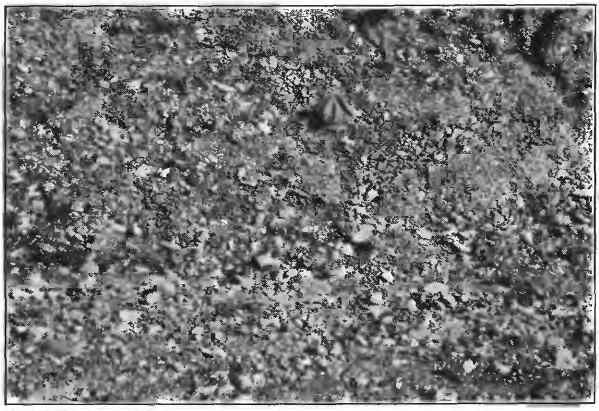
PHOTO MICROGRAPHS OF THIN SECTIONS OF ROCKS IN FORT UNION FORMATION

A. SANDSTONE IN LOWER PART OF TONGUE RIVER MEMBER OF THE FORT UNION FORMATION, SEC. 21, T. 1 S., R. 41 E.

Sandstones of this type yield a good quality of water. The interstitial spaces between grains in the sandstone are an important source of the ground water

B. A SANDSTONE IN THE TONGUE RIVER MEMBER OF THE FORT UNION FORMATION, ORIGINALLY SIMILAR TO *A*, WHICH HAS BEEN FUSED, SHEARED, AND FRACTURED BY THE BURNING OF AN UNDERLYING BED OF COAL

The color is dark red to deep purple. This type of material yields hard water. The principal yield here is from joints



A. PLEISTOCENE TERRACE GRAVEL, SEC. 18, T. 6 N., R. 43 E.

Gravel of this type yields considerable amounts of potable water

B. ALLUVIUM ALONG THE TONGUE RIVER

Gravel lenses in this material consist mostly of fragments from clinker beds. Such gravel yields hard water

A. FORSYTH FLATS, LOOKING SOUTHEAST ALONG THE LINE BETWEEN SECS. 16 AND 21, T. 6 N., R. 41 E.

A Pleistocene terrace standing about 200 feet above Yellowstone River. Below the surface lies well-rounded gravel that yields good water

B. FLAT NORTH OF THE YELLOWSTONE RIVER, NORTH OF FORSYTH, IN THE SW. ¼ SEC. 10, T. 6 N., R. 40 E.

A Pleistocene terrace formed by well-rounded gravel that yields good supplies of water a layer of light and dark red to purplish-red rock lies above the burned coal bed. The thickness and character of these red rocks obviously depend upon the mineralogic and geologic character of the original sediments and the degree of heat. Rogers[45] discussed the origin of these slags and concluded that the burning was started in the main by spontaneous combustion but that it may have originated in other ways. He described four well-recognized stages—baked rock, vitrified shale, glassy slag, and recrystallized slag. Zirkel[46] refers to this material, which occurs in numerous European coal fields and has been described as porzellanit and porzellanjaspis. After the coal is burned the overlying baked rock or slag settles, filling the space formerly occupied by the coal. By this movement the overlying red rock or clinker is invariably shattered and broken. Plate 8, *A*, shows a massive sandstone in the Tongue River member beneath which there has been no burning of coal, and Plate 8, *B*, shows sandstone of the same type characteristically shattered by the burning of underlying coal.

These red rocks are an extremely conspicuous feature and occur throughout the area of the Tongue River member. The thicker and more persistent ones make excellent key beds for working out structure and stratigraphy. The term "clinker" is often applied to these red strata, and they will hereafter be referred to by that name. Before considering the microscopic features of these red-clinker beds the petrologic character of the unaltered beds in the Tongue River member will be described.

The unburned Tongue River rocks are made up of angular grains consisting predominantly of strained quartz, rock fragments of igneous origin, and cherty quartzose fragments of probable sedimentary origin. The grains of igneous origin contain much glass, which has been highly altered. Orthoclase, plagioclase, muscovite, biotite, claylike material, and chlorite are also present, and in lesser amounts zircon and garnet. In general, thin sections of these rocks show considerably more secondary calcite than those from the Lance beds.

The bentonitic minerals, which are secondary after the glassy material in the sediments, are present in considerable amounts, but on the whole there is not so much of the leverrierite and the nontronite-like material as in the Lance formation. Most of the feldspar, especially the orthoclase, is greatly altered.

In a microscopic examination of the recrystallized slags Rogers[47] found that they contain diopside, basic plagioclase, magnetite, gar-

[45] Rogers, G. S., Baked Shale and Slag Formed by the Burning of Coal Beds: U. S. Geol. Survey Prof. Paper 108, pp. 1–10, 1917.

[46] Zirkel, Ferdinand, Lehrbuch der Petrographie, Band 3, pp. 75–76, 1894.

[47] Rogers, G. S., op. cit., p. 7.

net (probably almandite), hematite, and also probably clinoenstatite, cordierite, and spinel. In similar rocks in Wyoming Bastin [48] has identified oligoclase, pyroxene, and cordierite, as well as magnetite and hematite.

The rocks of the Tongue River member, because of their greater hardness, are conducive to a relatively smooth topography, as contrasted with the badland topography that characterizes the outcrop of the underlying Lebo shale. In the area of Tongue River rocks the erosion forms are controlled to a marked degree by the presence of the thick clinker beds, which are extremely resistant to erosion and form broad table-lands. In the region of lesser rainfall north of the Northern Cheyenne Indian Reservation the table-lands are dissected by broad steep-walled valleys or coulees, but in the southern part of the reservation, where there is more precipitation and consequently greater tree growth, the slopes are smoother although the topographic expression of the resistant clinker beds is nevertheless manifest. (See pls. 4, *B*, and 6, *B*.) There are no extensive clinker beds in the lower 300 feet of the Tongue River member, and in most places where this part of the member crops out the topography is undulating and fairly smooth, similar to that produced by beds higher in the section, where there is no clinker.

TERRACE GRAVEL

High-level terrace gravel occurs at different altitudes in numerous localities in this area. These gravel deposits are made up of well-rounded pebbles and cobbles in a matrix of fine sand and silt. The largest cobbles are about 1 foot in diameter, and many varieties of igneous, metamorphic, and sedimentary rocks are represented. (See pl. 9, *A*.)

In order to appreciate the significance in any given locality of the terraces on which the gravel was deposited, one must be familiar with the broader physiographic aspects of the northern Great Plains. These features have recently been described by Alden,[49] and the tentative correlations of the terraces, as suggested by him, have been accepted for this report.

OLDER GRAVEL

About 50 miles north of the international boundary, in Saskatchewan, is the broad plateau known as the Cypress Hills. These hills are covered with conglomerate as much as 50 feet thick, associated with cross-bedded sandstone, sand, clay, and marl, the thickness of

[48] Bastin, E. S., Note on Baked Clays and Natural Slags in Eastern Wyoming: Jour. Geology, vol. 13, pp. 408–412, 1905.

[49] Alden, W. C., Physiographic Development of the Northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 385–424, 1924.

the whole deposit aggregating 500 feet. These deposits have been studied by McConnell,[50] Cope,[51] Lambe,[52] Alden,[53] and others, and it seems well established that they were deposited by streams flowing eastward from the Rocky Mountains, which are 150 miles away. The vertebrate fossils collected from them indicate Oligocene or Miocene age. Alden [54] believes that the wide distribution of gravel at similar altitudes over Montana and North Dakota points to the former existence of a broad, gently eastward sloping alluvial plain, to which he gives the name Cypress Plain. Evidence is set forth by him indicating that the drainage at that time was probably northeastward to Hudson Bay rather than to the Mississippi River.

In Rosebud County, in Tps. 3 and 4 N., R. 39 E., and in the northeast corner of T. 4 N., R. 41 E., there are well-developed terrace-gravel deposits, the top of which, according to Dobbin,[55] is at an altitude of about 3,650 feet. The terraces on which they rest are the highest observed in the region and, according to Alden, are probably correlative with his Cypress Plain.

FLAXVILLE GRAVEL

Collier and Thom [56] have described another set of well-recognized terraces in the northern Great Plains which are below the level of the Cypress Plain as projected. The gravel on these terraces has been named Flaxville gravel. Regarding it they make the following statement: [57]

> The Flaxville gravel in Montana is from a few feet to 100 feet thick and is composed of well-rounded quartzite and argillite pebbles from the Rocky Mountains, sand, clay, and volcanic ash. It rests upon a series of plateaus cut on the Fort Union, Lance, and Bearpaw formations and ranging in altitude from 2,600 feet at the east to 3,200 feet at the west. Fragmentary fossils collected at 25 well-distributed localities were not good enough for specific determination, but it can be stated positively that the formation can not be older than Miocene nor younger than early Pliocene.

---

[50] McConnell, R. G., On the Cypress Hills, Wood Mountain, and Adjacent Country: Canada Geol. Survey Ann. Rept., new ser., vol. 1, pp. 1c–78c, 1886.

[51] Cope, E. D., The Vertebrata of the Swift Current Creek Region of the Cypress Hills: Canada Geol. Survey Ann. Rept., new ser., vol. 1, pp. 79c–85c; The Species from the Oligocene or Lower Miocene Beds of the Cypress Hills: Canada Geol. Survey Contr. Canadian Paleontology, vol. 3, pp. 1–25.

[52] Lambe, L. M., A New Species of *Hyracodon* (*H. priscidens*) from the Oligocene of the Cypress Hills, Assiniboia: Roy. Soc. Canada Proc. and Trans., 2d ser., vol. 11, sec. 4, pp. 37–42, 1906; Fossil Horses of the Oligocene of the Cypress Hills: Idem, pp. 43–52; Vertebrata of the Oligocene of the Cypress Hills, Saskatchewan: Canada Geol. Survey Contr. Paleontology, vol. 3, pt. 4, 1908.

[53] Alden, W. C., op. cit., pp. 389–395.

[54] Idem, pp. 392–395,

[55] Dobbin, C. E., oral communication.

[56] Collier, A. J., and Thom, W. T., jr., The Flaxville Gravel and Its Relation to Other Terrace Gravels of the Northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–183, 1917.

[57] Idem, p. 183.

Alden [58] has correlated the gravel on terraces at many other localities in Montana with the Flaxville gravel.

In central and southern Rosebud County there are no terraces that can be definitely assigned to the Flaxville Plain. However, most of the slopes between the supposed remnants of the Cypress Plain in Tps. 3 and 4 N., R. 39 E., and the uppermost well-developed Pleistocene terrace along the Yellowstone River (see pl. 10) are covered with well-rounded pebbles derived from the higher terrace, and the Flaxville gravel is doubtless represented by some of this material at intermediate altitudes. There are deposits of terrace gravel east and southeast of Rosebud Buttes in T. 5 N., R. 43 E., which are considerably lower than the highest gravel and yet well above the highest Pleistocene terrace. These may in part at least be correlative with the Flaxville gravel.

QUATERNARY SYSTEM

PLEISTOCENE TERRACE DEPOSITS

Along the Yellowstone River at altitudes of 150 to 350 feet above the river there are well-developed terraces younger than those just described. (See fig. 3.) The best preserved of these is about 200 feet above the river and forms the bench on both sides of the river in T. 6 N., R. 40 E., as well as Forsyth Flats in the northern part of T. 6 N., R. 41 E. (See pl. 10, *A*, and fig. 15.) An attempt was made to work out the sequence along the river, but it was found that in this area there is no sharp distinction between the terraces at different altitudes. The terraces about 200 feet above the river represent the second set of terraces described by Alden.[59] In connection with the geologic history of the Yellowstone River it is significant that no gravel deposits were observed north of the southern part of T. 7 N., but that south of the river gravel occurs as far as T. 3 N., R. 39 E. (See pl. 9, *A*.)

The maximum observed thickness of Pleistocene gravel is about 70 feet. At several places it has been cemented by carbonate and iron oxide to a hard conglomerate.

Where the terraces have not been greatly eroded they are covered with several inches to several feet of sandy loam devoid of cobbles or pebbles, and in several places on the south side of the Yellowstone River they slope about 1° toward the south away from the river. The southward slope of the surface is especially noticeable on the broad terrace in T. 6 N., R. 41 E., known as Forsyth Flats. These gentle slopes away from the river are suggestive of the former

[58] Alden, W. C., op. cit., pp. 401–403.
[59] Idem, pp. 409–411.

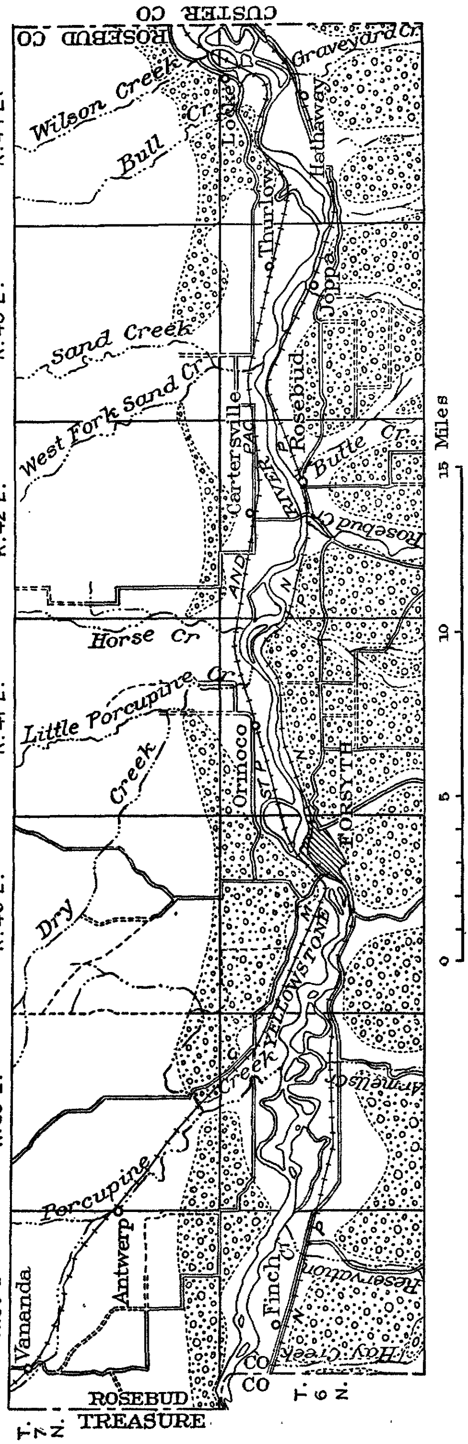


FIGURE 3.—Generalized map showing approximate distribution of Pleistocene terrace gravel along the Yellowstone River in Rosebud County

presence of a natural levee along the river near the northern limit of Forsyth Flats. In time of flood the river rose over this levee, covering the adjacent bottom lands to the south, Forsyth Flats, with a thin sheet of water. The present cover of sand and silt on top of the river gravel is the deposit left by many floods.

RECENT ALLUVIUM

The alluvium that is now being laid down in the channels of the streams and coulees is the latest material to be deposited in this area. These alluvial deposits have been mapped only along the Yellowstone and Tongue Rivers, but similar deposits occur along all the streams and their tributaries. (See pl. 9, *B*.)

Most of the alluvium consists of fine silt and sand, but at some places there is a considerable proportion of gravel. The character of the alluvium is largely dependent upon the type of material to which the stream has access. For example, in the northeast corner of the area, where the Lebo shale is the only accessible member, the alluvium is a dark-colored mud, with a small amount of sand and no gravel. Alluvium of the same type occurs in most places along Big Porcupine Creek, in the Porcupine dome, where this creek flows across the Colorado and Claggett shales. The alluvium along the Yellowstone River, however, contains a large amount of gravel, almost all the pebbles and cobbles of which are well rounded and are doubtless derived from the higher terrace gravel, whose material is also well rounded. (See pl. 9, *A*.)

In the southern part of Rosebud County there are no older terraces of well-rounded gravel. In this part of the county the only rocks are those of the Tongue River member, which contain a considerable amount of the erosion-resisting red clinker. The gravel lenses interbedded with the finer alluvium in this part, therefore, consist almost entirely of angular fragments of red clinker, with a small amount of sandstone and shale fragments, all derived from the near-by beds of the Tongue River member.

STRUCTURE

The geologic structure in central and southern Rosebud County is comparatively simple, and the strata are so well exposed that no difficulty is encountered in working out the structural features, which consist of relatively gentle folds and a few faults of slight displacement. (See fig. 4.)

FOLDS

Bull Mountain-Powder River syncline.—Extending across Rosebud County is a broad southeastward-pitching syncline, whose axis extends approximately from Ashland to the point where Rosebud, Big

Horn, and Treasure Counties meet. The beds dip toward the axis of this syncline at angles of less than 1°. This syncline belongs to the same structural basin as the Bull Mountain and Powder River synclines and connects them. (See fig. 4.)

Porcupine dome.—The Porcupine dome is the most pronounced structural feature in the region. The eastern part of the dome and the northern part, which is north of the area shown on Plate 1, have

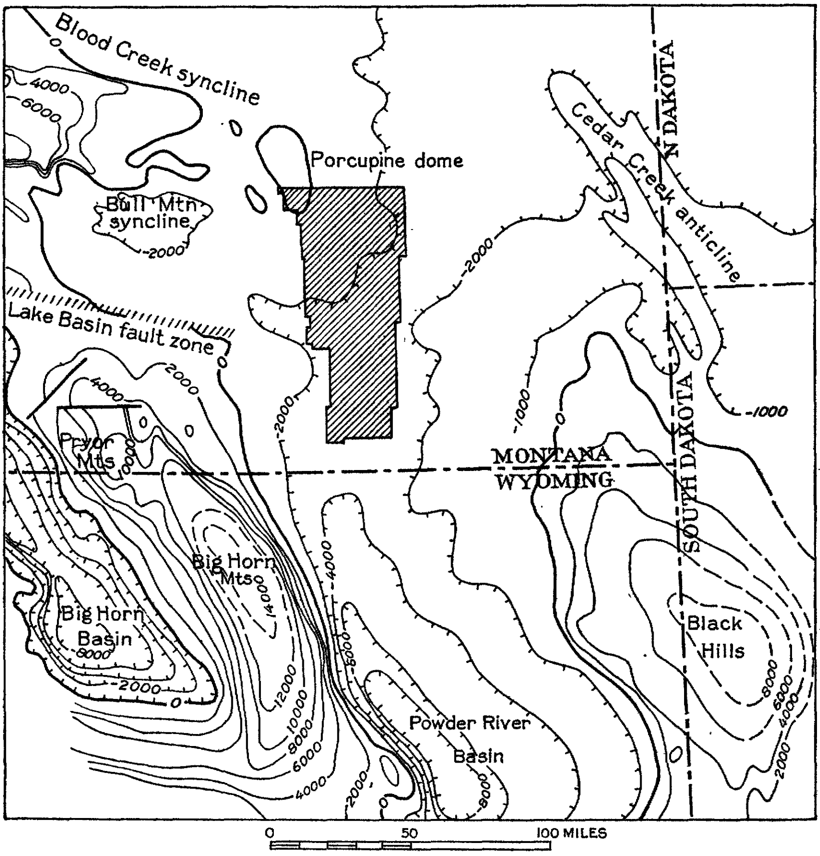


Figure 4.—Structural sketch map of the northern Great Plains and adjacent areas. Structure contours drawn on Dakota sandstone or on "First Cat Creek sand," datum sea level. (After Thom and Dobbin, op. cit., p. 482.) Area described in this report indicated by shading.

been mapped by Bowen,[60] and the southern and southwestern parts, which are within the area studied, have been mapped in less detail by the writer. A maximum dip of 10° was observed on the east limb in the northern part of T. 8 N., R. 40 E.; this dip decreases gradually to 2° on the nose, at the south, and to less than 1° on the west limb. (See pl. 1, section A–A.)

[60] Bowen, C. F., Possibilities of Oil in the Porcupine Dome, Rosebud County, Mont.: U. S. Geol. Survey Bull. 621, pp. 61–70, 1915.

Minor folds associated with the Porcupine dome.—Closely related orogenically to the Porcupine dome are several minor folds. The most conspicuous among them is a small fold, the north-south axis of which is about 2 miles west and southwest of Vananda. This fold has been referred to locally as the Vanada dome. Its east and west dips are less than 2°. In secs. 28 and 33, T. 7 N., R. 39 E., Big Porcupine Creek cuts across another fold which strikes about N. 23° E. This fold will be referred to as the Antwerp anticline, after the near-by railroad station of that name.

FAULTS

At several places on the south and west limbs of the Porcupine dome the rocks have been faulted. The maximum displacement observed on any of these fault planes is about 40 feet, and the strikes range from east-west to north-south. Dobbin [61] has mapped an area of northwest-striking faults west of Hopsonville. The amount of displacement is about the same in these faults as in those of the Porcupine dome.

AGE AND CAUSE OF THE DEFORMATION

The Fort Union strata are involved in the deformation of the Porcupine dome, a fact that clearly establishes the age of the uplift as later than Fort Union. It is very probable that the faults near Hopsonville originated during the same period of deformation. (See pl. 1.)

The structural features of Rosebud County are fundamentally related to other structural features throughout Montana. Thom,[62] in a recent paper, has discussed the origin of the structure in the central part of the State.

No igneous rocks were observed by the writer in the area studied, but basic dikes have been reported in and near the Porcupine dome north of T. 8 N. These are doubtless genetically related to the Porcupine uplift, and their presence lends support to Thom's hypothesis [63] that this dome, as well as the Big Snowy, Little Rocky, Moccasin, and Judith Mountains have resulted from the intrusion of igneous masses.

SUMMARY OF GEOLOGIC HISTORY

After the deposition of the fresh-water Kootenai formation, which is not exposed in this region but which is believed to be represented, there was a widespread and progressive submergence in Upper

[61] Dobbin, C. E., and Bass, N. W., op. cit.
[62] Thom, W. T., jr., The Relation of Deep-Seated Faults to the Surface Structural Features of Central Montana: Am. Assoc. Petroleum Geologists Bull., vol. 7, pp. 1–13, 1923.
[63] Idem, p. 7.

Cretaceous time, during which about 2,300 feet of Colorado shale was deposited. Bowen's description of the conditions of deposition of this shale member[64] follows:

> During the Colorado epoch great quantities of mud and silt were spread out over the floor of this epicontinental sea, and its waters teemed with life, the remains of which were in part entombed in the accumulating muds that now constitute the Colorado shale. The fine texture and homogeneous character of this shale and its freedom from notable amounts of sandy material, except perhaps near its base, indicate that it was laid down under uniform conditions. This implies that the relative elevations of land and sea must have remained nearly constant throughout the Colorado epoch. So the sea was filled to a depth of more than 2,300 feet by the accumulated mud, and as the land surface was necessarily lowered by the removal of this material, it seems necessary to infer that the relations between land and sea level could not have remained constant unless the sea floor was being gradually depressed at about the same rate as that at which the sediments accumulated.

After the Colorado epoch there was a gradual emergence of the western land mass, and near by to the west, as a result of this uplift, a considerable amount of sand was deposited. Little of this sand was transported as far as Rosebud County, and in consequence the horizon of the Eagle sandstone, the basal formation of the Montana group in central Montana, is scarcely recognizable here. The deposition of this sandstone was followed by another marine incursion in the early part of the Montana epoch, during which several hundred feet of mud was deposited forming the Claggett shale. Occasionally the waters cleared enough so that thin beds of calcium carbonate were laid down, and near the end of the Claggett epoch there was another emergence of the land mass to the west, during which coarse material was transported into this epicontinental Montana sea. Evidence of this last epigenetic movement is furnished by the sand in the upper part of the Claggett formation.

During the deposition of the sediments of the succeeding Judith River formation in this area there were gentle oscillations of the sea level caused by recurring emergences of the western land mass, as shown by the two well-marked sandstone members within this 300 feet of sediments.

The deposition of the Judith River beds was followed by another progressive marine submergence, during which mud with a small amount of carbonaceous material was deposited, forming the 950 feet of Bearpaw shale, which is the topmost formation of the Montana group of central Montana, and which records the last marine incursion into this part of North America.

There is no record of any orogenic disturbance at the end of the Bearpaw epoch, but gradual emergence followed, resulting in the

[64] Bowen, C. F., Gradations from Continental to Marine Conditions of Deposition in Central Montana during the Eagle and Judith River Epochs: U. S. Geol. Survey Prof. Paper 125, p. 19, 1921.

formation of broad epicontinental bodies of fresh water in which were deposited the sediments of the Lance formation. At this time there existed a rather delicate balance between water and land conditions. At times, especially during the deposition of the upper beds of the Lance formation, there were broad swamps and lowlands that supported luxuriant forests, which resulted in the formation of the thin beds of lignite in the Tullock member of the Lance. Much of the sediment, especially in the lower or Hell Creek member, probably represents ancient delta deposits across which flowed rivers that cut channels at least 50 feet deep. At many places have been found the remains of the land animals which lived at this time, the most impressive of which are the large dinosaurs. During the accumulation of the Lance beds the basin in which they were being deposited gradually sank until the total thickness of these beds was about 925 feet.

The beginning of Fort Union time was marked by the deposition of the Lebo shale member. This member contains a considerable amount of black shale, which in all probability was deposited in shallow water, and also, like many other shallow-water black shales, considerable sandstone. In Rosebud County the shale is nonmarine, but Thom and Dobbin[65] have shown that part of it grades eastward into marine beds. It is probable that the conditions of deposition during the accumulation of the Lebo shale were somewhat similar to those in the Baltic Sea described by Twenhofel,[66] who has reviewed the several theories of deposition of marine and nonmarine black shales. The organic material accumulated in place, and the inorganic material, particularly the arkosic sands in both the Lebo and the overlying Tongue River member, came from the rising Rocky Mountains to the west.

The end of Lebo time was marked by the beginning of accumulation of the light-colored sediments of the Tongue River member, the conditions being somewhat similar to those during Lance time, except that during certain stages of deposition of the Tongue River member swamp conditions prevailed for much longer periods than in the Lance, as indicated by the rather common occurrence of lignite beds that are as much as 10 feet thick and at a few places more than 30 feet. Although there were long periods of relative stability the diastrophic movement recorded throughout the Tongue River epoch was one of gradual depression, with compensating deposition.

A petrographic examination of the coarser-grained rocks, the sandstones, in the Judith River, Lance, and Fort Union formations reveals no noticeable difference in texture or mineralogic character and

[65] Thom, W. T., jr., and Dobbin, C. E., op. cit.

[66] Twenhofel, W. H., Notes on Black Shale in the Making: Am. Jour. Sci., 4th ser., vol. 40, pp. 272–278, 1915.

thus bears out the conclusion of Bowen[67] that the material of all these formations is from the same source, doubtless a large land mass to the west. Most of the material in these sandstones is derived from igneous rocks.

After the deposition of the sediments of the Tongue River member, which are now represented by at least 1,680 feet of strata, the sea receded, and these rocks became subject to erosion. Some time after their deposition and probably coincident with their emergence, the rocks were subjected to diastrophic movements, probably caused largely by the upward migration of subcrustal igneous masses. At this time the Porcupine dome and its related minor folds, the Ingomar dome and Antwerp anticline, were formed. At the same time the rocks throughout the country were very slightly wrinkled, and a large syncline oriented in a northwest-southeast direction was developed. In all probability the faulting around the margin of the Porcupine dome and in the vicinity of Hopsonville took place during this time of diastrophism.

The former course of at least one stream across this region subsequent to the uplift that followed Fort Union time is recorded by the older terrace gravel. Small fragments of clinker in the oldest terraces indicate that soon after the exposure of the Fort Union beds some of the coals burned along their outcrop. Uplift of several hundred feet followed, and, in consequence, the streams deepened and broadened their valleys. During late Miocene or early Pliocene time rivers flowing eastward from the mountains deposited the Flaxville gravel on a plain above which stood high land forms such as the Wolf Mountains.

The early Pleistocene extensions of the Keewatin ice sheet did not reach as far southwest as Rosebud County.[68] They did, however, invade what is believed to have been the lower part of the original valley of the upper Missouri River. The Yellowstone River was tributary to the Missouri when it flowed northeastward to Hudson Bay. The combined waters of the two streams were diverted to the present course of the Missouri River through the Dakotas by the early Pleistocene ice of the Keewatin glacier.

During Pleistocene time there was another uplift in consequence of which the Yellowstone River again deepened its valley, this time to levels 400 to 500 feet below the Flaxville gravel. This Yellowstone River of Pleistocene time flowed across Rosebud County, following much the same course that it does now. A third uplift resulted in leaving the well-developed Pleistocene terraces 150 to 350 feet above the river. Since the formation of the youngest of these

[67] Bowen, C. F., op. cit., pp. 18–19.
[68] Alden, W. C., Physiographic Development of the Northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 408–409, 1924.

terraces the Yellowstone River has deepened its channel in Rosebud County 150 feet or more. By tracing these Pleistocene terraces along the Yellowstone northwestward to Glacier National Park Alden[69] has found them to be of pre-Wisconsin age.

Because of the readiness with which the comparatively soft Cretaceous and Tertiary strata in this county are eroded and the general sparseness of vegetation over most of the area, the tributary coulees as well as the main streams are choked with Recent alluvium.

OCCURRENCE AND MOVEMENT OF GROUND WATER

This section of this report is concerned with the water that supplies springs and wells, which is known as ground water.

The fundamental principles pertaining to the occurrence of ground water and the definitions of ground-water terms have been presented in some detail in two reports by Meinzer.[70] Only a few of the essential facts will be outlined here.

Doubtless nearly all the ground water in the Montana group (Upper Cretaceous) and in the overlying younger beds that were examined is of meteoric origin—that is, it is derived from rain and snow water that has seeped down to the zone of saturation; some of the water in the Kootenai (?) formation (Lower Cretaceous) may be connate or fossil sea water—that is, water which was included in the sediments at the time they were deposited.

A part of the water that enters the ground sinks to a level below which all the pores and cracks are filled with water. This level is commonly called the water table, and the water in the saturated zone below is called ground water. The water table is seldom stationary but is generally moving slowly up or down as a result of variations in rainfall, evaporation, and other climatic conditions. During or after heavy precipitation or melting of snow it rises, and during dry and hot seasons it usually lowers; hence the variations in the level of water in wells and in the flow of springs.

Regarding the forces controlling the movement of water in rocks, Meinzer[71] has said:

> The two principal forces that control the water in the rocks are gravity and molecular attraction. Gravity is the force that causes the water to percolate from the surface deep into the earth and thence to percolate laterally for long distances. It is the principal force that causes the water to seep out of the earth in low places, to flow from springs, or to enter wells, and to issue from flowing wells. This force acts in a system of rocks with interstices very much

[69] Alden, W. C., op. cit., p. 414.

[70] Meinzer, O. E., The Occurrence of Ground Water in the United States, with a Discussion of Principles: U. S. Geol. Survey Water-Supply Paper 489, 1923; Outline of Ground-Water Hydrology: U. S. Geol. Survey Water-Supply Paper 494, 1923.

[71] Meinzer, O. E., The Occurrence of Ground Water in the United States, with a Discussion of Principles: U. S. Geol. Survey Water-Supply Paper 489, pp. 18–19, 1923.

as it does in a system of waterworks with standpipe, mains, and service connections.

In rocks having only large openings comparable to the mains and service pipes of a system of waterworks gravity is the controlling force, and the ordinary laws of hydraulics apply without much modification. But many rocks have very small interstices, and in these another force becomes very effective. This is the force of molecular attraction—the attraction of the walls of the interstices for the adjacent molecules of water and the attraction of the molecules of water for one another. The relative importance of this force is the most significant fact in the behavior of water in rocks; it is the condition which makes the hydraulics of this water a distinctive subject.

PHYSICAL PROPERTIES OF THE ROCKS

Samples were collected from the outcrops of the water-bearing and non water-bearing strata in Rosebud County and sent to the hydrologic laboratory of the Geological Survey, where they were tested by Norah Dowell Stearns, who, in addition to making mechanical analyses of the samples, determined, so far as practicable, their porosity, moisture equivalent, and permeability.[72] The results of the tests for these physical properties are given in the table below. In this table the term "apparent specific gravity" means the specific gravity of the material tested, including the pore space, not the specific gravity of the constituent grains; the 10 per cent size, often called the effective size, is the diameter of a grain that is just larger than 10 per cent of the material; the uniformity coefficient is the ratio of the 10 per cent size to the 60 per cent size; the moisture equivalent is the quantity of water that remains in a sample after it has been saturated and then centrifuged at one thousand times gravity (here expressed in per cent of the total volume of the sample); the coefficient of permeability is the rate at which water percolates through the material, expressed in gallons a day through each square foot of the cross section under a head of 1 foot for each foot the water percolates.

---

[72] Stearns, N. D., Laboratory Tests on Physical Properties of Water-Bearing Materials: U. S. Geol. Survey Water-Supply Paper 596, pp. 121–176, 1927.

Physical properties of rock materials from Rosebud County, Mont.

[By Norah Dowell Stearns]

No.	Apparent specific gravity of oven-dry sample	Mechanical composition (per cent)									10 per cent size (millimeter)	Uniformity coefficient	Porosity (per cent)	Moisture equivalent (per cent by volume)	Porosity minus moisture equivalent by volume	Coefficient of permeability
		>5 millimeters	5–2 millimeters	2–1 millimeters	1–0.5 millimeter	0.5–0.25 millimeter	0.25–0.10 millimeter	0.10–0.05 millimeter	Silt 0.05–0.005 millimeter	Clay <0.005 millimeter						
P-38	1.36		3.92	0.43	0.66	2.31	18.57	49.61	18.58	5.93	0.02	4.0	49.9	17.6	32.3	[a] 0.55
P-42	1.36	76.33	8.03	1.99	1.44	1.57	5.14	3.03	2.18	.28	.20	>25	29.3			68
P-70	2.19	62.94	11.85	2.86	.86	5.07	13.32	2.22	.45	.42			20.2			827
P-37	1.99	73.27	7.07	.62	.20	4.36	10.57	2.68	.86	.37	.19	>26	24.1			53
P-63	2.02	66.02	6.79	12.76	2.58	1.93	2.98	.86	3.41	2.67			27.1			856
P-65	2.04	82.90	5.77	.58	.49	1.92	5.35	1.17	1.52	.31	.55	>9	25.1			120
P-68	2.05	78.22	2.17	2.07	6.56	8.62	1.25	.22	.76	.13	.55	>9	23.6			1,233
P-31	1.71				.44	1.72	78.27	10.68	8.13	.76	.06	3.1	36.6	12.1	24.5	
P-32	1.85					.23	50.97	31.82	12.61	4.36	.03	3.7	31.6	16.8	14.8	
P-49	1.82				1.51	7.86	75.67	5.70	9.26		.06	3.5	30.7	13.1	17.6	
P-50	1.87				5.34	9.60	52.82	23.99	7.97	.29	.06	3.3	30.6	10.8	19.8	
P-51	2.19			9.02	9.69	16.29	32.54	20.79	5.49	6.18	.05	4.6	19.1	16.1	3.0	
P-52	2.50		3.40	9.87	15.97	12.64	24.33	20.29	7.15	6.36	.04	8.6	9.4	20.5		
P-54	2.06					.30	.17	1.76	46.99	50.79	<.005	>2.6	23.5	76.7		
P-55	1.81			.22	.67	8.51	76.78	9.53	3.58	.71	.08	2.5	32.9	8.4	24.5	132
P-56	1.67				.49	.58	.82	4.80	36.09	57.21	<.005	<1.0	36.9	41.8		
P-57	1.84				.36	1.45	6.04	64.99	14.04	13.13	<.005	>14	31.4	27.7	3.7	
P-58	1.27						1.01	58.23	15.07	25.69	<.005	>12	53.6	76.4		Imperm.
P-59	1.79					.42	7.62	64.37	24.96	2.64	.02	3.8	34.9	21.5	13.4	13
P-36	1.91						2.23	28.03	42.97	26.77	<.005	>7.8	26.2	122		
P-60	2.07						1.70	4.96	32.16	61.17	<.005	<1.0	21.2	124		
P-66	1.93				.52	.84	44.34	13.14	17.30	23.85	<.005	>22	27.7	172		
P-35	1.65					.38	6.13	8.86	54.57	30.07	<.005	>6	40.1	52.5		
P-48	2.00				.75	1.66	8.69	42.17	37.75	8.98	.006	10.0	26.7	41.7		
P-53	1.73				.21	1.41	35.17	47.55	8.45	7.21	.03	2.9	36.6	61.9		
P-61	1.92						3.51	9.92	51.17	35.40	<.005	>5.6	29.8	72.0		
P-64	1.73					44.84	42.62	1.33	11.21		<.05	>5.7	34.0	10.7	23.3	77
P-30	2.08			13.74	24.77	14.08	21.74	15.02	8.73	1.92	.05	9.1	24.8	21	3.3	
P-33	1.72				.42	6.48	87.40	3.28	2.42		.10	2.0	36.1	6.4	29.7	
P-34	1.66				3.05	8.39	80.25	5.69	2.62		.09	2.1	38.3	5.7	32.6	236
P-45	1.73				1.52	40.69	50.46	2.61	4.71		.10	2.8	35.2	11.4	23.8	314
P-62	1.80				.65	2.14	59.50	29.00	8.70		.05	2.5	32.8	10.8	22.0	
P-28	1.72				1.34	4.86	42.04	41.60	9.68	.48	.05	2.1	36.7	16.3	20.4	31
P-44	1.72					.51	53.24	38.02	8.23		.05	2.0	38.4	17.9	20.5	
P-46	1.87				.77	3.52	19.91	60.74	12.85	2.20	.03	2.5	30.8	19.5	11.3	
P-47	2.01					.54	1.03	8.02	75.84	14.57	<.005	>6.4	27.4	52.5		
P-67	1.54					.94	54.90	37.96	6.19		.07	1.9	43.0	11.7	31.3	[b] 14
P-39	1.57				.25	1.57	13.50	11.37	53.94	19.37	<.005	>7.8	41.1	85.2		
P-40	1.54				.50	1.45	12.50	49.79	29.60	6.16	.01	7.0	44.8	39.2	12.1	
P-29	1.78				.38	2.60	44.30	46.69	5.57	.46	.05	2.1	32.3	13.0	19.3	
P-69	1.73				.45	14.94	75.75	1.78	7.08		.09	2.2	33.2	7.6	25.6	134
P-43	1.91				1.12	9.09	82.57	1.44	4.94	.84	.10	2.1	51.2	11	40.1	13
P-41	1.81			8.00	9.73	7.57	10.64	17.08	36.93	10.04	.005	15	36.3	48.6		

[a] Volumetric sample, compacted too much; coefficient probably too small.

[b] Volumetric sample, compacted too little; coefficient probably too large.

P-38. Center of sec. 22, T. 2 S., R. 44 E. Alluvium silt from Tongue River. Quaternary. Recent.

P-42. Center of sec. 22, T. 2 S., R. 44 E. Alluvium gravel from Tongue River. Consists mostly of clinkered shale and sandstone in matrix of sand and silt. Gravel lenses in silt. Quaternary. Recent.

P-70. NW. ¼ NW. ¼ sec. 23, T. 6 N., R. 40 E. Alluvium from gravel bar in Yellowstone River. Quaternary. Recent.

P-37. SW. ¼ sec. 21, T. 6 N., R. 42 E. Terrace gravel. Quaternary. Pleistocene (?).

P-63. Center of sec. 4, T. 6 N., R. 44 E. Terrace gravel. Quaternary. Pleistocene (?).

P-65. SE. ¼ sec. 14, T. 6 N., R. 42 E. Terrace gravel which covers top of terrace between Sweeney and Rosebud Creeks. Quaternary. Pleistocene (?).

P-68. NE. ¼ sec. 19, T. 6 N., R. 41 E. Terrace gravel from top bench. Quaternary. Pleistocene (?).

P-31. NW. ¼ sec. 24, T. 3 N., R. 41 E. On Burleigh ranch. Lenticular, grading into shale at places. Gives rise to a never-failing spring. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-32. NW. ¼ SW. ¼ sec. 4, T. 2 N., R. 39 E. Sandstone from Fort Union formation below first clinker and above Lebo shale member. These sandstone beds yield good water in this locality. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-49. NE. ¼ sec. 6, T. 2 S., R. 41 E. Sandstone about 75 feet below the Rosebud coal. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-50. NW. ¼ sec. 33, T. 2 N., R. 43 E. Within lower 75 feet of formation. Grades from coherent massive sandstone with concretionary beds to slightly cemented sand. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-51. SW. ¼ sec. 29, T. 6 S., R. 43 E. Typical of massive sandstone members above the Rosebud coal. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-52. NW. ¼ sec. 21, T. 7 S., R. 44 E. Typical massive sandstone above Rosebud coal. From horizon of massive sandstone above first large lavender clinker bed and below the second large clinker bed that forms top of plateau. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-54. NE. ¼ NE. ¼ sec. 16, T. 5 S., R. 43 E. Typical arenaceous shale above Rosebud coal. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-55. NW. ¼ NW. ¼ sec. 32, T. 5 N., R. 43 E. Sand below the first clinker and above the Lebo shale member. Water bearing. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-56. SW. ¼ sec. 34, T. 1 S., R. 41 E. Typical light-colored shale of Fort Union formation, about 75 feet below clinker of Rosebud coal. Interbedded with massive sandstone. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-57. NW. ¼ sec. 29, T. 6 S., R. 43 E. Typical sandy silt of Fort Union formation of the region above Rosebud coal. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-58. SW. ¼ sec. 30, T. 5 S., R. 43 E. Typical sandy silt of Fort Union formation of the region above Rosebud coal. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-59. SW. ¼ sec. 16, T. 1 S., R. 44 E. Typical sand of Fort Union formation above Rosebud coal. Grades into cemented sand which weathers easily. Tertiary. Fort Union formation (Eocene), Tongue River member.

P-36. NE. ¼ sec. 28, T. 2 N., R. 43 E. From light-colored beds of Lebo member. Tertiary. Fort Union formation, Lebo shale member.

P-60. SW. ¼ sec. 2, T. 8 N., R. 44 E. Black shale from lower part of Lebo member. Tertiary. Fort Union formation, Lebo shale member.

P-66. NW. ¼ sec. 34, T. 8 N., R. 42 E. Sandstone from Lebo member. Tertiary. Fort Union formation, Lebo shale member.

P-35. NW. ¼ sec. 29, T. 7 N., R. 44 E. Non water-bearing shale of Lance formation which is identical in appearance with Lebo shale member of Fort Union formation. Tertiary (?). Lance formation, Tullock member.

P-48. SE. ¼ sec. 31, T. 4 N., R. 43 E. Massive sandstone at top of Tullock member. Tertiary (?). Lance formation, Tullock member.

P-53. SE. ¼ sec. 35, T. 7 N., R. 44 E. Typical of much of upper part of Lance formation. Tertiary (?). Lance formation, Tullock member.

P-61. Center of sec. 4, T. 6 N., R. 44 E. Shale. Mineralization is characteristic of much of this shale. Tertiary (?). Lance formation, Tullock member.

P-64. NE. ¼ sec. 6, T. 6 N., R. 44 E. Slightly indurated cross-bedded sandstone from top of Tullock member. Tertiary (?). Lance formation, Tullock member.

P-30. NE. ¼ sec. 7, T. 5 N., R. 41 E. On Kenealey ranch. Contributes water to spring. Lenticular. Tertiary (?). Lance formation, Hell Creek member.

P-33. NW. ¼ sec. 26, T. 6 N., R. 39 E. Basal sandstone. Tertiary (?). Lance formation, Hell Creek member.

P-34. NW. ¼ sec. 20, T. 6 N., R. 41 E. Sandstone. Tertiary (?). Lance formation, Hell Creek member.

P-45. SE. ¼ sec. 15, T. 6 N., R. 40 E. Sandstone. Tertiary (?). Lance formation, Hell Creek member.

P-62. NE. ¼ sec. 29, T. 6 N., R. 40 E. Typical sandstone. Tertiary (?). Lance formation, Hell Creek member.

P-28. SW. ¼ sec. 24, T. 6 N., R. 44 E. Incoherent sandstone. Good aquifer. Tertiary (?). Lance formation.

P-44. SW. ¼ sec. 22, T. 5 N., R. 42 E. Sandstone at base of coal series. Aquifer. Tertiary (?). Lance formation.

P-46. NE. ¼ sec. 12, T. 4 N., R. 42 E. Sandstone, interbedded with shale, No. 47. Tertiary (?). Lance formation.

P-47. NE. ¼ sec. 12, T. 4 N., R. 42 E. Shale interbedded with sandstone, No. 46. Tertiary (?). Lance formation.

P-67. South end Tenth Street, Forsyth. Lance quicksand. Tertiary (?). Lance formation.

P-39. SW. ¼ sec. 5, T. 6 N., R. 39 E. Shale. Upper Cretaceous. Bearpaw shale.

P-40. SW. ¼ sec. 17, T. 7 N., R. 44 E. Sandy shale in upper 75 feet of Judith River formation. Upper Cretaceous. Judith River formation, upper sandstone.

P-29. SE. ¼ sec. 6, T. 8 N., R. 38 E. Basal sandstone. Loosely coherent. Upper Cretaceous. Judith River formation, lower sandstone.

P-69. SW. ¼ sec. 5, T. 7 N., R 38 E. Tower sandstone. Very incoherent. Upper Cretaceous. Judith River formation, lower sandstone.

P-43. SW. ¼ SW. ¼ sec. 33, T. 8 N., R. 38 E. Sandstone. Upper Cretaceous. Judith River formation.

P-41. NW. ¼ sec. 26, T. 8 N., R. 38 E. Shale, fractured easily. Fractures filled with gypsum. Upper Cretaceous. Claggett shale.

Other things being equal, the best water-bearing materials have the smallest amounts of clay and silt, the largest 10 per cent size, the smallest uniformity coefficients, the largest porosities, the smallest moisture equivalents, and the largest coefficients of permeability. Material that has a 10 per cent size of less than 0.05 millimeter will yield water very slowly or be entirely worthless for water supply. Material whose moisture equivalent is nearly as great or greater than the porosity is likely to yield no water. Further discussion of some of the data given in the table will be found under "Water-bearing properties of the different formations," pages 52 to 61.

ARTESIAN CONDITIONS

GENERAL PRINCIPLES

The conditions governing artesian wells are discussed in numerous reports of the United States Geological Survey and State surveys and in most textbooks of geology.[73]

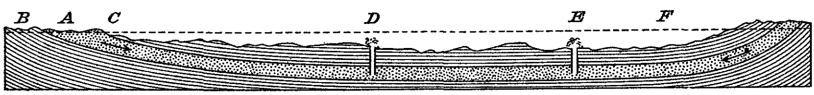


FIGURE 5.—Ideal section illustrating the chief requisite conditions for artesian wells. A, Permeable bed; B, C, impermeable beds below and above A; D, E, flowing wells from bed A. (After Chamberlin)

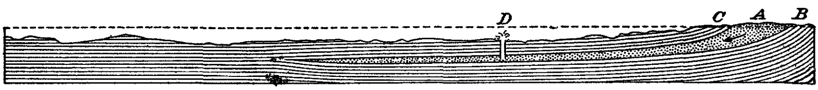


FIGURE 6.—Section illustrating the thinning out of a permeable water-bearing bed. A, Permeable bed inclosed between impermeable beds B and C, thus furnishing the necessary conditions for artesian fountain D. (After Chamberlin)

FIGURE 7.—Section illustrating the transition from a permeable water-bearing bed (A) into a close-textured impermeable bed. Bed A, being inclosed between impermeable beds B and C, furnishes the conditions for artesian flow D. (After Chamberlin)

In order to obtain an artesian flow it is necessary to have a permeable stratum which permits the passage of water, with an impervious or water-tight stratum above and below in order to prevent the escape of the water. Moreover, these beds must lie in such a position that water will enter the permeable bed at a considerable height above the mouth of the well. The necessary height depends upon the horizontal distance between the intake area and the well,

---

[73] See especially the following: Norton, W. H., Artesian Wells of Iowa: Iowa Geol. Survey, vol. 6, pp. 122–128, 1897. Chamberlin, T. C., Requisite and Qualifying Conditions of Artesian Wells: U. S. Geol. Survey Fifth Ann. Rept., pp. 131–173, 1885. Fuller, M. L., Summary of the Controlling Factors of Artesian Flows: U. S. Geol. Survey Bull. 319. 1908.

because there is a considerable decrease in head due to frictional resistance as the water percolates laterally through the permeable stratum. These principles of artesian flow are illustrated by Figures 5–7.

ARTESIAN WATER IN THE LANCE AND FORT UNION FORMATIONS

The Lance and Fort Union formations supply the water to all the flowing wells that were found in Rosebud County at the time this survey was made. An inspection of the cross sections in Plate 1 and Figure 8 shows that the conditions necessary for artesian flows exist along the flood plain of the Yellowstone River in this county, where the rocks dip eastward and southeastward away from the Porcupine dome. This dip slope forms the west flank of a large syncline, whose center is near Miles City, Mont., and whose east flank merges into the Cedar Creek anticline near Glendive, Mont. In this syncline flowing wells have been obtained along the flood plain of the Yellowstone River from a point a few miles east of Forsyth approximately to Fallon, and also along several of the tributaries to the Yellowstone, including the Tongue River, the Powder River, and O'Fallon Creek.

The water that flows from the basal sandstone of the Lance formation has been confined between the impermeable underlying Bearpaw shale and an impermeable shale stratum higher in the Lance; for the more or less lenticular beds of sandstone in the Lance formation (see pl. 4, *A*) the confining beds are shales within the formation.

The maximum artesian head in Rosebud County in 1923 was 18 feet at the surface, observed in a flowing well beside the Yellowstone River 3 miles east of Carterville. The mouth of this well is about 300 feet lower than the outcrop of the bottom of the Lance formation. The well is supplied from the basal sandstone of the Lance, which here lies about 500 feet below the surface of the area that furnishes the artesian water. As the well is about 15 miles from the outcrop the hydraulic gradient is about 20 feet to the mile. The loss in

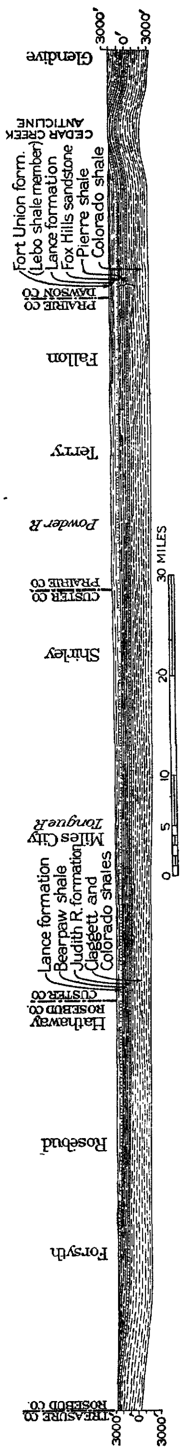


FIGURE 8.—Geologic cross section showing structure of the artesian basin along the Yellowstone River in Rosebud, Custer, Prairie, and Dawson Counties

head can be accounted for by the frictional resistance to flow of the water in the sandstone. Calculations show that the lifting power of the gas liberated from the water in the wells is negligible. The maximum gas content of the samples analyzed is only about 65 cubic centimeters per liter. (See p. 44.)

Flowing wells are obtained from the sandstones in the Tongue River member of the Fort Union formation along the Tongue River in the vicinity of Ashland and north of Brandenburg. This region is within the southeastward-pitching syncline that connects the Bull Mountain and Powder River synclines. (See fig. 4.) A well in the NW. ¼ sec. 8, T. 1 N., R. 43 E., along Rosebud Creek, ending in the Tongue River member, has a small flow.

At many places outside of these two well-defined basins the water comes within a few feet of the surface, this being especially along Rosebud and Armells Creeks.

Drillers fail to obtain a flow at many places where flowing wells would be expected. The cause of these failures is not always apparent, but in certain wells the failure has been due to defective construction. (See p. 50.)

ARTESIAN WATER IN THE CRETACEOUS ROCKS

Small flows of water have been obtained from certain sandstones in the Cretaceous rocks in drilling for oil, but these waters are highly mineralized and have not been utilized. Henry Schleuter, in prospecting for oil in the SW.¼ sec. 6, T. 6 N., R. 43 E., reported a small flow of salt water at 1,500 feet. This seems to have been encountered in a sandstone in the Judith River formation.

At the time the field study of the region was carried on there were no flowing wells deriving their water from the sandstones of the Kootenai (?) formation, the lowermost Cretaceous formation recognized, but artesian flows would be expected from this formation in the flood plain of the Yellowstone River in the central and eastern parts of the county. Such water would probably be highly mineralized. In the well 3,357 feet deep at Vananda (see p. 72) the water came within 50 feet of the surface.

QUALITY OF THE GROUND WATER

GENERAL CHARACTERISTICS

The chemical characteristics of the ground waters in Rosebud County, especially the waters in the Lance and Fort Union formations, have already been considered by the author in two papers[74] that deal mostly with the mode of origin of waters of these types.

[74] Renick, B. C., Base Exchange in Ground Water by Silicates, as Illustrated in Montana: U. S. Geol. Water-Supply Paper 520, pp. 53–71, 1925; Some Geochemical Relations of Ground Water and Associated Natural Gas in the Lance Formation, Montana: Jour. Geology, vol. 32, pp. 668–684, 1924.

Riffenburg, in a later paper,[75] has summarized the chemical data regarding ground waters in Montana and North Dakota. In the present paper the chemical character of the water in each formation is described. (See pp. 52 to 61.)

The waters in Rosebud County have as their principal dissolved constituents the basic radicles calcium, magnesium, sodium, and some potassium and the acid radicles sulphate, bicarbonate, carbonate, chloride, and some nitrate. The rocks through which the waters move contain varying proportions of these constituents, and the amount of the several constituents in the ground water depends upon the formation and the depth from which the water comes.

In this region the rocks that are of fresh-water origin (Lance and Fort Union formations, terrace gravel, and Recent alluvium) yield potable water, whereas the rocks of marine origin (Colorado, Claggett, Judith River, and Bearpaw formations, with the exception of the sandstones in the Judith River formation under certain conditions), generally yield highly mineralized nonpotable water. The high mineralization of most of the waters in the marine Cretaceous beds is probably due to the presence of some original sea water that was included within the sediments when they were deposited, or to salts that were deposited by the evaporation of sea water when the beds were laid down and have since been dissolved by the circulation of meteoric ground water.

CHANGES IN CHEMICAL CHARACTER DUE TO BASE EXCHANGE

In descending from the water table to deeper levels the ground water in this region undergoes certain changes. Because of these changes there is a considerable variation in the quality of water in near-by wells that extend to different depths in the same or in different formations. Field studies showed that in the areas of Lance and Fort Union strata the ground water near the surface is hard, while that at a somewhat greater depth is soft. With the aid of the chemical analyses of the waters made by Riffenburg it was possible to work out the depth relations requisite for this softening. Of the 20 waters from the Lance formation that were given special study those from wells less than 125 feet deep contain a maximum of 162 parts per million of calcium and magnesium and a minimum of 43 parts per million, whereas those from wells more than 125 feet deep contain a maximum of 18.1 parts per million of calcium and magnesium and a minimum of 5.2 parts per million. Of the 10 waters from the Fort Union formation that were given special study, those from wells less than 75 feet deep contain a maximum of 212 parts per

[75] Riffenburg, H. B., Chemical Character of Ground Waters of the Northern Great Plains: U. S. Geol. Survey Water-Supply Paper 560, pp. 31–52, 1925.

million of calcium and magnesium and a minimum of 99 parts per million, whereas those from wells more than 75 feet deep contain a maximum of 23 parts per million of calcium and magnesium and a minimum of 5.2 parts per million. In general there is no marked difference in the total dissolved solids in the waters from different depths but only in the kind of solids. As the water percolates to greater depths it exchanges its calcium and magnesium, which make the water hard, for sodium, which is not a hardening constituent. The conclusion as to the origin of the soft waters given in this paper has been arrived at entirely from a study of data obtained from the Lance (Tertiary?) and Fort Union (Tertiary) formations. In all probability a similar exchange of bases with increasing depth has also taken place in the underlying Upper Cretaceous beds in this region, but data sufficient to establish this point are not available.

CHANGES IN CHEMICAL CHARACTER INVOLVING ACID RADICLES

A study of the analyses of the waters in Rosebud County, especially those from the Lance and Fort Union formations, brings out the fact that certain waters contain a considerable quantity of sulphate and that others do not. Nearly all of the waters from flowing wells carry gases, some of which burn readily. A study of the water and gas analyses from 10 representative wells in the Lance formation showed that there is a relation between certain of the acid radicles and the included gases.[76] (See p. 44 and fig. 9.)

At each of the 10 wells examined two samples of the gas-bearing waters were collected. The container used was a 1-pint magnesium citrate bottle with porcelain stopper and rubber gasket. The bottles were filled rapidly, about 1 cubic centimeter of free air space being left to allow for changes in temperature, the stopper was quickly clamped down, and the temperature of the water at the time of collection was recorded.

The apparatus ordinarily used in the laboratory for gas analysis is intricate and requires expert technique for its proper manipulation, but Messrs. Jones, Yant, and Buxton,[77] of the United States Bureau of Mines, have designed and described a simple field apparatus, which does not require the services of an experienced gas chemist, for determining the gas content of ground waters.

[76] Renick, B. C., Some Geochemical Relations of Ground Water and Associated Natural Gas in the Lance Formation, Montana: Jour. Geology, vol. 32, pp. 668–685, 1924.

[77] Jones, G. W., Yant, W. P., and Buxton, E. P., Gaseous Content of Ground Waters as an Aid to the Petroleum and Natural Gas Prospector: U. S. Bur. Mines Serial 2553, 1923.

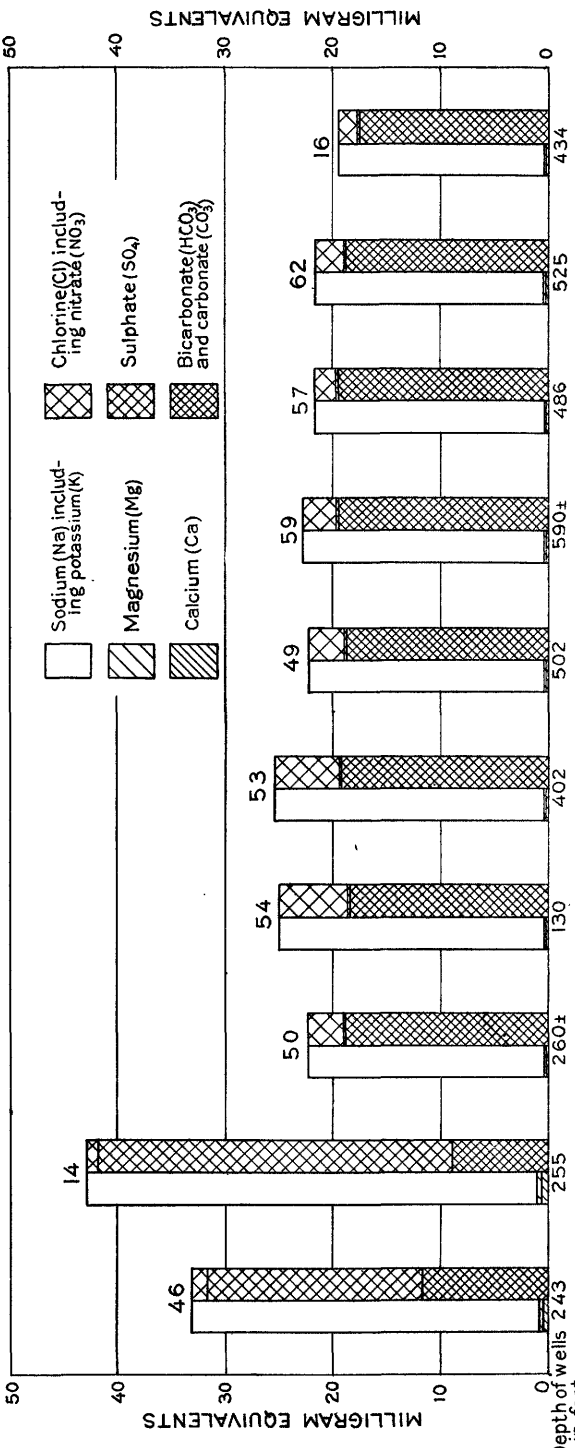


FIGURE 9.—Graphic representation of analyses of waters from gas-bearing artesian wells in the Lance formation along the Yellowstone River

Analyses of gases from artesian wells that end in the Lance formation

[Analyzed by G. W. Jones. Recorded in nearest per cent. The numbers used in this table for the gas analyses correspond with the numbers used in the table on pp. 130 to 138, and in fig. 11 for the water analyses of the same wells]

	G-46	G-14	G-50	G-54	G-53	G-49	G-59	G-57	G-62	G-16
Temperature.....°F..	52	53	54	53	52	54	55	55	55	53
Gas at 24° C. and 745 millimeters pressure per liter of water.....cubic centimeters..	29.3	33.2	45.9	55.6	46.6	61.9	62.1	60.9	64.2	44.4
Methane (CH_4)........	0	0	58	60	58	66	66	60	60	37
Ethane (C_2H_6)........	0	0	0	0	0	0	0	0	0	0
Carbon dioxide (CO_2)........	3	2	4	2	5	3	3	3	3	4
Oxygen (O_2)........	1	3	2	0	0	6	0	0	0	0
Nitrogen (N_2)........	96	95	36	38	37	30	31	37	37	59
	100	100	100	100	100	100	100	100	100	100

The waters represented by samples 46 and 14 are more highly mineralized than the other eight and are high in the sulphate radicle, though they contain also considerable amounts of bicarbonate. Samples 50, 54, 53, 49, 59, 57, 62, and 16 are essentially sodium bicarbonate waters; in them the sulphate radicle is negligible. In all 10 samples the sodium radicle is especially high and the calcium and magnesium radicles are negligible. The analyses of the gases contained in these artesian waters show that samples 46 and 14 are different from the others in that they contain no methane and are especially high in nitrogen. The water from well 46 was the only one that gave off a readily detectable amount of hydrogen sulphide. No observable amount of hydrogen sulphide was given off from the other nine wells.

It is believed that the methane gas was derived from the coal and disseminated carbonaceous material in the Lance and Fort Union formations and that the nitrogen comes largely from the decomposition of carbonaceous material, though some of it may be of atmospheric origin; further, that the methane has reduced the sulphate to hydrogen sulphide, and has formed carbonates and bicarbonates. The hydrogen sulphide thus liberated would combine with oxides of iron or other metallic elements, especially in the absence of oxygen, to form pyrite or other metallic sulphides. The reaction of methane with calcium and magnesium sulphates in these waters has very probably caused some deposition of calcium and magnesium carbonates. It is believed that in well 46 the methane that is being evolved from carbonaceous material is being consumed by reduction of the sulphate in the water to form hydrogen sulphide, whereas in wells 50, 54, 53, 49, 59, 57, 62, and 16 essentially all the sulphate has been reduced, with the formation of carbonates and bicarbonates, and there is a surplus of methane. In well 14 the water contains considerable sulphate but no methane and no noticeable amount of hydrogen sulphide. The explanation of these chemical relations probably lies in the fact that this well does not encounter much carbonaceous material from which methane might be produced, and as there is no methane, the sulphate is not reduced, and no hydrogen sulphide is liberated.

CLASSIFICATIONS OF THE WATERS

Numerous schemes have been devised for classifying waters with respect to use, such terms as good, fair, poor, and bad usually being employed. All classifications of this nature are inadequate, because a water may be good for drinking but poor for washing, or good for irrigation but poor for boiler use, or good for washing but poor for irrigation, and so on. No classification is suggested in this report. The analyses of the waters are given on pages 130 to 138, and statements as to their utility and chemical character are given under the heading "Water-bearing properties of the different formations," pages 52 to 61.

Whether a water is regarded by the inhabitants of a region as good or bad is determined in large measure by the quality of water to which they are accustomed. In a region where most of the natural waters contain a relatively large amount of dissolved mineral matter a water is likely to be regarded as good which in another region, where the residents are accustomed to water containing relatively little mineral matter, would be regarded as poor.

In this part of Montana the deeper soft waters from the Lance and Fort Union formations, which contain as much as 1,500 parts per million of total dissolved solids, have a pleasant taste, and even those containing as much as 2,000 parts per million are not unpleasant and are regarded as satisfactory for domestic uses. On the other hand, a hard ground water from shallower depths that contains as much as 1,500 parts per million is likely to have an unpleasant taste, possibly because of the magnesium content, and would be regarded as bad.

NECESSITY FOR CHEMICAL TREATMENT OF THE GROUND WATERS

Some of the waters in Rosebud County are of poor quality for certain uses and need treatment to render them serviceable. The near-surface hard waters should be softened in order to improve them for boiler and laundry use. The sodium bicarbonate ground waters from a depth of 125 feet or more habitually foam and prime when used in boilers. Foulk[78] has pointed out that castor oil is the best material for preventing foaming in boilers. The soft ground waters are not satisfactory for irrigation because water of this type forms sodium

[78] Foulk, C. W., Foaming of Boiler Waters: Ind. and Eng. Chemistry, vol. 16, pp. 1121–1125, 1924.

carbonate or black alkali. Possibly the land may be economically treated with gypsum or some other material that will prevent the formation of black alkali, but it is doubtful whether it will be feasible to treat the soft waters themselves in order to render them fit for irrigation.

ALKALI AND OTHER MINERAL SUBSTANCES IN THE ROCKS AND SOIL

The surface of the ground in the areas of the Colorado, Claggett, Judith River, and Bearpaw formations is covered in many places with a white or gray alkali,[79] and crystals of selenite (gypsum, $CaSO_4.2H_2O$) several inches long are abundantly scattered over the surface. On digging a few feet into the outcropping shales the small cracks and fractures in the rock are observed to be filled with small gypsum crystals and other noncrystalline alkali. These materials have been dissolved from the shale by the water and reprecipitated by evaporation of the water. There are also deposits of white noncrystalline alkali on the surface in some of the areas of Lance and Fort Union rocks as well as in the tracts of alluvium along the principal streams.

Obviously the chemical character of the ground water is related to these alkali and mineral deposits, and the same salts that occur on the surface of the ground should be found in the water, though it is to be expected that the proportions will be different. The subject of alkali in soils with special reference to its relation to agriculture, as well as the method of removal and the relation of soil alkalinity to ground-water circulation, has been discussed in considerable detail by Harris.[80]

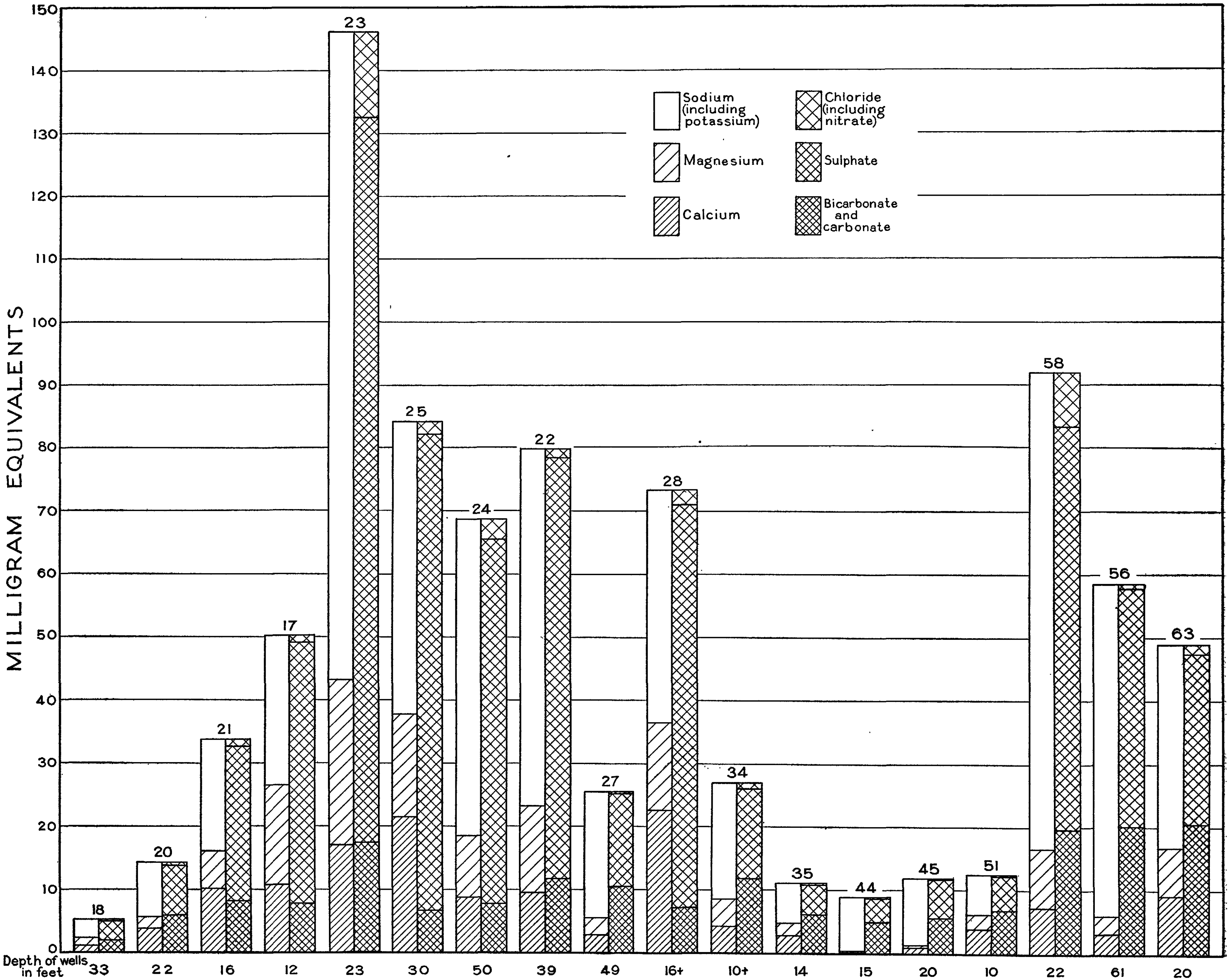
Samples of different types of alkali and associated material were collected in Rosebud County. The water-soluble and acid-soluble constituents of the rocks and soil were determined by Miss Margaret D. Foster, and the results are given in the table below. The method of analysis is described by Miss Foster as follows:

Most of the determinations of the water-soluble content of soil and crushed rock material were made upon 100 grams of the crushed and thoroughly mixed material. If, however, the sample consisted mainly of alkali, only 10 grams was taken, as in analyses A-1, A-6, A-7, and A-16. One sample, No. A-20, represented alkali deposited upon rocks; the alkali scraped off amounted to 4.0 grams, of which 3.5 grams was used for the determination of the water-soluble content. One liter of distilled water was added to each weighed sample (except No. A-20, to which 350 cubic centimeters was added). After standing

---

[79] The word "alkali," as used in this report, is not confined merely to the salts of the alkalies—sodium and potassium—but also includes the salts of the alkaline earths—calcium and magnesium—all of which go to make up the material deposited on the surface of the ground in most arid and semiarid regions.

[80] Harris, F. S., Soil Alkali, Its Origin, Nature, and Treatment: New York, John Wiley & Sons, 1920. Includes a very full bibliography.



GRAPHIC REPRESENTATION OF ANALYSES OF WATERS FROM SHALLOW WELLS IN IRRIGATED TRACTS ALONG THE YELLOWSTONE RIVER IN ROSEBUD COUNTY for 30 minutes the solution was filtered off through a Berkefeld filter stone. The clear filtrate was analyzed for calcium, magnesium, carbonate, bicarbonate, sulphate, chloride, and nitrate by the same methods as are used for the determination of these constituents in the analysis of water. The sodium was calculated from the results obtained for the other constituents. In samples A–6 and A–7 the moisture, iron and aluminum oxides, and iron were also determined.

To determine the character of the salts present in the soil and rock materials analyses were made either upon an acid solution of the whole material, using a 5.0-gram sample, as in analyses A–9, A–11, A–12, and A–15, or upon alkali scraped from the surface of the rock, as in analysis A–20; or, when possible, upon lumps of the salts picked out of the material, using 0.50 to 0.25 gram samples, as in analyses A–16a, A–19, and A–21. After being weighed the sample was digested upon the steam bath with hydrochloric acid (1 volume hydrochloric acid of specific gravity 1.19 to 1 volume of distilled water). The amount of effervescence which took place upon the addition of the hydrochloric acid to the sample was noted. After it had digested for about 20 minutes the sample was evaporated to dryness and the residue was taken up with about 5 cubic centimeters of hydrochloric acid (1–1) and 20 cubic centimeters of distilled water. When the sample had again digested 20 minutes the insoluble material was filtered off and weighed. The filtrate was used for the determination of iron and aluminum oxides, iron, calcium, magnesium, and sulphate. Sodium was also determined in analyses A–16a, A–19, and A–21. In analyses A–9a, A–11a, A–12a, and A–15a the sodium determination was not necessary, as these analyses were made upon the whole material, not upon lumps of salts picked out, and the figure for sodium found in the analysis of the water-soluble content of the material could be used. From these results and from the amount of effervescence which took place upon the addition of hydrochloric acid to the sample, the character of the salts present in the material, whether carbonate or sulphate, could be determined.

Analyses of water-soluble and acid-soluble constituents of rock materials and soils, Rosebud County, Mont.

[Analyzed by Margaret D. Foster, February, 1924. Per cent of air-dried sample]

Water-soluble

No.	Location	Material	Iron (Fe)	Aluminum (Al)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)[a]	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Sum of constituents determined
A-1	NE. ¼ sec. 24, T. 8 N., R. 39 E.	Alkali from Colorado and Claggett shales.			0.56	4.73	9.94	0.00	0.26	39.90	0.48	Trace.	55.86
A-2	NE. ¼ sec. 6, T. 7 N., R. 39 E.	White sandstone from top of Judith River formation.			.24	.07	.01	.00	.02	.85	Trace.	Trace.	1.19
A-3	SE. ¼ sec. 6, T. 8 N., R. 38 E.	Basal sandstone of Judith River formation.			.02	.01	.002	.00	.02	.06	Trace.	0.02	.13
A-4	SE. ¼ SW. ¼ sec. 13, T. 8 N., R. 38 E.	White alkali from natural evaporation of ground water from Judith River formation.			.51	2.74	1.10	.00	.08	14.26	.01	Trace.	18.70
A-5		Bearpaw shale.			.01	.01	.18	.00	.02	.42	Trace.	Trace.	.64
A-6	NE. ¼ sec. 26, T. 7 N., R. 39 E.	Alkali derived from evaporation of surface water and of ground water of Bearpaw shale.	0.01	0.13	.55	5.01	11.78	.00	.15	45.48	.09	Trace.	63.20
A-7	Sec. 1, T. 8 N., R. 36 E.	Alkali from Bearpaw shale at Ahles.	.01	.99	.32	5.61	11.80	.00	.00	49.88	.03	Trace.	68.65
A-8	SW. ¼ sec. 4, T. 6 N., R. 43 E.	Alkali scraped from outside of wooden watering tank supplied from Matt Barley well.			.10	.39	32.91	37.44	11.42	.79	.58	Trace.	83.63
A-9	Bluff at south end of Tenth Street, Forsyth.	Sand in Lance formation.			.01	.00	.28	.00	.03	.58	Trace.	Trace.	.91
A-10	NE. ¼ sec. 12, T. 4 N., R. 42 E.	Shale in Lance formation.			.05	.02	.32	.00	.05	.85	Trace.	Trace.	1.29
A-11	SW. ¼ sec. 27, T. 7 N., R. 40 E.	Shale in Lance formation.			.03	.04	.34	.00	.05	.87	.03	.01	1.36
A-12	SE. ¼ sec. 15, T. 6 N., R. 40 E.	Sandstone in Lance formation.			.00	.00	.01	.00	.02	.02	Trace.	Trace.	.05
A-13	SE. ¼ NE. ¼ sec. 5, T. 2 N., R. 39 E.	Tongue River member of Fort Union formation.			.17	.64	1.71	.00	.04	6.42	.04	Trace.	9.02
A-14	SW. ¼ sec. 30, T. 5 S., R. 43 E.	Alkali from evaporation of ground water from Tongue River member.			.14	.03	.65	.00	.05	1.75	Trace.	.01	2.61
A-15	NW. ¼ NW. ¼ sec. 32, T. 5 N., R. 43 E.	Sand in Fort Union formation.	.00	.01	.01	.01	.01	.00	.04	.02	Trace.	Trace.	.08
A-16	Sec. 18, T. 7 S., R. 44 E.	Fort Union formation.			.05	.13	.14	.00	.29	.70	Trace.	Trace.	1.31
A-17	SW. ¼ sec. 10, T. 6 N., R. 38 E.	Alkali from evaporation of ground water.			.45	1.29	5.19	.00	.10	16.75	.13	.01	23.91
A-18	SW. ¼ sec. 30, T. 5 S., R. 43 E.	Sandy silt of Fort Union formation.			.05	.03	.28	.00	.08	.77	Trace.	Trace.	1.22

Acid-soluble

A-19		Lumps of alkali picked from sample 5	0.51	0.55	18.66	0.60	[b]0.38			46.85			
A-9a	Bluff at south end of Tenth Street, Forsyth.	Sand in Lance formation	1.25	.77	1.04	.87	[c].28			.65			
A-11a	SW. ¼ sec. 27, T. 7 N., R. 40 E.	Shale in Lance formation	2.22	1.09	1.54	1.19	[c].34			1.29			
A-12a	SE. ¼ sec. 15, T. 6 N., R. 40 E.	Sandstone in Lance formation	2.27	.92	.37	.56	[c].01			.10			
A-15a	NW. ¼ NW. ¼ sec. 32, T. 5 N., R. 43 E.	Sand in Fort Union formation	1.0	.26	4.21	1.83	[c].01			.11			
A-16a	Sec. 18, T. 7 S., R. 44 E.	Lumps of alkali picked from sample 16	.06	3.35	22.48	4.66	[b].38			3.03			
A-20	SE. ¼ sec. 14, T. 6 N., R. 42 E.	White material from lower surface of pebble of terrace gravel.	.14	2.49	30.46	1.62		48.02		1.06			
A-21	SW. ¼ sec. 10, T. 6 N., R. 38 E.	Lumps of alkali picked from sample 17	1.12	.51	1.92	6.83	[b]8.37			30.62			

[a] Calculated. [b] Determined. [c] From water-soluble analysis.

A-2. The soluble white material forms small white stalactites in places.
A-7. Acidity due to $Al_2(SO_4)_3$ 2.34 included in SO_4.
A-10. The surface of this shale was covered with white alkali.
A-13. Alkali salts precipitated at surface by ground water.
A-16. Within the first large clinker bed about 1 foot above ash of coal. This is a clinker below the one which forms the summit of the plateau.
A-17. In irrigated tract.
A-18. White alkali is deposited by evaporation of ground water from this bed.
A-19, A-9a, A-12a. No effervescence upon addition of acid.
A-11a, A-21. Slight effervescence upon addition of acid.
A-15a, A-16a. Strong effervescence upon addition of acid.
A-20. Moisture 0.30; silica (SiO_2) 14.14. Strong effervescence upon addition of acid.

The analyses of the alkali in the area of Cretaceous rocks, where there is an abundance of gypsum ($CaSO_4.2H_2O$) on the surface, show considerable amounts of magnesium as sulphate. The absence of the mineral epsomite ($MgSO_4.7H_2O$) is easily accounted for by its solubility. It may well be deposited from an evaporating solution along with gypsum, but with the first rain it would be redissolved and carried along with the soluble sodium salts. In the areas of Lance and Fort Union rocks gypsum in any considerable amount was not observed. A comparison of the analyses shows that the same salts are available in all the formations, though the relative amounts differ considerably in different formations and in different localities in the same formation.

In the rock and soil, as in the ground water, calcium, magnesium, and sodium are the principal bases, with sulphate, carbonate, bicarbonate, and silicate as the most abundant acids. Chlorine is noticeable in one sample of sandstone from the Judith River formation. The relatively large amounts of iron and aluminum shown in the analyses of some of the acid-soluble material indicate that the rock and soil associated with the alkali, some of which doubtless occurs as a silicate, has been partly dissolved by the acid treatment, and that these analyses therefore do not represent the chemical composition of the typical white alkali alone.

The chemical constituents of the alkali and related material of each formation are described under "Water-bearing properties of the different formations."

TYPES OF WELLS AND OF WELL DRILLING

Drilled and dug wells are the two most common types of wells in Rosebud County. There are a few driven wells, which are mostly confined to the alluvial tracts along the principal streams. Wells bored with power augers are comparatively rare. The dug wells are relatively shallow, usually reaching a depth of a few tens of feet, but the drilled wells are seldom less than 100 feet deep and generally considerably more. The water in most of the shallow dug wells is hard, and the water in the deeper drilled wells is generally soft.

In this report frequent reference is made to so-called shallow and deep wells. These terms are somewhat arbitrary, but all wells under 60 feet have been referred to as shallow and all wells over 100 feet as deep. For wells between 60 and 100 feet the exact depths are generally given.

The several methods of well drilling have been discussed in many United States Geological Survey publications[81] and in trade journals

[81] See Meinzer, O. E., Bibliography and Index of the Publications of the United States Geological Survey Relating to Ground Water: U. S. Geol. Survey Water-Supply Paper 427, pp. 161–163, 1918.

and catalogues. A recent publication by Ziegler[82] contains much information on the subject.

The jetting method,[83] with a portable rig, is very successfully used in Rosebud County. By this method a stream of water under pressure is forced downward through hollow drill rods and out through the drill bit at the bottom of the hole. This stream of water aids in loosening the rock material, which is forced upward to the surface on the outside of the pipe. Throughout the drilling operation the bit is alternately raised and dropped as in other percussion rigs and is slowly turned in order to obtain a straight hole. For the ordinary private wells a 4-inch casing is put down through the alluvium and is set in some suitable consolidated sandstone or shale bed by firmly driving it a short distance into the rock. A coal bed is commonly fractured and is therefore unsatisfactory for setting a casing. The casing prevents the hard water near the surface from entering the well. A smaller hole, usually capable of taking a 2½-inch casing, is then drilled inside the 4-inch casing. Water is generally encountered in sandstone or coal beds and is generally soft if the well reaches a depth of 125 feet, provided that the hard water near the surface has been effectively cased off. At the end of the string of 2½-inch casing, which should extend into the water-bearing bed, a packer intended to grip firmly the sides of the drill hole is attached. This packer is set at the top of the bed from which the water supply is derived. A type commonly used and regarded as satisfactory is made by wrapping a section of casing about 18 inches long with canvas, tapering the thickness of the canvas to a cone shape at each end, and painting with white lead paint. It is referred to as a "canvas and white-lead packer" and has been found to be more satisfactory than one of rubber, leather, or other substance. With the use of such a packer fastened to the casing below a coupling, the casing may be easily removed by pulling the pipe out of the canvas packer, which remains in the hole.

Within the area of Fort Union rocks or within the area of Lance rocks in a location where these formations have a thickness of as much as 200 feet a supply of soft water may be assured from a drilled well. Drilled wells are strongly recommended, if they can be afforded, in the interests of sanitation as well as adequate supply of soft water. However, in the areas of thick deposits of high-level terrace gravel, within the tracts of alluvium along the Yellowstone and Tongue Rivers, and in places where the sandstones of the Judith River formation, especially the lower sandstone, are at the surface, hard

[82] Ziegler, Victor, Oil Well Drilling Methods: John Wiley & Sons, 1923.

[83] Bowman, Isaiah, Well-Drilling Methods: U. S. Geol. Survey Water-Supply Paper 257, pp. 70–75, 1911.

water of satisfactory quality may be obtained from shallow dug wells, and in such localities the drilling of a deep well is usually not necessary.

SANITATION OF WELLS

The samples of water collected in Rosebud County have been analyzed for their dissolved mineral matter, and no cognizance has been taken of their bacterial content. If due precaution is taken in locating and equipping a well there is not much danger from disease-bearing bacteria in the water.

Inadequate curbing and covering is a source of pollution in many wells, especially in the dug wells. A board top, unless well constructed, allows water to run back into the well, and the use of such a cover should be discouraged. A concrete cover with a tightly fitting manhole is the most satisfactory type of cover for a dug well. Concrete, stone, and brick are the most satisfactory types of curbing. A wooden curbing or casing is undesirable, because the action of the mineralized sulphate waters characteristic of the shallower depths upon the wood may give a rather undesirable taste to the water and because the wood rots easily and allows animals and surface water to enter. Above the water table the curbing should be essentially water-tight. If the curb is made of concrete, and clay is tightly packed around it in the upper part of the well, the danger of pollution is greatly reduced.

As the water table, or upper surface of ground water, generally slopes in the same direction as the land surface the flow of the ground water is generally from the higher land toward the valleys. At many ranches the outhouses and barns stand on a hill above a shallow dug well in a coulee. This is likely to mean that the well is receiving seepage from these sources of pollution. Such conditions constitute one of the most general sources of pollution of ground water.

To prevent pollution in drilled wells a tight and substantial casing should be carried through an impermeable clay bed or to a considerable depth below the water table. There should be a tight connection between the casing and the base of the pump, and care should be taken to prevent leakage from the surface into the well or into any open space that might be left between the drilled hole and the casing.

WATER-BEARING PROPERTIES OF THE DIFFERENT FORMATIONS

KOOTENAI (?) FORMATION

The Kootenai (?) formation, a part of which is sandstone, has been penetrated in drilling for oil near the apex of the Porcupine Dome, but in every hole reported it is said to yield salty water. The

Chicago, Milwaukee, St. Paul & Pacific Railway Co. drilled a well for a water supply at Vananda, but the results were disappointing; the Kootenai (?) rocks were encountered at a depth of 3,200 feet, and the water is said to have risen within 50 feet of the surface[84] but was reported to be nonpotable, hard, and alkaline. From all the data at hand it would seem that in this region the sandstones of the Kootenai (?) formation should be regarded as an unfavorable source of ground water for drinking, domestic, or industrial purposes, or irrigation.

COLORADO AND CLAGGETT SHALES

The Colorado and Claggett shales yield rather meager supplies of ground water, and without exception the quality is inferior. C. W. Johnson's well, in the SW. ¼ sec. 24, T. 8 N., R. 38 E., is 28 feet deep and within the area of the Claggett outcrop, but it is uncertain whether the source of this water is in the Claggett shale or in alluvial material derived from the near-by Colorado and Claggett shales. The water is hard and has a decided alkaline taste. (See analysis 10.)[85] The community well in the center of the village of Vananda (see p. 72), which is 225 feet deep, obtains its water from the upper sandy phase of the Claggett formation. This water is highly mineralized (see analysis 13 and fig. 11) and is nonpotable and unserviceable for cooking but is utilized for some other domestic purposes by the inhabitants of the village: The analysis of this water shows relatively little calcium and magnesium as compared with other waters in the Cretaceous rocks, a fact which is entirely in accord with the observations on the removal of calcium and magnesium with increase in depth noted on pages 41 and 42.

A sample of alkali derived from the Colorado and Claggett shales (see analysis A-1) consists almost entirely of sodium and magnesium sulphates. A sample of non water-bearing Claggett shale was found to contain a large percentage of silt but also considerable clay and sand and to have a high moisture equivalent. (See analysis P-41.)

JUDITH RIVER FORMATION

The sandstones of the Judith River formation, especially the lower sandstone, yield some of the most desirable water in Rosebud County in situations where the wells begin and end in the same sandstone

[84] Bowen, C. F., Gradations from Continental to Marine Conditions of Deposition in Central Montana during the Eagle and Judith River Epochs: U. S. Geol. Survey Prof. Paper 125, pp. 11–21, 1921; Possibilities of Oil in the Porcupine Dome, Rosebud County, Mont.: U. S. Geol. Survey Bull. 621, pp. 61–70, 1915.

[85] The analyses referred to in this and subsequent sections of this report are given in the following tables: Water, pp. 130 to 138; gas, p. 44, designated by letter G; physical properties of rock materials, pp. 36 and 37, designated by letter P; water-soluble and acid-soluble constituents of rock materials and soils, pp. 48 and 49, designated by letter A (alkali).

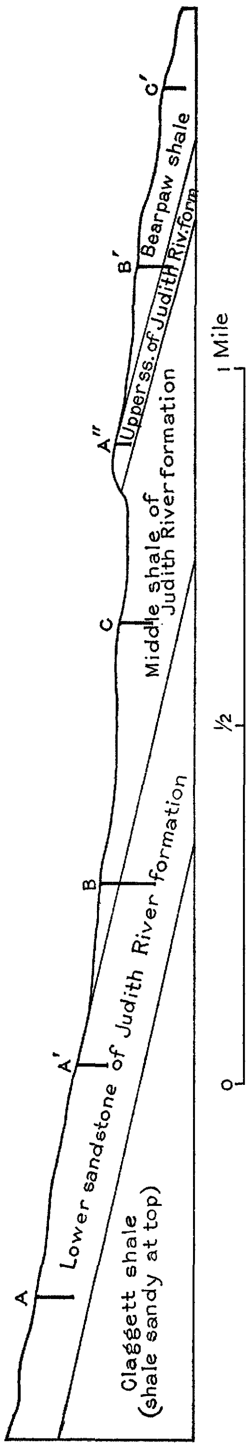


FIGURE 10.—Diagrammatic cross section showing the cause for the difference in quality of the water in the different members of the Judith River formation. Wells A, A', and A'', which extend only into the sandstone, yield water of good quality; wells B and B', which, though extending into the Judith River sandstones, first penetrate mineralized shale, yield water of poor quality. Wells C and C', which obtain their water from only the mineralized shale, yield a small amount of nonpotable water

member, but where the well penetrates a shale bed before reaching the underlying water-bearing sandstone the water is generally of inferior quality.

In Figure 11, analyses 12 and 7 represent samples from wells that penetrate a shale bed before entering the water-bearing sandstone of the Judith River formation, and analyses 8 and 9 samples from wells that are in sandstone from the surface to the bottom of the well. The contrast in chemical character of the water from these two types of environment in the Judith River formation, which is depicted in Figure 10, was observed in the field and seems to be corroborated by the analyses shown in Figure 11. Some ground water probably moves downward through the shale, which is impregnated with mineral matter and later finds its way into one of the underlying sandstone beds. The slight mineralization of the water in sandstones that are not covered by shale may also be due to the free circulation of water in the upper rocks and the consequent leaching out of the mineral matter.

The waters from wells that penetrate shale before entering a sandstone of the Judith River formation are commonly regarded as nonpotable and are often not even satisfactory for stock. No place was observed where waters of this type were utilized for irrigation, and it is probable that they would prove to be unsatisfactory. The waters from wells that penetrate only sandstone of the Judith River formation contain as small an amount of mineral matter as any other waters in Rosebud County. All the water from the Judith River formation, whatever the source, is hard.

Analyses of the water-soluble material in the top and bottom sandstones of the Judith River formation (A–2 and A–3) show that the soluble material consists of calcium and magnesium, mostly as

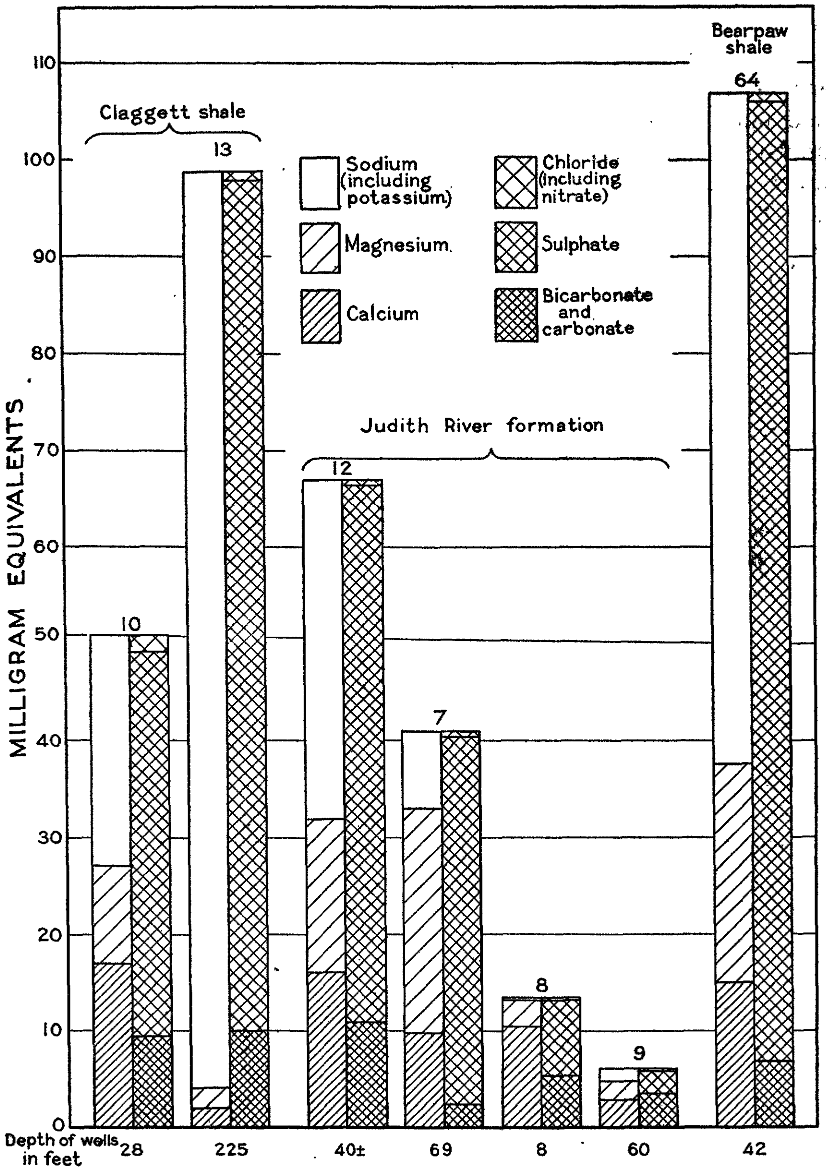


FIGURE 11.—Graphic representation of analyses of ground waters from the Cretaceous rocks

sulphate; A–3, material from the basal sandstone, shows more chlorine than any other sample. A–4 is a sample of alkali formed by the natural evaporation of ground water from the Judith River formation and consists mostly of magnesium, but calcium and sodium are present in noticeable amounts. These bases are present mostly as sulphates. It is significant that the samples from the Judith River formation contain less sodium than those from other formations.

The physical properties of samples of the Judith River formation are shown by analyses of three sandstones (P–29, P–69, and P–43) and one sandy shale (P–40). The three sandstones are relatively uniform in size of grain, and have effective or 10 per cent sizes ranging from 0.05 to 0.10 millimeter; their moisture equivalents are much less than their porosities. Two of these (P–69 and P–43) should yield small to moderate supplies of water; the other (P–29) may also yield small supplies if the material is sufficiently coherent to prevent its running into the well.

BEARPAW SHALE

Only meager supplies of water can be obtained from the Bearpaw shale, and these only locally. All the water is highly mineralized, hard, and unserviceable for most uses. Stock, however, will drink some of it. Samples 64 and 15, analyses of which are shown in the table, are typical of the Bearpaw waters. No. 64 is represented graphically in Figure 11.

The samples of alkali represented by analyses A–6 and A–7 consist mostly of sodium sulphate and are representative of the water-soluble material deposited by evaporation of surface and ground water that has had access to the Bearpaw shale. A–19, which is almost entirely calcium sulphate, represents the acid-soluble material and shows that acid leaching of the Bearpaw shale dissolves the gypsum, which is so abundant.

The physical properties of a sample of Bearpaw shale are shown by analysis P–39. The material tested consists chiefly of silt and clay and has an excessive moisture equivalent. It is obviously not a water-bearing material.

LANCE FORMATION

The Lance formation furnishes more ground-water supplies than any other formation in Rosebud County, owing chiefly to the fact that it is the most accessible aquifer along the Yellowstone River, where the largest centers of population are. The tracts favorable for obtaining artesian wells are indicated on Plate 1. The difference in chemical character of the water in the shallow and the deep wells is considered on page 41. Ample supplies of ground water of satisfactory quality for domestic and stock use can generally be obtained at any place in the area of Lance rocks where there is a thickness of as much as 200 feet of Lance strata below the water table, and at some places where the thickness is much less. The heavy sandstones at the base of the Lance formation are good water-bearing beds throughout Rosebud County. Most of the pump wells that reach the deeper soft water have 2½-inch casings and yield 5 gallons or more a minute when they are pumped with gasoline engines or actively working windmills. It seems safe to predict that a yield of 100 gallons a minute or more can be obtained by putting down wells 8 to 12 inches in diameter.

The Lance waters that contain an average of 1,500 parts per million total dissolved solids are regarded as satisfactory for drinking, stock, and most domestic purposes. The deeper waters in the Lance formation are considered very desirable for washing but are not always satisfactory for cooking. Tea or coffee made with these waters (sodium-bicarbonate waters) has a rather unusual if not unpleasant taste. The soft water from the deeper wells is generally unfit for irrigation because of its high content of sodium bicarbonate, which forms the injurious sodium carbonate or black alkali. Sample (A–8) is representative of alkali deposited by the natural evaporation of soft water from a well in the Lance formation. Farmers report that where these waters have been used for irrigation the black alkali appears on the surface of the ground at the end of the second or third season, making it difficult if not impossible to raise a crop thereafter. The soft waters have generally been found to be unsatisfactory also for boiler use because of their tendency to foam.

Analyses of the water-soluble material in representative samples of Lance sand (A–9) and shale (A–10 and A–11) and of an alkali deposit within an area of Lance strata (A–12) show that the principal water-soluble material is sodium sulphate (Na_2SO_4), though there are noticeable amounts of calcium and magnesium mostly as carbonate or bicarbonate. The acid-soluble constituents of the same rock samples were analyzed (A–9a, A–11a, and A–12a), and it seems that most of the calcium and magnesium dissolved is present in the rocks as silicate, as there was little or no effervescence upon addition of hydrochloric acid.

The physical properties of 15 samples of material from the Lance formation are shown in the table on pages 36 and 37. Three of these are non water-bearing shale; the rest are classed as sandstone. Most of the sandstones are sufficiently low in silt and clay to yield water in practicable amounts, and a few, such as P–34 and P–45, from the Hell Creek member might yield 100 gallons a minute, or even more to properly constructed drilled wells of large diameter.

FORT UNION FORMATION

Lebo shale member.—The Lebo shale member of the Fort Union formation is not water-bearing in most places but includes some sandy lenses that yield water locally. It is generally advisable to drill through this member into a sandstone of the underlying Lance formation to case off any bad water that is found in the Lebo member, such as that represented by sample 83. Potable water can not usually be obtained from shallow wells in the areas of Lebo rocks, but sample 10 is from a well that ends in alluvium derived wholly from the Lebo member and is fairly satisfactory though hard.

The physical properties shown by analyses P–36, P–60, and P–66 indicate that this member contains too much clay and has too high a moisture equivalent to be a source of water supply. The sandstone (P–66) appears to be quite as unpromising as the shale (P–60).

Tongue River member.—The waters from the Tongue River member of the Fort Union formation, though in general not so highly mineralized, are similar to the Lance waters and are essentially equal to them in domestic, stock, agricultural, and industrial utility. The lithologic character of the massive sandstones in the lower part of the Tongue River member indicates that this member is a more permeable water-bearer than the Lance formation, especially where a coal bed capped by a sandstone has been burned, causing the overlying sandstone to become fractured and shattered as it settles to the position formerly occupied by the coal. (See pl. 8, *B*.) Most of the water in the Tongue River member is encountered in the numerous thick and persistent coal beds which this member contains, and springs issuing from coal and clinker beds are fairly common.

In places where the thickness of the Tongue River member below the water table is not sufficient to insure an adequate water supply, water may be obtained by drilling through the Lebo member into the Lance formation. The artesian wells deriving their water from the Tongue River member are described on pages 118, 119, and 122. All the wells in the Tongue River member visited were less than 3 inches in diameter with yields not exceeding 10 gallons a minute, but larger supplies could doubtless be obtained by drilling wells of larger diameter.

In the Tongue River member, as in the Lance formation, the waters near the surface are hard and the deeper waters are soft. In both the Lance and Fort Union formations there is apparently no difference in the chemical character of the waters in the shale and in the sandstone, a condition entirely different from that which exists in the underlying Cretaceous rocks. (See p. 54.)

Analyses A–13, A–14, and A–19 represent samples of alkali deposited by the evaporation of seepages of ground water from the Tongue

River strata. Sodium sulphate is the most abundant constituent; but calcium and magnesium, mostly as sulphate and in part as bicarbonate, are present in noticeable quantities. A–15a, which consists mostly of calcium and magnesium as carbonate and silicate, represents the acid-soluble components in a typical sand of the Tongue River member.

The physical properties of 12 samples of material from the Tongue River member are shown in the table on pages 36 and 37. These range from shales and clayey sandstones that will not yield water to fairly pure, even-grained sandstones that will yield moderate sup-

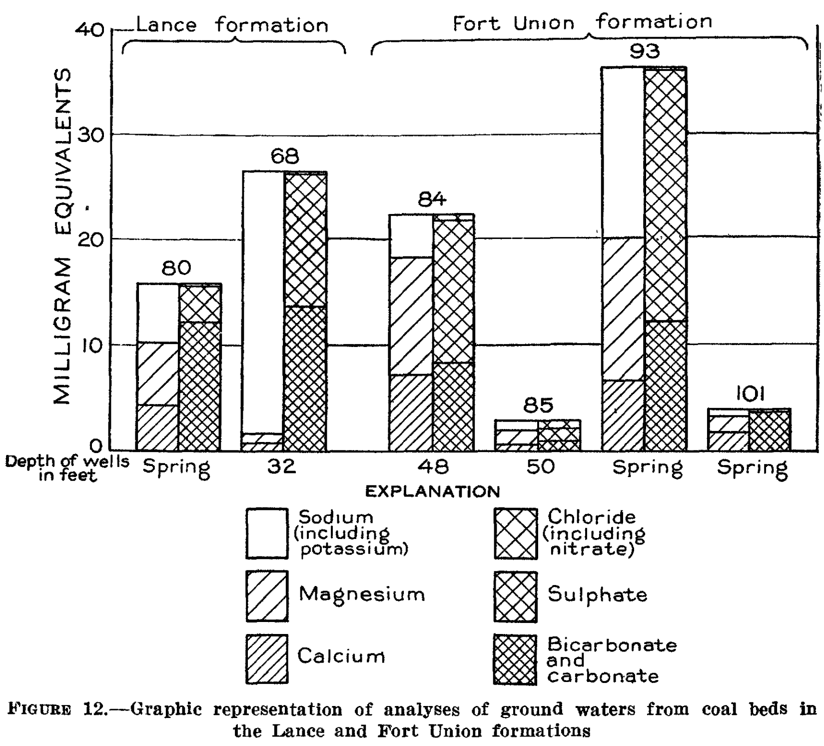


FIGURE 12.—Graphic representation of analyses of ground waters from coal beds in the Lance and Fort Union formations

plies. In all these samples, however, the 10 per cent size is notably small, indicating that the sandstones are not coarse and clean enough to yield water freely.

COAL AND CLINKER BEDS

The analyses of some waters from coal beds of the Lance and Fort Union formations, graphically represented in Figure 12, show considerable variation in the amount of dissolved mineral matter, and some of the waters from the coal beds contain less dissolved material than the waters from the incasing rocks of these formations.

All the samples of water from coal beds were collected from relatively shallow depths and are hard. The water from coal beds at somewhat greater depth is doubtless soft.

The well drillers in this region report that the water obtained in clinker beds is invariably hard. This is in accord with Rogers's statement[86] that with an overburden of as much as 100 feet a coal bed will probably not burn more than a few feet beyond the outcrop. This means that the clinker beds lie within shallow depths, at most places less than 50 feet, and the water from these depths in this region is hard.

Where a spring issues from a clinker bed there has generally been deposited a considerable amount of white amorphous material. Analyses of this material (A–16 and A–16a) show a relatively small proportion of water-soluble material, sodium and magnesium sulphates, and a high content of calcium and magnesium carbonates.

TERRACE GRAVEL

The terrace gravel, which is confined almost entirely to a strip along the Yellowstone River (see fig. 3), yields the best water in Rosebud County. The water from the gravel, though hard, has a pleasant taste and is very satisfactory for irrigation. (See analyses 47, 48, and 67.)

At every place where the water table is as much as a few feet above the bottom of the gravel deposits a considerable supply of water may be had. Up to the present time the water supplies in the gravel have been developed mainly for small farm water systems, but there is no doubt that it will yield larger supplies, and the possibility of supplying the city of Forsyth with water from this source is considered on page 84. Four samples of terrace gravel whose physical properties were tested (P–37, P–63, P–65, and P–68) consist of notably coarse material with only moderate amounts of clay, silt, and very fine sand. All are rather freely permeable though they differ greatly in their coefficients of permeability. Much of this gravel, where it is saturated to sufficient depth, should yield a few hundred gallons a minute to properly constructed wells of large diameter. Additional information regarding the water-bearing character of the gravel is contained in the descriptions of townships, especially those in the tier T. 6 N.

The under surface of most of the pebbles and cobbles in the portion of the terrace gravel above the water table is covered with a white deposit. This white coat was found on analysis to contain only about 1 per cent of water-soluble material. Analysis A–20 shows that it is

---

[86] Rogers, G. S., Baked Shale and Slag Formed by the Burning of Coal Beds: U. S. Geol. Survey Prof. Paper 108, p. 4, 1917.

about 75 per cent calcium carbonate, but that there are significant amounts of silica, alumina, and magnesium (probably mostly as carbonate).

QUATERNARY ALLUVIUM

GENERAL CONDITIONS

The alluvium depends for its water-bearing character upon the gravel beds which it contains. The gravel lenses in the alluvium along the Yellowstone, which consist mostly of well-rounded pebbles and cobbles derived largely from the higher terraces, yield abundant supplies of water, but the gravel lenses in the alluvium along the Tongue River, which consist mostly of fragments from the clinker beds, are less permeable and yield smaller supplies. (See analyses P-38, P-42, P-70.)

Ground water can always be obtained from the alluvium along the Yellowstone and Tongue Rivers within a depth of 40 feet and generally at less depth. The quality of the water is influenced to some extent by the adjacent outcropping rock formation—that is, the water in the Quaternary alluvium is very much less mineralized where it receives accessions from a near-by deposit of high-level terrace gravel than where it receives water from Lebo or Bearpaw shale. The water in the alluvium is hard except adjacent to high bluffs of Lance or Fort Union rocks, where it may be soft. Soft water occurs in such a position at Forsyth. (See pl. 12.)

CONDITIONS IN THE IRRIGATED DISTRICTS

There are three extensive irrigation projects along the Yellowstone River in this county, known as the Cartersville, Hammond, and Yellowstone projects. (See fig. 13.) The Cartersville project, which is the largest, embraces an area of about 10,000 acres north of the Yellowstone River in T. 6. N., Rs. 41, 42, 43, and 44 E.; the Hammond project embraces an area of about 5,000 acres north of the Yellowstone River in T. 6 N., Rs. 39 and 40 E.; and the Yellowstone project, which is south of the Yellowstone River, embraces about 5,000 acres in T. 6 N., Rs. 38 and 39 E. Besides these projects there are many separate fields that have been irrigated by individual ranchers. The water utilized for irrigation is taken from the Yellowstone River and is conveyed to the land by gravity ditches. Other small tracts of land are irrigated with water from the Tongue River and Rosebud and Armells Creeks. The statements pertaining to ground water in the irrigated tracts are based almost entirely upon data obtained from the three large projects along the Yellowstone River.

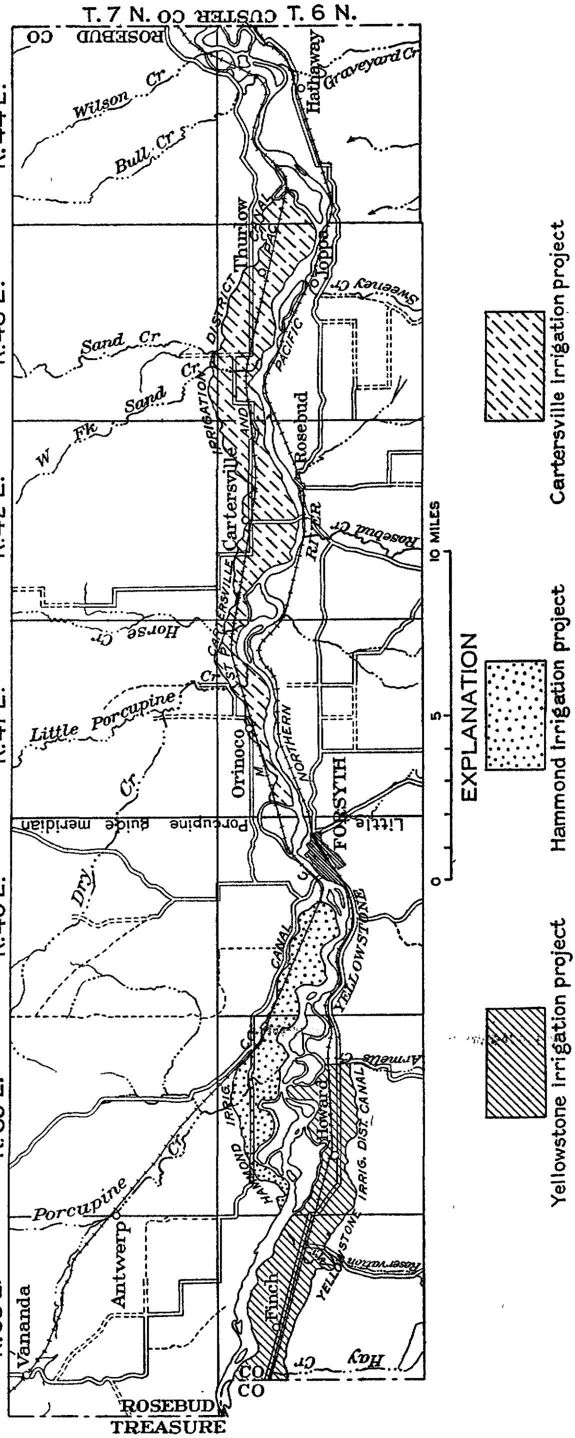


FIGURE 13.—Map showing irrigation projects along the Yellowstone River in Rosebud County

The water in the shallow wells in the alluvium within the irrigated tracts is generally very hard, and much of it is so highly mineralized that it is unfit for use, stock even refusing to drink it. Analyses 17, 18, 20, 21, 22, 23, 24, 25, 28, 34, 44, 45, 51, 58, and 63 represent samples of waters taken from shallow wells in the alluvium in the irrigated tracts.

The residents report that the high mineralization which characterizes the water of many of the shallow wells has been brought about since the surrounding land has been irrigated. Some of the most undesirable of these waters are No. 23, which contains over 9,600 parts per million, and Nos. 22, 24, 25, and 58, which contain over 4,800 parts per million. It is probably significant that all these waters, except No. 58, are within the Yellowstone irrigation project, which crosses the outcrops of the Judith River formation and the Bearpaw shale, both of which contain highly mineralized water, and it may be that this highly mineralized water, flowing underground toward the Yellowstone River and therefore through the alluvium, tends to increase the amount of dissolved mineral matter in the shallow wells of the irrigated flood plain.

The most undesirable water usually occurs in the central parts of the irrigated tracts. The water in wells in an irrigated tract within a few hundred feet of the irrigation ditch is often of satisfactory quality, because it is constantly replenished with fresh water from the ditch. Analysis 45 represents a water of this type. Wells near the channel of the river also seem to yield water of lower mineralization, perhaps because of more active ground-water circulation near the stream. It was noted that in some places a well on the concave side of a meander in the stream yields water which is less mineralized than that in other wells near by; this difference may be due to a slight downstream current within the permeable alluvium, induced by the current of the river. Analysis 44 shows the chemical character of a sample of water collected comparatively near the bank of the river on the concave side of a meander. In places where streams tributary to the Yellowstone cross the irrigated tracts the water derived from the alluvium near the channel of the tributary stream is of much better quality than the water from wells farther away. Sample 18, taken from a well near the channel of Reservation Creek, contains less mineral matter than the water of any other well in the alluvium within any of the irrigated districts and is in marked contrast to the very highly mineralized waters from near-by wells in the Yellowstone project. (For comparison see analyses 17, 22, 23, 24, and 25 and pl. 11.) It is difficult to account for the relatively good water shown by analysis 20. This well is within the Hammond project, is rather remote from the river and from any tributary to the Yellowstone, and is within the area of Bearpaw shale, yet the water is very satisfactory. Perhaps the relatively large amount of water drawn from this well causes an active ground-water circulation, thereby preventing an excessive accumulation of alkaline salts in the water.

The surface of the ground in many places within the irrigation projects is covered with a coating of white alkali derived from the evaporation of surface and ground water. Analyses A-17 and A-21, which give the water-soluble and acid-soluble constituents, respectively, of a typical alkali of this sort, show that it is not different from the numerous other samples of alkali analyzed and has as its constituents the bases calcium, magnesium, and sodium, with carbonate and sulphate as the most abundant acid radicles.

Scofield and Headley[87] have recently discussed the quality of water with special reference to its utility for agriculture and the methods of rendering undesirable waters serviceable for irrigation.

SURFACE-WATER SUPPLIES

STREAMS

Water from the rivers and principal creeks is utilized for domestic purposes and drinking in not more than half a dozen places, and such practice should be discouraged, because the stream waters have generally been polluted by man as well as stock. The analyses of some waters from the Yellowstone River, collected at Billings and Glendive, Mont., have been published in an earlier paper.[88] At times of high water the dissolved mineral matter is much lower than during the dry season. The water from the Yellowstone River is utilized at some places by the Northern Pacific Railway for its locomotives with none too satisfactory results, owing to the scale-forming constituents and suspended matter which the water contains. Sample 32, from the Forsyth sedimentation basin, was collected during a flood stage and is therefore less mineralized than is normal for the water from the Yellowstone River.

ICE

Most of the ranchers living outside of the larger communities cut ice from the streams during winter and store it in ice houses for use in the summer. The ice is usually clear and is used not only for refrigeration but also for drinking by those people who are not fortunate enough to have a well that yields potable water. The water

[87] Scofield, C. S., and Headley, F. B., Quality of Irrigation Water in Relation to Land Reclamation: Jour. Agr. Research, vol. 21, No. 4, pp. 265–278, 1921.

[88] Stabler, Herman, Some Stream Waters of the Western United States: U. S. Geol. Survey Water-Supply Paper 274, pp. 134–141, 1911.

obtained from ice generally contains less mineral matter than the water from which it froze. In some places, where ice is not available, snow is used. However, ice cut from a body of polluted water or snow that has drifted and picked up surface filth is more or less polluted and dangerous to health. Where there is any danger of pollution it is advisable not to drink water melted from the ice but instead to use a water cooler with the drinking water obtained in clean receptacles from a good well or spring.

RESERVOIRS

In the areas of Cretaceous and Lebo shales it is difficult and in many places impossible to obtain sufficient water for stock from wells, and the settlers in such localities have resorted to small earth reservoirs, commonly called "ponds" or "tanks," in which can be stored surface water sufficient for a considerable herd of livestock. Such reservoirs are constructed by building a dam at a suitable place across a ravine of not too steep gradient. If the dam is properly constructed the waste will be chiefly from evaporation, for the impervious shale beds prevent much loss by seepage into the ground. The dam is made of earth plowed up and scooped into place, either alone or with stones if it is not practicable to utilize concrete. A spillway for excess water should be provided. Hall [89] points out that care must be taken to prevent trash, roots, and vegetation from getting into such dams, because water will percolate along these objects, thereby removing fine particles in the dam and finally washing it out. Several types of dams for surface reservoirs have been described by Bryan.[90]

CISTERNS

In the areas of Cretaceous shales, where the inhabitants are unable to obtain supplies of potable ground water, some have collected the rainfall from the roofs of houses and barns in cisterns. Such methods of obtaining water supplies have been only partly successful, for the reason that the precipitation varies notably from year to year, and years of droughts are common; moreover, the available roof space is generally not sufficiently large.

Murdock [91] has described the various types of cisterns adaptable for such purposes, and Bryan [92] has made some calculations on the

[89] Hall, G. M., in Ellis, A. J., and Meinzer, O. E., Ground Water in Musselshell and Golden Valley Counties, Mont.: U. S. Geol. Survey Water-Supply Paper 518, pp. 46–47, 1924.

[90] Bryan, Kirk, in Ross, C. P., The Lower Gila Region, Ariz.: U. S. Geol. Survey Water-Supply Paper 498, pp. 50–61, 1923.

[91] Murdock, H. E., The Domestic Water Supply on the Farm: Montana Univ. Agr. Exper. Sta. Circ. 66, 1917.

[92] Bryan, Kirk, in Ellis, A. J., and Meinzer, O. E., Ground Water in Musselshell and Golden Valley Counties, Mont.: U. S. Geol. Survey Water-Supply Paper 518, pp. 43–46, 1924.

requisite size of cisterns and on the amount of water available by precipitation in Musselshell and Golden Valley Counties, where the rainfall is about the same as in Rosebud County.

PURIFICATION OF SURFACE WATER BY CHLORINATION

Cobleigh[93] gives the following method for purifying water that is to be used for domestic purposes:

When a surface water that has been procured at a point below human habitations or other sources of contamination is used for domestic purposes, a decided risk is involved. A water of this character should be purified before it is used for human consumption. The following procedure is recommended for purifying a contaminated water which is stored in a cistern for domestic use: Calculate the number of gallons of water in the cistern. Add to the cistern water the proper amount of the solution of chloride of lime or bleaching powder, according to the following procedure: Break up all lumps in a small portion of the powder from a can of fresh bleaching powder or chloride of lime. It has been calculated that one level teaspoonful of the dry powder will disinfect under ordinary conditions approximately 315 gallons of water. As the number of gallons of water in the cistern is known, the number of teaspoonfuls of bleaching powder required to disinfect all the water in the cistern can be calculated. In measuring the bleaching powder fill a teaspoon even full by leveling off with a small stick or lead pencil. To the measured quantity of bleaching powder add a few drops of water, stir, and make a thick paste. This operation can conveniently be carried out in an ordinary bowl. The paste is then diluted with water, and this thinner paste should then be poured into a 5-gallon or 10-gallon pail of water. Allow the sediment in this solution to settle for a few minutes. Then pour the solution into the cistern and thoroughly mix it with the cistern water. This can be done with a pail to which is attached a rope. The pail can be alternately filled with water and emptied back into the cistern to assist in properly mixing or the pail should be filled with water and then dropped from a convenient elevation back into the cistern again.

After thoroughly mixing the bleaching powder solution with the cistern water allow the action to continue for 10 minutes. Fill a drinking glass with water from the cistern and add a few drops of orthotolidin solution. If a slight yellow color appears when viewing the water through the glass placed in front of a white sheet of paper, then it is certain that the proper amount of bleaching powder has been added. When this color appears it indicates that there is an excess of chlorine in the water, which will destroy germs of the intestinal type in a very few minutes' time. If no yellow color appears on addition of orthotolidin, then more of the bleaching powder solution should be added to the cistern water. In that event add a little more of the bleaching powder solution and repeat the color test with the orthotolidin. If this procedure is properly carried out, there will be no disagreeable odors and tastes left in the water. This procedure does not introduce poisonous chemical substances into the drinking water. This method of water disinfection is perfectly safe and effective when controlled by the orthotolidin test.

The citizens of the State desirous of using this method of disinfecting cistern water may secure the necessary orthotolidin on application to the State board of health.

[93] Cobleigh, W. M., in Ellis, A. J., and Meinzer, O. E., Ground Water in Musselshell and Golden Valley Counties, Mont.: U. S. Geol. Survey Water-Supply Paper 518, pp. 48–49, 1924.

DESCRIPTIONS OF TOWNSHIPS

In the following pages the geologic formations exposed at the surface, the geologic structure, the topography and drainage, the available ground-water supplies, and the quality of water are described for each township in the county. In the townships where several formations are exposed (see pl. 1), especially in the areas of Cretaceous rocks, there are considerable variations in the ground-water conditions in the different formations and therefore in different parts of the township. But in the parts of Rosebud County where the Lance and Fort Union formations are at the surface there is a general similarity of ground-water conditions over large areas.

T. 8 N., R. 36 E.

The only part of T. 8 N., R. 36 E., that lies in Rosebud County is sec. 1, in which is the station of Ahles, on the Chicago, Milwaukee, St. Paul & Pacific Railway. Dark-gray and black fissile Bearpaw shale with a dip of about 1° SW. is at the surface throughout this section. The shale is characterized by numerous fossiliferous concretionary bands. It is highly mineralized with gypsum and calcite, and its weathered surface in many places is covered with an abundance of selenite crystals. In depressions where evaporation of surface or ground water has taken place the ground is covered with noncrystalline alkali.

Owing to the high mineralization of the rocks, no potable ground water is obtained. The few residents at the station of Ahles depend upon water hauled by the Chicago, Milwaukee, St. Paul & Pacific Railway from the company's well at Forsyth. (See p. 81.)

T. 8 N., R. 37 E.

Northeast of a line drawn approximately from the northwest to the southeast corner of T. 8 N., R. 37 E., the Judith River formation is at the surface, and southwest of this line the Bearpaw shale is at the surface. In this township the three members of the Judith River formation are not easily distinguished, but they are nevertheless present; the massive upper sandstone, so prominent in T. 7 N., Rs. 38 and 39 E., and T. 8 N., R. 40 E., is represented at most places in this township by an incoherent sandy phase. The Bearpaw shale in this township is typical and is identical with that in T. 8 N., R. 36 E. All the rocks dip southwest from the Porcupine dome, and the drainage is carried southwestward by Starve-to-Death Creek and the tributaries of Horse Creek. A series of ridges caused by the resistance to erosion of the calcareous concretionary beds in the Bearpaw shale and the hard sandy beds of the Judith River formation parallel the strike of the strata, extending across the township from northwest to southeast. The lower sandstone of the Judith River formation, which is by far the best aquifer in this formation, crops out over only a very small area in this township; therefore the supplies of water from the Judith River formation are generally poor for domestic use and drinking. However, Amelia Manser's well, in sec. 2, obtains water which, though hard, has a satisfactory taste from a sandstone in the Judith River formation at a depth of 8 feet. (See analysis 8 and fig. 11.) The Bearpaw shale does not generally yield potable water.

T. 8 N., R. 38 E.

In T. 8 N., R. 38 E., the regional dip is southwest, away from the Porcupine dome. The sandstone at the base of the Judith River formation appears in a conspicuous rim along the southwest side of the Porcupine dome. The underlying Claggett and Colorado shales, which form the center of the Porcupine dome, occupy the northeast corner of the township. An observer standing on the rim of sandstone and looking toward the north and east into the area of eroded shale several hundred feet below is impressed with the desolation of the scene. Big Porcupine Creek and its numerous tributaries drain the shale area. The drainage from the area of Judith River rocks is down the dip of these beds south and southwest toward Horse Creek and its tributaries.

Water from the Colorado and Claggett shales is uniformly poor, but in some places along Big Porcupine Creek water which is highly mineralized yet can be used for domestic purposes is obtained from the alluvium. On C. W. Johnson's ranch, in the SW. ¼ sec. 24, there is a well which obtains its water from the alluvium along the creek. This well is 28 feet deep and 6½ feet in diameter, and the water level is 8 feet above the bottom. The water is hard and highly mineralized and has an unpleasant taste. (See analysis 10 and fig. 11.)

Water obtained from the lower sandstone of the Judith River formation is soft, potable, and of good quality where the sandstone is not covered with shale. The water from the middle shale member is hard, mineralized, and nonpotable. Water of fairly satisfactory taste is obtained from the somewhat thinner upper sandstone member of the Judith River formation. A well 60 feet deep belonging to Martin Schow, in the SW. ¼ SE. ¼ sec. 20, yields water of better quality, than most of the other waters in this region, though slightly hard. (See analysis 9.) The satisfactory quality is attributed to the fact that the well begins and ends in sandstone of the Judith River formation. A well in the NE. ¼ NW. ¼ sec. 5, T. 7 N., R. 38 E., which obtains water from the middle of the Judith River formation, contains over eleven times as much mineral matter. (See analysis 12.)

No large quantities of ground water should be expected from wells near the sandstone rim, because the underground drainage is southwestward and the collecting area between the escarpment and these wells is not large.

T. 8 N., R. 39 E.

With the exception of a very small area in the southeastern part of T. 8 N., R. 39 E., where the Judith River formation crops out, the surface rocks of the entire township are the Colorado and Claggett shales. These shales are easily eroded and form a gumbo soil. All of this township is desolate and nearly barren of vegetation. The resistance to weathering of the calcareous concretionary bands within the shales produces a slight relief. The rocks in this township dip away from the Porcupine dome, toward the southeast in the eastern part, the south in the southern part, and the southwest in the western part.

The drainage is eastward and southeastward into Little Porcupine Creek and westward and southwestward into Big Porcupine Creek. The tributaries to these creeks are choked with alluvium from the shales. It is not surprising that the ground water is highly mineralized, as the shales themselves contain an abundance of gypsum and calcite.

T. 8 N., R. 40 E.

The dark-colored Colorado and Claggett shales are at the surface over most of T. 8 N., R. 40 E. The overlying Judith River formation, which is composed of sandstone at the top and the bottom with soft shale between, crops out in a belt near the eastern margin, and the upper sandstone forms a prominent hogback. Dark-brown and gray shales of the Bearpaw formation overlie the Judith River and crop out in a narrow belt along the east margin of the township. All the rocks in this township dip eastward or southeastward, at angles ranging from less than 1° to as much as 10°; the greater dips are in the northeastern part of the township. All the drainage goes southeastward into Little Porcupine Creek, by way of Hay Creek, Dry Creek, and several smaller tributaries.

The Colorado, Claggett, and Bearpaw shales support little vegetation and have an extremely barren aspect. A slight relief is produced by the resistance of the numerous thin fossiliferous limestone concretionary bands within the shales.

Potable water probably can not be obtained from the Colorado, Claggett, and Bearpaw shales or from the alluvium derived from them. The two sandstones of the Judith River formation, especially the lower one, are capable of yielding good potable water in sufficient quantity for all ordinary domestic and stock purposes, provided that in reaching the water-bearing sandstone mineralized shale is not penetrated. No potable water supplies can be obtained from the Bearpaw shale.

T. 8 N., R. 41 E.

The oldest formation in T. 8 N., R. 41 E., is the Bearpaw shale, which crops out in a strip about 1 mile wide along the west boundary. Over the remainder of this township the Lance formation crops out. All the rocks have a monoclinal dip of 2° or less toward the southeast, away from the Porcupine dome.

The tributaries to Little Porcupine and Horse Creeks have produced a dissected topography adapted to grazing, and the broad flood plain of Little Porcupine Creek affords excellent hay meadows.

Ground water from shallow wells along Little Porcupine Creek and in all the area of Bearpaw shale is hard and unfit for domestic use. Water suitable for domestic purposes is extremely scarce in the western part of the township, although there are a few small springs in the area of Lance rocks. In the eastern part of the township the Lance formation is sufficiently thick to indicate that it will doubtless be possible to obtain soft water by drilling 150 feet or more. Numerous coulees in the western part of the township are favorable locations for shallow dug wells, from which water of fair quality might be expected.

T. 8 N., R. 42 E.

In the southern part of T. 8 N., R. 42 E., the divide between Sand and Horse Creeks is capped by a small patch of the lowermost beds of the Lebo shale member of the Fort Union formation, which in this township contain considerable sandstone. All the remaining surface rocks belong to the Lance formation. The top resistant sandstone of the Lance formation dips about 1° ESE., forming a broad flat-topped divide sloping in the same direction. Away from the divide, which on the average is less than a mile wide, the surface is rough and dissected.

Supplies of hard water suitable for stock and in some places for domestic purposes can be obtained by digging shallow wells into the alluvium along Horse and Sand Creeks, and supplies of fairly good-tasting hard water can be obtained from shallow dug wells in some of the tributary coulees. H. T. Penick has a well in a deep coulee in the Lance formation in the NE. ¼ SE. ¼ sec. 27, which is 10 feet deep and 4 feet in diameter and which contained when visited about 7 feet of hard but fairly good-tasting water. Supplies of potable water can be had by drilling into the Lance formation.

T. 8 N., R. 43 E.

The Lance formation and the Lebo shale member of the Fort Union formation are about equally distributed in the eastern and western parts, respectively, of T. 8 N., R. 43 E. The regional dip is about 1° E. Sand Creek flows in a general southeasterly direction across the southwest corner of this township and has deeply incised its valley. The resistant upper member of the Lance formation forms a broad plateau for approximately 2 miles back from the steep valley wall. In the western part of the township the somber-colored hills of Lebo shale have been eroded into a typical badland topography by the waters draining into Sand Creek and its tributaries.

Water that is hard but of fair quality can be obtained from shallow depths in the valley of Horse Creek and some of its tributaries in the area of Lance rocks. The area underlain by Lebo shale is in general unfavorable for shallow wells. Soft water can be obtained by drilling 150 feet or more into the Lance formation. Ground water from the Lance formation may be tapped in the areas of Lebo rocks by drilling through the Lebo member and casing off any undesirable water that it may yield.

T. 8 N., R. 44 E.

The Lance formation is exposed in the valley of Coal Creek in sec. 12, T. 8 N., R. 44 E., but with this exception the Lebo shale member of the Fort Union formation is the surface rock. The township is drained to the east by Coal Creek and to the southeast by smaller streams tributary to the Yellowstone River.

Supplies of soft water may be had by drilling through the Lebo shale member into the Lance formation. In general, the water obtained from the Lebo shale is undesirable, but a fairly satisfactory supply of hard water has been obtained by Zeno Ottinger in the SW. ¼ SW. ¼ sec. 4, from a well 16 feet deep and 6 feet in diameter dug into the alluvial silt derived from the Lebo member. (See analysis 11.)

T. 7 N., R. 38 E.

In T. 7 N., R. 38 E., the Claggett, Judith River, and Bearpaw formations crop out. A good section of the Judith River formation is exposed in the bluff southeast of the village of Vananda. A small anticline, the center of which is about 2 miles southeast of Vananda, exposes the lower sandstone along Horse Creek, and the upper sandstone forms the top of the prominent escarpment southeast of Vananda. This upper sandstone in the south half of the township conforms to the regional structure and therefore dips southwest and south away from the Porcupine dome. Owing to the resistance to erosion of this upper sandstone, its dip slope forms the surface through the southern part of the township.

In this township the lower sandstone of the Judith River formation is a massive member and yields satisfactory water. The water from the upper sandstone is not so satisfactory as that from the lower, and the water in the middle shale member is inferior in quality. In places where the lower sandstone is covered by shale the water in the sandstone has generally been rendered unsatisfactory by the water from the highly mineralized shale above seeping into it; the same conditions hold with regard to the water in the upper sandstone where it is covered with Bearpaw shale.

The community well in the center of the village of Vananda, in the NW. ¼ sec. 5, starts in the middle shale member of the Judith River formation. It is 225 feet deep and ends in the Claggett shale. This well obtains its water from a sandy bed in the Claggett, and the water rises within 4 to 20 feet of the surface. The water is highly mineralized (see analysis 13), a condition doubtless caused by the large amount of mineral matter in the shale beds which it penetrates. This water is not so hard as some others in the region, but it has a rather unpleasant taste and is not used for drinking. The Chicago, Milwaukee, St. Paul & Pacific Railway drilled 3,357 feet at Vananda without obtaining potable water, and as a consequence the drinking water used by the village is hauled by the railroad from its well in the Yellowstone River at Forsyth. (See p. 81.)

A sample of water was taken from a bored well 1 foot in diameter and about 40 feet deep belonging to S. Sigman, in the NE. ¼ NW. ¼ sec. 5. (See analysis 12.) This water is presumed to come from a sandy lens in the middle member of the Judith River formation. It is hard and unsatisfactory for most uses; its taste is disagreeable, and it is used only for watering the chickens. A graphic representation of analyses 12 and 13 is given in Figure 11.

The Pleistocene gravel deposits in secs. 34, 35, and 36 should be a good source for potable water if they extend below the water table.

T. 7 N., R. 39 E.

A broad belt of the Judith River formation extends across T. 7 N., R. 39 E., from east to west. North of the Judith River outcrop there is a narrow discontinuous belt of Claggett shale, and south of the Judith River outcrop there is a similar narrow discontinuous belt of Bearpaw shale. The conspicuous escarpment in T. 8 N., R. 38 E., formed by the lower sandstone of the Judith River formation, does not exist in this township, where the lower sandstone is loosely cemented and not sufficiently resistant to erosion to form any notable topographic feature. The upper sandstone of the

Judith River formation in this township, however, forms a conspicuous escarpment, as it does in T. 7 N., R. 38 E. A thin veneer of Pleistocene gravel extends in a belt across the southern tier of sections. (See fig. 3.)

In this township the rocks have a regional southward dip from the Porcupine dome, with divergences toward the southeast and southwest. There is, however, one notable exception to the regional dip—an anticline whose structure is plainly observable in the upper sandstone of the Judith River has an axis trending about N. 25° E. and extending from the southwest corner of sec. 33 to the northeast corner of sec. 28. A well drilled along this axis near the middle of the north line of sec. 33 on the flood plain of Big Porcupine Creek would be near the apex of the fold and would undoubtedly reach the lower sandstone of the Judith River within less than 100 feet. This anticline is referred to as the Antwerp anticline, from the near-by station of that name. Big Porcupine Creek flows southeastward across the southwest corner of the township.

The ground-water conditions are essentially the same as in T. 7 N., R. 38 E. No samples of water were collected for analysis in this township, but the quality of water from wells is doubtless the same as from wells in similar geologic members in adjoining townships. In the SW. ¼ sec. 22, on Jacob Gould's ranch, there is a dug well 8 feet deep in the upper sandstone of the Judith River formation, which yields fairly hard but good-tasting water.

T. 7 N., R. 40 E.

From the northwest corner of T. 7 N., R. 40 E., the Claggett, Judith River, Bearpaw, and Lance formations crop out in the order named in belts extending from northeast to southwest across the township, with the Lance as the surficial formation in the south-central and southeastern parts. The lithologic features of the Claggett, Judith River, and Bearpaw formations are essentially the same as in T. 7 N., R. 39 E. Of the Lance strata only the Hell Creek member crops out in this township. The dip of all the rocks is southeast.

Most of the run-off in T. 7 N., R. 40 E., goes southeastward by Dry and Short Creeks and their tributaries, but some of it in the western part of the township goes southward and westward into Big Porcupine Creek. The most striking topographic features are the ledges formed by the resistant upper sandstone of the Judith River formation and the resistant basal sandstone of the Lance formation.

Small supplies of ground water satisfactory for domestic use and drinking may be had in most places in this township from the upper and lower sandstones of the Judith River formation, where these members are not covered with shale. The Bearpaw shale yields either no water or water of poor quality. Fairly satisfactory hard water may be obtained by digging shallow wells into the Lance formation, and soft water may be obtained by drilling 150 feet or more into the Lance formation. K. Weidenbach, whose well in the NW. ¼ sec. 34 is 252 feet deep, states that he encountered soft water at 195 feet. Several springs are known to occur near the western margin of the Lance outcrop, the lower sandstones in the Lance formation being the source.

T. 7 N., R. 41 E.

All the rocks at the surface in T. 7 N., R. 41 E., are of Lance age and dip gently east-southeast. The Quaternary alluvium of the Yellowstone River covers most of secs. 34, 35, and 36. The drainage goes southward by Little Porcupine and Horse Creeks and southeastward by Dry Creek, a tributary to Little Porcupine Creek. Because some of the Lance shales in this township are easily eroded, the surface has been considerably dissected by the streams, which have produced a rather rugged topography.

Water from shallow wells in the alluvium along the creeks is generally rather highly mineralized, hard, and often unpleasant to the taste. Its mineral content has no doubt been obtained more from the highly mineralized portions of the Colorado, Claggett, Judith River, and Bearpaw formations and the Lebo shale, which crop out upstream, than from the adjoining Lance beds, which are much less mineralized.

Soft water may be had in most places by drilling 150 feet or more into the Lance formation. The western limit of the area of the artesian basin along the Yellowstone is in the southwest corner of this township. On F. V. H. Collins's ranch, in the SW. ¼ sec. 35, a drilled well 255 feet deep yields a flow of soft but rather highly mineralized water from the Lance formation at the rate of 4 gallons a minute. The flow was encountered at a depth of 210 feet. The water contains more dissolved mineral matter than the water from any other well in the Lance formation. It also contains considerable gas. (See analyses 14 and G–14; also pp. 42 to 44 and fig. 9.)

T. 7 N., R. 42 E.

In T. 7 N., R. 42 E., there is a broad eastward-sloping table-land several hundred feet above the river, formed by the resistant top sandstone of the Lance formation. Horse Creek, the West Fork of Sand Creek, and their tributaries have dissected the country on both sides of this township to a considerable degree. A thin cover of Lebo shale caps the divide between the West Fork and the main

Sand Creek and between the West Fork and Horse Creek. The black hills in the central part of the township, which are erosional remnants of Lebo shale, are locally known as the Black Buttes.

Ground water for domestic and stock use can be obtained at relatively shallow depths from the Lance rocks in some of the tributary coulees, the most favorable places being near the bottoms of sandstone ledges in the coulees on the east side of the plateau between Horse Creek and the West Fork of Sand Creek. Soft water can be obtained by drilling 150 feet or more into the Lance strata, as in the adjoining townships.

T. 7 N., R. 43 E.

Sand Creek flows from north to south across T. 7 N., R. 43 E., exposing a belt of Lance rocks 3 miles or more in width through the center of the township. The overlying Lebo shale member of the Fort Union formation crops out on each side of this belt. The tableland caused by the resistant sandstone at the top of the Lance formation, which is so pronounced in T. 7 N., R. 42 E., is also conspicuous in this township. This plateau slopes 1° or less to the east, in conformity with the dip of the rocks. The dark-colored hills of Lebo shale, which are so well developed in the eastern and northeastern parts of the township, are in striking contrast to the underlying light-yellow and grayish Lance strata. The Quaternary alluvium of the Yellowstone River covers secs. 31 and 32 and parts of secs. 28, 33, 34, and 36.

Hard and somewhat mineralized water can be had from shallow dug wells in the alluvium along Sand Creek and the West Fork of Sand Creek. Supplies of soft water can be obtained by drilling into the Lance strata. The Barley Bros. have recently drilled a well on their ranch in the NE. 1/4 sec. 20. This well is 300 feet deep and yields good-tasting soft water. The water level is reported to be 50 feet below the surface. A gasoline engine is used for pumping the water, which is used mostly for stock, but is entirely satisfactory for domestic purposes and drinking. When this well was examined in 1923, it had been drilled only a few weeks. The pump delivered 12 gallons a minute, and the water was turbid, a condition doubtless due to the fact that there was only 70 feet of casing in the well. The casing should be extended to a greater depth.

In the NE. 1/4 sec. 8, on Joe Barley's ranch, there is a well 652 feet deep. The first soft water was reported at 70 feet and other aquifers at 280 feet and 450 feet. The water level now stands 70 to 75 feet below the surface. Recently this water has become so mineralized that stock refuse to drink it. This well may have reached the Bearpaw shale, which contains highly mineralized water. Analysis 15 shows that the water contains over 3,600 parts per million dissolved solids, which is considerably more than is customary in Lance waters. This well may very likely be restored to its former utility by sealing off the lowest water and utilizing the water obtained at the 280 and 450 foot depths. Care should be taken that the near-surface hard water is also prevented from entering the well.

T. 7 N., R. 44 E.

The Lebo shale member of the Fort Union formation is at the surface in most of T. 7 N., R. 44 E., and attains its maximum thickness of about 300 feet. The beds dip east-southeast 1° or less. The largest streams draining this township are Bull, Wilson, and Whitetail Creeks, which flow in a general southeasterly direction, exposing the Lance beds in their valleys. The upper part of the Lance formation (Tullock member) in this township contains considerable carbonaceous shale and in this respect is somewhat similar to the Lebo member of the Fort Union formation. The top sandstone of the Lance is conspicuous in this township, as elsewhere in Rosebud County.

The Lebo shale yields little or no potable ground water, but soft potable water can be obtained by drilling through this member into the Lance formation, care being taken to case off any undesirable water that might be encountered in the Lebo. Soft-water artesian wells in the Lance formation occur along the flood plain of Yellowstone River in parts of secs. 25, 35, and 36. C. W. Wilson has an artesian well in the SW. 1/4 sec. 36, which is 434 feet deep and flows at a rate of slightly less than 1 gallon a minute. The character of the water and the nature of the gas contained are shown by analyses 10 and G–10. These analyses are representative of the waters from the artesian wells along the Yellowstone River in this township.

The water from shallow wells in the alluvium along the creeks and the river is hard and in general not so palatable as the soft artesian water. The inferior quality of water in shallow wells in the alluvium on the flood plain of the river is in part due to irrigation of the flood plain.

T. 6 N., R. 38 E.

The Yellowstone River flows in a general southeasterly direction across T. 6 N., R. 38 E., entering in section 5 and leaving in section 12. The upper sandstone of the Judith River formation is exposed along the north bluff of the river almost entirely across the township, and on the south side of the river it crops out in the bluff south of the railroad in the western part of the township. Pleistocene gravel covers most of this township, but in ravines where the gravel has been removed by erosion the Bearpaw shale is exposed in the northeast corner of the township as well as through the entire south half. The alluvium of the Yellowstone River occupies a strip from a mile to a mile and a half in width on the south side of the river. The rocks in this township have a general dip of about 1° SSE. Reservation Creek and Hay Creek, which flow northward, are the chief tributaries to the river in this township.

The water obtained from the Bearpaw shale in this township, as elsewhere in Rosebud County, is highly mineralized and often unfit even for stock. George Mace states that he drilled to a depth of 500 feet in the SE. 1/4 sec. 14 and obtained only salty water unfit for domestic use or drinking. This depth would reach the lower sandstone of the Judith River formation, but, as already explained, where the sandstones of that formation are covered with Bearpaw shale or shale of the middle member of the Judith River formation, the water in the sandstones is highly mineralized, and this is probably the reason that the water obtained in Mr. Mace's well was unsatisfactory. The water which Mr. Mace now utilizes for his household is obtained from a dug well 33 feet deep and comes from the underflow of Reservation Creek. It is superior in quality to most waters in the irrigated tracts. (See analysis 18 and pl. 11.)

The waters from the shallow dug wells on the Mellon Lewis estate, in sec. 17, and on Fred McCormack's ranch, in the NE. 1/4 sec. 18, both of which are within the Yellowstone irrigation project, are very highly mineralized. (See analyses 19 and 17.) They are hard and unpleasant to the taste. Fairly satisfactory but hard water can be obtained from the alluvium north of the river.

The Pleistocene gravel that caps the hills adjacent to the river contains the most desirable water that is to be had in this township.

T. 6 N., R. 39 E.

The Yellowstone River enters T. 6 N., R. 39 E., in secs. 7 and 18, flows in an easterly direction, and leaves the township in sec. 13. In this township the river is a braided stream and has many sloughs.

The Bearpaw shale crops out in a strip along the northern boundary of the township and in the southwest corner. The Lance formation, which overlies the Bearpaw, is at the surface in most of the southeast quarter. The Bearpaw-Lance contact is well exposed along Armells Creek near the center of sec. 23. Pleistocene gravel caps the divides along the north and south boundaries of the township, and the younger Quaternary river alluvium occupies a belt of considerable width across the center. The general dip of the rocks is less than 1° ESE. The heavy sandstone at the bottom of the

Lance formation forms a noticeable escarpment in much of this township.

Here as elsewhere the Bearpaw shale yields ground water unfit for drinking and domestic purposes. The Lance formation, especially the massive basal sandstone, yields excellent water for domestic use and stock. Wellington Payne's well, in the NE. 1/4 sec. 26, is 19 feet deep and obtains its water from the bottom sandstone of the Lance formation. The water is of good quality for most uses. (See analysis 26.) Its taste is very pleasant.

The Pleistocene gravel, which in general does not exceed 40 feet in thickness, may be expected to yield good water where the water table is above its bottom.

On the north side of the river most of the flood plain is within the Hammond irrigation project. Much of the ground water in this irrigated alluvium is of poor quality. An exception is found in Bert Hammond's well, in the SW. 1/4 SW. 1/4 sec. 2. The well is 22 feet deep and 16 feet in diameter. It is in the center of the irrigation district and obtains its water from alluvium within the area of the Bearpaw shale. Nevertheless, the water, though somewhat hard, is of very satisfactory quality. (See analysis 20 and pl. 11.) The water from James McGraw's well, in the SE. 1/4 sec. 12, which is 16 feet deep and within the Hammond irrigation project, is much harder and more highly mineralized (see analysis 21), yet it is utilized for domestic purposes, drinking, and stock.

Most of the flood plain south of the Yellowstone River west of Armells Creek is within the Yellowstone irrigation project. Within this irrigated tract the shallow wells that obtain their water from the alluvium have almost without exception become too highly mineralized for domestic use. The waters from the shallow wells of Andersen & Tadsen (analysis 22), Sam Newnes (analysis 23), Dennis Myerhoff (analysis 24), and E. F. Myerhoff (analysis 25), all of which are within the Yellowstone irrigation project, contain from 6,000 to more than 10,000 parts per million dissolved salts. The average depth to the water table in the irrigated tract is about 20 feet.

The water obtained from the alluvium outside the irrigated tract is of much better quality, as shown by a comparison of the analyses above cited with analysis 27, of water from C. W. Longley's well, in the valley of Armells Creek in the SE. 1/4 sec. 23, which is east of the irrigated tract. This is a driven well 49 feet deep, which obtains its water in part, at least, from the underflow of Armells Creek and contains only about 1,600 parts per million total dissolved solids.

T. 6 N., R. 40 E.

GENERAL CONDITIONS

With the exception of the narrow outcrop of Bearpaw shale near the center of sec. 7, T. 6 N., R. 40 E., the only bedrock formation in this township is the Lance, which dips less than 1° SE. The basal sandstone of the Lance formation makes a prominent escarpment in the northwest corner of the township. The Yellowstone River enters the township in sec. 18, flows southeastward and then northeastward, and leaves the township in sec. 13. The river occupies a relatively narrow valley and meanders little in this township where it crosses the lower strata of the Lance formation. Steep bluffs have been developed on both sides of the river and culminate in a broad terrace, which stands somewhat more than 200 feet above the river and is capped with Pleistocene gravel. The gravel is especially noteworthy on the broad upland in secs. 10, 11, 14, and 15. The Yellowstone and its tributaries, the largest of which are Smith Creek and Slaughter House Creek, have developed in places lower subsidiary terraces. The river alluvium, though forming a strip about 1 mile wide in the west-central part of the township, is not so conspicuous as in T. 6 N., R. 39 E., where the Yellowstone River crosses the outcrop of Bearpaw shale.

In T. 6 N., R. 40 E., the ground-water problems are not acute, as supplies adequate for domestic use and of good quality can be obtained from several geologic sources. The Lance formation yields water of good quality for domestic and stock use, of which a typical sample is the water from the public spring along the Yellowstone Trail in the NW. ¼ sec. 28. (See analysis 43.) The water in the Pleistocene terrace gravel is of especially good quality for this region, being similar to the water from similar gravel in T. 6 N., R. 41 E., where several samples were collected. (See analyses 47 and 48.)

In the NE. ¼ sec. 16 there is a spring which flows at the rate of about 10 gallons a minute. From the field relations it is not certain whether the water comes from the lower sandstone of the Lance formation or from the Pleistocene gravel. Probably the water is derived from both formations. This water is of exceptional quality and contains less than 600 parts per million total dissolved solids. (See analysis 33.) Many people living in Forsyth haul this water to their residences for drinking.

The flood plain north of the river in the eastern part of this township is within the Hammond irrigation project, and most of the wells contain water which is highly mineralized. The water from the dug well of the Cold Spring Livestock Co., in the NE. ¼ SW. ¼ sec. 7, contains over 5,000 parts per million of dissolved salts (see analysis 28) and is representative of the waters from the alluvium in the irrigated tract. It is hard to account for the fact that a well 10 feet deep in the NE. 1/4 sec. 17, in the irrigated tract, yields water of fairly satisfactory quality, as shown by analysis 34. A driven well 14 feet deep on the E. J. Cline farm, on the flood plain south of the river, in the SE. 1/4 sec. 20, outside the irrigated area, yields water which, as shown by analysis 35, contains less than 700 parts per million total dissolved solids. These analyses are shown graphically on Plate 11.

FORSYTH

The town of Forsyth, which is the county seat and the largest town in Rosebud County, occupies parts of secs. 13, 14, 22, 23, and 24, T. 6 N., R. 40 E. In 1920 it had a population of 1,838. It is on the south bank of the Yellowstone River, on the flood plain, the southern boundary of the town being marked by a steep bluff of Lance rocks, which stands more than 200 feet above the plain. Forsyth has the facilities of two railroads—the Northern Pacific, which runs through the town on the south side of the river, and the Chicago, Milwaukee, St. Paul & Pacific, which runs along the north bank and has a small station called Forsyth at the north end of the bridge over the Yellowstone.

Present water supply.—Forsyth obtains its water supply from the Yellowstone River. The pumping plant, which was installed in 1907, is on the south bank of the river at the north end of Third Street. In 1923 it was equipped with two pumps—a centrifugal 2-stage 6-inch pump, connected directly to an electric motor, and a steam pump, which is used only in an emergency. A. Anderson, superintendent of the waterworks, reports that each pump has a daily capacity of 1,000,000 gallons and that the daily consumption for Forsyth ranges from 180,000 to 550,000 gallons.

The water in the Yellowstone River is very muddy during parts of the year, and in order to remedy this condition a sedimentation basin was constructed adjacent to the pumping plant in 1914. The basin measures 135 by 52 feet and has a maximum depth of 22 feet. The walls are concrete, and the structure is covered with a wooden roof. It is divided into three compartments by concrete walls. The water is supposed to decant over the top of one compartment into the adjoining one, depositing in each compartment a certain amount of sediment and thus decreasing the turbidity at each stage. The sedimentation basin is, however, a failure and when the river is especially muddy does not remove any considerable amount of the detrital material. The failure is, no doubt, due in part to the fact that the bottom of the basin consists of the natural alluvium, which allows a considerable amount of seepage back into the river; consequently the water does not flow uniformly from one sedimentation compartment into the next but fluctuates as the level of the water in the basin fluctuates with the river level. A concrete bottom would improve this sedimentation basin, but there may be additional mechanical difficulties. The total capacity of the basin is about 800,000 gallons.

The water from the sedimentation basin or from the river when that is clear is pumped, after chlorination, either into the mains or into a concrete reservoir situated south of Forsyth on a bench about 100 feet above the town. From this reservoir the water is distributed to the town by gravity through 6-inch or 4-inch mains.

Railroad water supplies.—The two railroads have their own water supplies. Near the south bank of the Yellowstone River, on Willow Street at the end of Seventh Avenue, the Northern Pacific Railway maintains a pumping plant equipped with a pump having a maximum capacity of 35,000 gallons an hour, driven by a 32-horsepower kerosene engine. The water from the river is pumped into a sedimentation basin 125 feet long and 60 feet wide, divided into three compartments. This basin is much more successful than the one installed by the town of Forsyth, but sample 32, collected on September 29, 1923, during a period of very high water, shows that the water is slightly turbid even after going through the sedimentation system. From the settling basin the water is pumped through a 5-inch main into a standpipe on the Northern Pacific right of way.

The Chicago, Milwaukee, St. Paul & Pacific Railway obtains its water in a rather unusual way. Several hundred feet from the north bank of the channel of the river a well has been constructed on a sand bar. (See pl. 12.) The top of the well is approximately level with the river surface at times of low stage. Edward Murray, district engineer, states that this well is 12 feet deep and 18 inches in diameter, with brick walls and concrete top. Gravel was encountered from the top to the bottom of the well. The water from this well is therefore contributed from the underflow of the river, and it is very clear, in contrast to the turbidity of the water from the sedimentation basins of the Northern Pacific Railway and the town of Forsyth during high stages of water. Sample 31, which was collected from this well on the same day that No. 32 was collected from the Northern Pacific sedimentation basin, shows that there is no essential difference in chemical character of water between the underflow and surface flow of the Yellowstone River. The water is pumped from the well through a 5-inch main by a centrifugal pump driven by a 15-horsepower kerosene engine into a standpipe near the Chicago, Milwaukee, St. Paul & Pacific Railway station. Mr. Murray reports that about 114,000 gallons in each 24 hours is pumped from the well without any diminution in supply or any roiliness. Besides being utilized by the railroad for locomotives, the water from this well is hauled by water cars to Vananda, Ahles, Ingomar, and other stations which are unable to obtain a satisfactory domestic water supply.

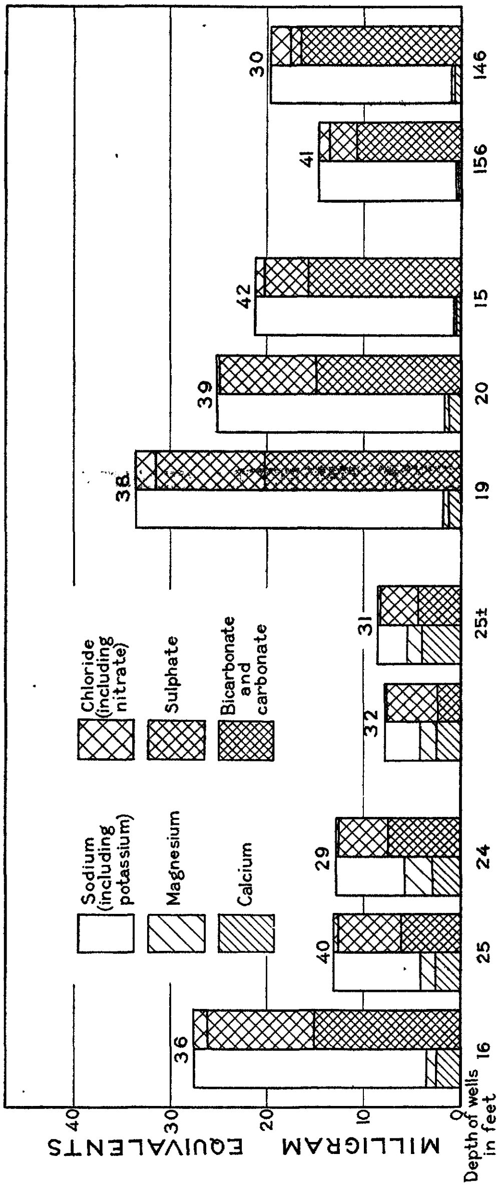


FIGURE 14.—Graphic representation of analyses of surface and ground waters at Forsyth

Ground-water conditions at Forsyth.—In the town of Forsyth ground water is encountered in the alluvium on which the town is built, at depths of 8 to 20 feet. On account of the likelihood of contamination from outhouses this shallow ground water is not to be recommended for development for general domestic use, though in some places it may be safe for drinking.

As is shown in Plate 12 the ground water is comparatively soft near the base of the bluff south of Forsyth and gets progressively harder toward the river. (See analyses 38, 39, 42, 41, and 30 and fig. 14. (This variation in hardness can be accounted for by the fact that much of the water which falls on the bluff readily percolates through the cap of Pleistocene gravel down into the Lance formation and is softened during its passage through these sandstones and shales. This softening is no doubt accomplished within 125 feet and possibly less. The water table slopes toward the valley, and the softened ground water flows away from the bluff toward the river. Gradually this soft water becomes admixed with the hard ground water in the alluvium of the flood plain, which has percolated through only 40 feet or less of alluvium and therefore has not been softened. The result is a gradation from soft to hard water from the south bluff northward toward the river. The foregoing statements regarding the hard and soft waters apply only to wells 40 feet or less in depth and not to wells that penetrate the Lance beds below the alluvium.

The alluvium at Forsyth is reported by drillers to be from 18 to 40 feet thick with the average closer to the latter figure. Below the alluvium there is about 125 feet of Lance rocks, of which the lower 25 feet is sandstone. This sandstone in the lower part of the Lance formation, as elsewhere in Rosebud County, yields soft water that is very satisfactory for domestic purposes. The well of J. E. Edwards, on Eleventh Avenue between River and Park Streets, is 146 feet deep and obtains its water from Lance strata. The water rises within 6 feet of the surface; it is relatively soft and contains 1,100 parts per million dissolved solids. (See analysis 30.) W. H. Kelley has a well of similar character, on the corner of Fifth Avenue and River Street. This well is 156 feet deep, the water rises within 13 feet of the surface, and its source is the lowermost Lance strata. The water is soft and pleasant tasting; it contains 860 parts per million total dissolved solids. (See analysis 41.)

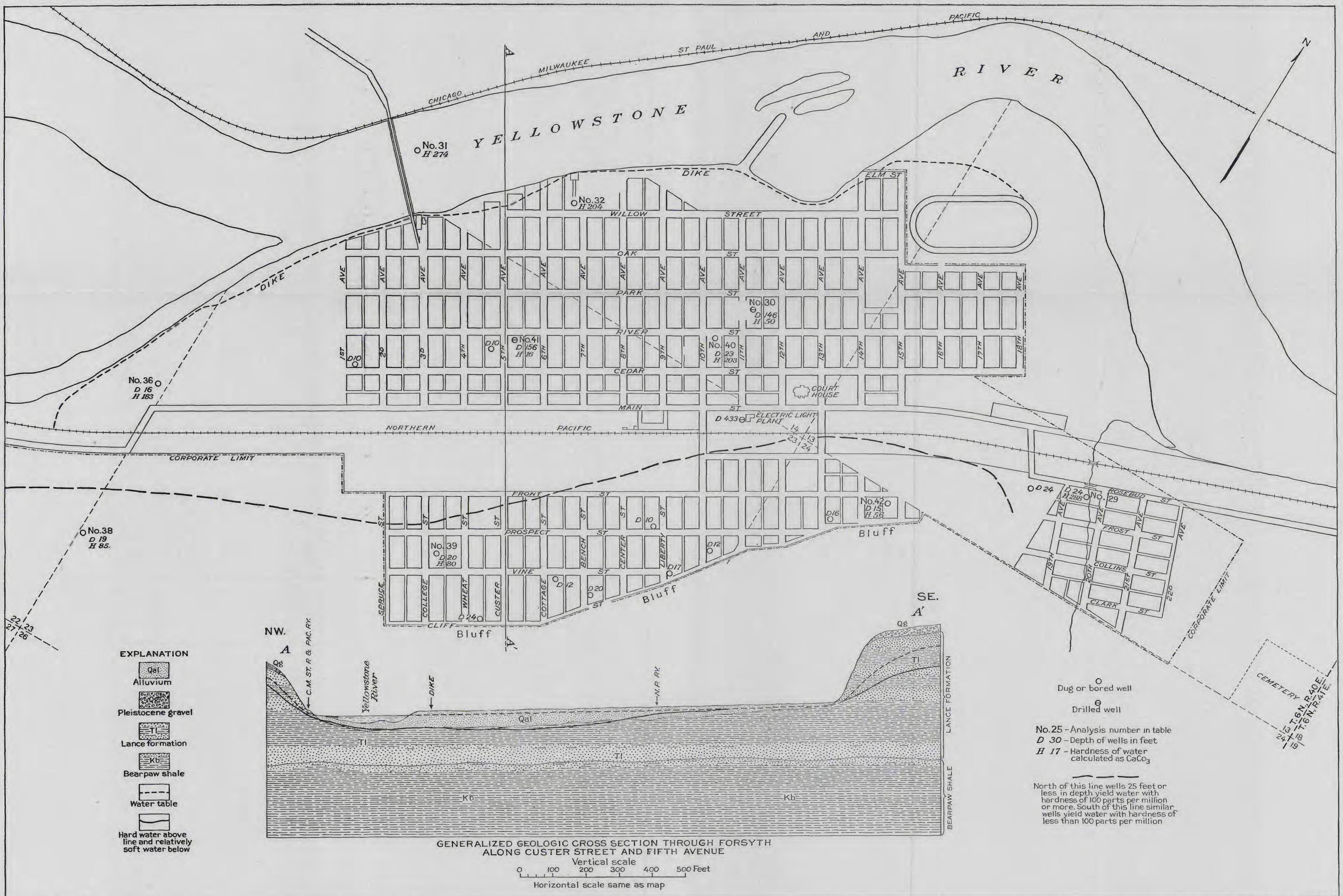
Prospective town water supply.—Several shallow wells obtaining water from the alluvium of the flood plain on which the town is built would, no doubt, yield an adequate supply of water for Forsyth, but from sanitary considerations it would not be advisable to develop a water supply from the alluvium. So far as its mineral content is concerned, the water from the alluvium north of the Northern Pacific right of way (see analyses 29, 33, and 40) would be satisfactory for drinking, domestic and industrial use, and irrigation. The water from shallow wells south of the Northern Pacific, though in general soft (see analyses 38, 39, and 42), is more highly mineralized than the water from the alluvium north of the railroad, and though satisfactory for drinking and domestic purposes, could not be utilized for irrigating lawns and gardens.

A water supply for Forsyth could very probably be obtained by drilling several wells into the basal sandstone of the Lance formation, which, according to drillers, is reached at about 125 feet below the town. The water in this basal sandstone would not only be recharged by water from precipitation at the outcrop but also by water from the river, where it crosses the outcrop of the sandstone near the west boundary of the township. But this sandstone at the bottom of the Lance formation yields water of the soft sodium bicarbonate type (see analyses 30 and 41), which has been found to be unsatisfactory for gardens and lawns, and this fact should preclude any proposed development from the Lance formation for a town supply.

The best water near Forsyth is to be had from the Pleistocene terrace gravel, which forms the so-called Forsyth Flats, in T. 6 N., R. 41 E. This water is of exceptional quality for Rosebud County (see analyses 47 and 48), and it seems that there is an ample quantity to supply the town, but no attempt should be made to develop a water supply from the gravel without putting down one or more test wells and keeping an accurate record of the yield in order to determine definitely if there is an adequate supply. The thickness of the gravel and additional data regarding the ground-water conditions on Forsyth Flats are given in the description of T. 6 N., R. 41 E. The nearest point to the town of Forsyth at which it would be advisable to make such a test is in the SE. ¼ sec. 17, T. 6 N., R. 41 E., about 2 miles from the town limits and from the nearest water mains. The cost of installing a pipe line for this distance of 2 miles would be considerable; furthermore, if a well for a town supply should be developed on Forsyth Flats it would probably be necessary to construct a reservoir on the flats. As they are 200 feet or more above the town, the water could be distributed to the town by gravity.

After giving due consideration to all other possible sources of water supply for Forsyth the writer believes that the best place for the town to undertake to develop a supply which will be of satisfactory quality and not turbid is on a gravel bar in the bed of the Yellowstone River near its south bank. Although there is more than one location which might be utilized, the gravel bar east of the wing dam at the north end of Eleventh Avenue is regarded as a satisfactory place for putting down such a well. (See pl. 12.) The type of well now being used by the Chicago, Milwaukee, St. Paul & Pacific Railway would be satisfactory, but it should probably have a diameter of several feet instead of 18 inches or there should be several 18-inch wells to insure a sufficient supply of water during the dry seasons. One or more such wells constructed so that the top of the well in the gravel bar would be not far above the low stage of the river could be relied upon throughout the year to furnish an ample supply of clear water that would be satisfactory for all domestic and agricultural purposes, though it might not be economically utilized in a steam laundry without softening. The chemical character of the Yellowstone River water on September 29, 1923, is shown by analyses 31 and 32. Water obtained from a well in the river would be desirable for drinking, provided that it was chlorinated as the river water is at the present time.

The cost of constructing a well of this type would be relatively small, and only a few feet of additional pipe line would be required in order to connect with existing water mains. Whether it would



MAP AND GEOLOGIC CROSS SECTION SHOWING GROUND-WATER CONDITIONS AT FORSYTH be possible to utilize the present pumping plant or whether it would be necessary to install a new plant or move the old one would depend somewhat upon the location of the well. These engineering features do not come within the scope of a ground-water investigation.

T. 6 N., R. 41 E.

The oldest and only rocks other than Pleistocene gravel and alluvium which crop out in T. 6 N., R. 41 E., are of Lance age. The erosive action of the Yellowstone River, which flows in a northeasterly direction across the northern part of the township, has developed a bluff of Lance strata 175 feet or more in height on the south

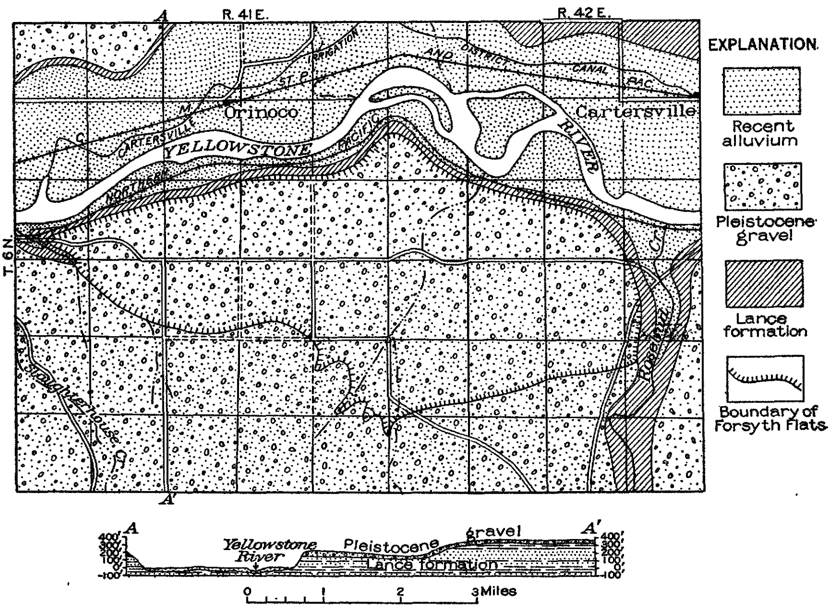


FIGURE 15.—Geologic map and cross section of Forsyth Flats. The vertical scale of the section refers to river level

bank. South of the river the Lance strata are capped with Pleistocene gravel of an average thickness of 50 feet. Overlying the gravel is a few feet of sandy silt, which makes an excellent soil. The Pleistocene terrace gravel immediately south of the river comprises part of the well-developed 200-foot terrace which is conspicuous along the Yellowstone River in Rosebud County. This terrace, which has a gentle southward slope of a few feet to the mile, is known as Forsyth Flats. It terminates in the southern part of the township in a higher terrace, which in turn grades into other terraces of greater and less altitude. (See pl. 10, *A*, and fig. 15.)

Most of the country north of the river is underlain with alluvial material of the flood plain. The southern part of the flood plain north of the river is within the Cartersville irrigation project. Little Porcupine and Horse Creeks, the only large tributaries to the Yellowstone River in this township, flow southward across this part of the flood plain.

The rocks in T. 6 N., R. 41 E., dip gently east-southeast from the Porcupine dome, and the west edge of the central Montana artesian basin is in this township. Along the flood plain there are several artesian wells, which obtain their flows from the basal sandstone of the Lance formation. Noteworthy among these is the Peter Jackson well, in the SW. ¼ sec. 10, which is 243 feet deep. Mr. Jackson reported that it flowed at the rate of 37 gallons a minute when first drilled in July, 1923. On October 6, 1923, it flowed 20 gallons a minute. This well yields considerable hydrogen sulphide, a feature which is unusual in these artesian wells. (See analyses 46 and G–46.) Artesian flows are not obtained along the bluff south of the river.

Good water for domestic use may be obtained from Lance strata south of the river, but as the overlying Pleistocene gravel yields an ample supply of ground water which is excellent for drinking and stock and satisfactory for irrigation, it is rarely necessary to penetrate the Lance formation for a supply. John Borer's well, in the SW. ¼ sec. 16, and B. A. Thomas's well, in the SW. ¼ sec. 17, both obtain their water from the Pleistocene terrace gravel, and the analyses (Nos. 47 and 48) show that the water, though slightly hard, contains less than 400 parts per million total dissolved solids and that its quality is satisfactory for domestic and industrial uses and irrigation. The average depth to the water table in this area of Pleistocene gravel is about 30 feet.

The alluvium at some places along the Yellowstone River yields water which is satisfactory for drinking and domestic use. The 15-foot driven well on the Jacobi ranch in the SE. ¼ sec. 8, within 200 feet of the channel of the river, obtains its water from river alluvium; nevertheless its water is soft. (See analysis 44.) The Stevens 20-foot driven well, in the NW. ¼ NW. ¼ sec. 10, is within 100 feet of the Cartersville irrigation ditch, and the water is satisfactory for most uses. (See analysis 45 and pl. 11.)

T. 6 N., R. 42 E.

GENERAL CONDITIONS

The oldest rocks exposed at the surface in T. 6 N., R. 42 E., belong to the Lance formation, and the Pleistocene gravel here overlies the Lance strata. The gravel caps the highest hills in the southern part of the township (see fig. 3), where it averages 40 feet in thickness. The eastern edge of Forsyth Flats lies west of Rosebud Creek in this township. The Yellowstone River, which flows in a general easterly direction across the township, has developed a flood plain about 2 miles wide on the north side of the river, and a considerable part of this fertile strip has been reclaimed by the Cartersville irrigation project. Rosebud Creek is the only large tributary to the Yellowstone in this township.

The ground-water conditions at Rosebud are discussed below and the following statements refer to the ground-water resources in the remainder of the township.

Almost all of the flood plain in this township south of the Cartersville irrigation ditch is within the area of artesian flow. (See pl. 1.)

Flowing wells, which obtain their water from the Lance formation, are from 130 to 500 feet in depth, and yield from half a gallon to 4 gallons a minute. The water is soft and is satisfactory for stock and domestic purposes, though rather poor for tea and coffee. It can not be successfully utilized for irrigation. (See analyses 49, 50, and 54 and fig. 9.)

In the southeastern and southwestern parts of the township, in places where the water table is above the base of the Pleistocene gravel, good water is to be had from the gravel. There are several springs on Butte Creek, the water from which comes from Pleistocene gravel and sandstone in the Lance formation. There are several good springs in the SW. ¼ sec. 24, on William Droegemueller's place. One of these springs, which was being used for watering stock, yielded 3 gallons a minute. The water used at B. H. Droegemueller's house is obtained from a hole 1½ feet deep in Lance sandstone in the side of the bluff, approximately 50 feet above the creek. This water is satisfactory for most purposes. (See analysis 55.)

The alluvium along Rosebud Creek yields water similar in character to that yielded by alluvium along this creek in T. 5 N., R. 42 E.; analysis 69 is typical of the water from the alluvium in both townships.

In general the water in the irrigated alluvium of the flood plain north of the river is highly mineralized and unfit for domestic use, but at some places in this irrigated district it is satisfactory, though slightly hard; for example, the Polzin Bros.' well, in the NE. ¼ NE. ¼ sec. 12, which is in alluvial gravel and is 10 feet deep, yields a hard but fairly pleasant-tasting water containing less than 1,000 parts per million total solids. (See analysis 51.)

ROSEBUD

Rosebud, on the Northern Pacific Railway, is, next to Forsyth, the largest community in the area covered by this report. In 1920 it had a population of 445. The town lies south of the river, on a narrow strip of the flood plain. Bluffs of Lance rocks covered with Pleistocene gravel rise to the south. Butte Creek, a short tributary to the Yellowstone, empties into the river just east of the town. The people of Rosebud obtain their water supply partly from wells in the Lance formation and partly from wells in the river alluvium. Wells 150 feet or more deep, extending into the Lance formation, yield soft water. The artesian pressure was sufficient to produce a flow in at least two wells at Rosebud, but flowing wells can not be predicted with certainty at the town. One flowing well, which is owned by Joseph Muggli, is reported to be 402 feet deep. It is on a bench about 25 feet above the river, and flows at the rate of half a gallon a minute. Analysis 53 shows that this water belongs to the soft sodium bicarbonate type. Somewhat hard water, satisfactory for most domestic purposes, may be had from the alluvium of the river in wells less than 50 feet in depth, and many of the inhabitants of Rosebud depend upon wells of this type, but such wells can not be regarded as wholly sanitary because of the possibility of pollution from numerous outhouses and barns. Sample 52 was taken from a well 30 feet deep in river alluvium. This water, which contains over 700 parts per million total dissolved solids, is fairly hard, but the owner, Joseph Muggli, has found it satisfactory for irrigating his garden, a quality which the soft water from his deeper well (No. 53) does not possess.

T. 6 N., R. 43 E.

The Yellowstone River flows in a general southeasterly direction across T. 6 N., R. 43 E., entering the township in sec. 7 and leaving it in sec. 24. The oldest rocks in the township, which are of Lance age and which dip less than 1° SE., are well exposed along the bluffs of the river and Sweeney Creek.

Terraces of Pleistocene gravel are particularly well developed on the bluffs south of the river. These terraces, which are of varying altitude, grade into one another; the highest is between 150 and 300 feet above the river. The broad terrace that embraces most of secs. 16 to 21 is very similar to Forsyth Flats (see p. 84) and is probably to be correlated with it. Like Forsyth Flats, this terrace slopes gently southward away from the river, at an angle of about 2°. North of the river essentially all of T. 6 N., R. 43 E., is covered with alluvium.

Flowing wells yielding soft water may be obtained on the flood plain north of the Yellowstone River almost anywhere south of the irrigation ditch by drilling 200 to 600 feet into the Lance formation. The water from these wells is suitable for stock and domestic use but not for irrigation. (See analyses 57, 59, 60, 61, 62, and G–57, G–59, G–62.)

There are a number of springs along the course of Sweeney Creek, and they are especially plentiful near its mouth. The water is derived from the Lance sandstone and coals and from the Pleistocene gravel and is of good quality. A spring or small group of springs in the SE. 1/4 SE. 1/4 sec. 21, most of the water of which is derived from Pleistocene gravel, supplies the Northern Pacific Railway standpipe at Joppa, to which the water is conducted by a 4-inch pipe.

Water of satisfactory quality for domestic and stock use can be obtained from shallow wells in the Pleistocene gravel south of the river and from the sandstones of the Lance formation below the gravel. The alluvium of the flood plain south of the irrigation ditch yields water which is generally unfit for domestic use and poor for stock, as illustrated by the waters from the Berry and Hawley wells. G. W. Berry's driven well, 22 feet deep, in the SE. 1/4 sec. 5, yields an undesirable water with over 6,000 parts per million of dissolved material. (See analysis 58.) The water in W. L. Hawley's 20-foot dug well is somewhat better but is very hard and contains over 3,500 parts per million of total solids. (See analysis 63.)

Sand Creek, West Fork, and Sweeney Creek are the only large tributaries to the Yellowstone River in T. 6 N., R. 43 E. The alluvium along Sand Creek in this township and for some miles upstream yields water which is rather highly mineralized, as illustrated by analysis 56 of water from Fred Frederickson's well, which shows 3,830 parts per million total solids. This well is in the NW. 1/4 NW. 1/4 sec. 3, outside the irrigated district, and is 61 feet deep. The alluvium from Sweeney Creek yields hard water which is satisfactory for domestic use and stock.

T. 6 N., R. 44 E.

The Yellowstone River flows across T. 6 N., R. 44 E., in a northeasterly direction from sec. 19 to sec. 1. The oldest rocks that the river exposes belong to the Lance formation. In the bluffs south of the river the Fort Union strata crop out, and along Graveyard Creek the entire thickness of the Lebo shale member is revealed. These rocks have a gentle monoclinal dip of less than 1° E. In this township the upper 200 feet of the Lance formation has considerable carbonaceous material and resembles the Lebo. Pleistocene gravel covers these rocks in many places along the bluffs on the north and south sides of the river. The river alluvium is particularly well developed south of the river, where it forms the broad flat known as Hathaway Bottoms. Coal Creek, Iron Jaw Creek, and Graveyard Creek are the principal tributaries of the Yellowstone River from the south, and Bull Creek from the north.

Flowing wells have been obtained at almost every prospective site along the flood plain of the river in this township south of the Cartersville irrigation ditch and north of the Northern Pacific Railway, and a flow was obtained on the bench above the flood plain in the NW. ¼ sec. 22. The water from the flowing and nonflowing wells in the Lance formation is soft. The Lebo shale can not be expected to yield satisfactory water for domestic use. The Pleistocene gravel will yield good water. The water from the alluvial fill of Coal, Iron Jaw, Graveyard, and Bull Creeks is hard but otherwise satisfactory.

T. 5 N., R. 38 E.

The six western sections of T. 5 N., R. 38 E., are in Treasure County, the county adjoining Rosebud on the west. The Bearpaw shale crops out at the surface over most of the north half of this township and the Lance formation in the south half. The well-defined sandstone member at the bottom of the Lance formation stands in contrast with the underlying dark-colored Bearpaw shale. The regional dip of the rocks in this township is about 1° SSE.

Reservation Creek, the only large stream in this township, flows northward to the Yellowstone River across the eastern part of the township. There is considerable alluvium in the valley of this creek at some places, and the adjacent divides are capped with terrace gravel.

The water from the Bearpaw shale is very poor, as is shown by the well of H. J. Chapin, in the NW. ¼ sec. 14, which is 42 feet deep. (See analysis 64.) The basal sandstone of the Lance formation yields satisfactory water from wells and also at some places from springs. The alluvium of Reservation Creek, in general, will yield hard water satisfactory for domestic and stock supplies. The water in the terrace gravel on the high divides, is doubtless of good quality and is probably similar to that in the terrace gravel in T. 6 N., R. 41 E. (See analyses 47 and 48.)

T. 5 N., R. 39 E.

The Bearpaw shale crops out in secs. 5 and 6 of T. 5 N., R. 39 E. Throughout the remainder of the township the Lance formation is exposed at the surface. The Pleistocene terrace gravel, which is well developed to the north in T. 6 N., R. 39 E., is also present on the divides in this township. Armells Creek, a tributary to the Yellowstone River, flows northward across the township, and along the flood plain of this creek there are strips of alluvium almost a mile in width, which in most places are cultivated.

The Bearpaw shale does not yield potable water. A well in the valley of Armells Creek in the NE. ¼ NW. ¼ sec. 11, 180 feet deep, is reported to have had a very small flow when first drilled, but when examined two months later by the writer the well did not flow. The well on J. T. Garland's ranch, in the NW. ¼ sec. 14, is 143 feet deep, and the water is reported to come within 20 feet of the surface. These wells are in Lance strata and yield soft water. (See analyses 113 and 114.) Each yields sufficient water for 25 men and 50 head of stock, with no apparent tendency toward depletion of the supply.

The Pleistocene gravel will doubtless yield water of a quality satisfactory for domestic purposes, stock, and irrigation. The water from the alluvium along Armells Creek is hard and in general too highly mineralized for drinking but is said to be satisfactory for irrigation. The water from a well 23 feet deep in the NE. ¼ sec. 26, belonging to W. H. Hardy, is hard and contains over 4,800 parts per million total solids. (See analysis 65.) On Mr. Hardy's ranch in the SW. ¼ NW. ¼ sec. 25 there is a spring that yields hard water containing over 2,000 parts per million. (See analysis 115.)

T. 5 N., R. 40 E.

The Lance formation is at the surface over most of T. 5 N., R. 40 E., but in the southern and southeastern parts of the township the Lebo shale member of the overlying Fort Union formation crops out, and in sec. 36 there are some strata which belong to the Tongue River member of the Fort Union formation. Gravel caps most of the divides. Smith Creek flows northward to the Yellowstone River across the middle of T. 5 N., R. 40 E.

Soft water can be obtained by drilling wells 150 feet or more into the Lance formation. A spring on B. M. Hamre's ranch, in the SW. ¼ sec. 20, issues from a coal or carbonaceous bed in the Lance formation and yields hard but otherwise satisfactory water. (See analysis 66.) It is reported never to go dry or freeze and to yield sufficient water for 100 cattle the year round. Springs yielding good water are also reported to occur in the SW. ¼ sec. 20, NE. ¼ sec. 30, and NW. ¼ sec. 34. The Lebo shale member of the Fort Union formation, which rests on the Lance formation, will yield water of inferior quality. There is little doubt that the high-level gravel will yield water of satisfactory quality where it is not drained. The water from the alluvium of Smith Creek is satisfactory in some places for domestic use, but in other places it is very poor. It is generally satisfactory for irrigating lawns and gardens.

T. 5 N., R. 41 E.

The oldest rocks that crop out in T. 5 N., R. 41 E., belong to the Lance formation. The Lebo shale member of the Fort Union formation is well developed in the north-central and southwestern parts of the township, and the overlying light-colored beds of the Tongue River member of the Fort Union formation are present in a part of sec. 31. The terrace gravel which is so prominent to the north in Forsyth Flats (T. 6 N., R. 41 E.) grades into higher-level gravel in this township. The rocks in T. 5 N., R. 41 E., dip southeastward, away from the Porcupine dome, at an angle of less than 1°.

Slaughter House Creek, a tributary to the Yellowstone River, flows northwestward across the township, and West Rosebud Creek, a tributary to Rosebud Creek, flows eastward across the southeastern part. In the area of Lebo shale these creeks and their tributary coulees have developed a rugged, broken topography.

Wells drilled 150 feet or more into the Lance formation will yield soft water. A well 225 feet deep, belonging to W. C. Smith, in the SE. 1/4 sec. 18, is typical. The water obtained from it is used for domestic purposes and stock. In coulees where sandstone of the Lance formation is exposed and the adjoining upland is covered with terrace gravel conditions are favorable for springs. Such conditions exist along many of the tributaries to Slaughter House Creek in the northern part of the township. In the NE. 1/4 sec. 7, on J. A. Kenealy's ranch, there are several springs with an average yield of 4 gallons a minute. The taste of this water is pleasant; it contains approximately 500 parts per million of total solids. (See analysis 67.) The water is used successfully for stock, drinking, domestic purposes, and irrigation. At J. P. Mitchell's residence, in the SE. 1/4 sec. 28, in the valley of West Rosebud Creek, a dug well 32 feet deep obtains water from a coal bed in the Lance formation. (See analysis 68.)

The Lebo shale in general does not yield satisfactory water, especially in shallow wells. The terrace gravel is best developed in the northeast and northwest corners of this township, and good water can be obtained from it in places where it is sufficiently thick. At many places in the valley of Slaughter House Creek, especially in the northern part of the township, water that is hard though generally satisfactory for domestic use, stock, and irrigation can be obtained from the alluvium.

T. 5 N., R. 42 E.

Rosebud Creek flows northward to the Yellowstone River across the center of T. 5 N., R. 42 E., through a deep valley cut in the Tullock member of the Lance formation. Back from this Lance escarpment in the eastern part of the township the Lebo shale member of the Fort Union formation is present, and some of the lighter-colored rocks of the younger Tongue River member are present in the southeast corner of the township. The regional dip of the rocks is less than 1° ESE. Terrace gravel is best developed in the northeast corner of the township. The alluvium of the meandering Rosebud Creek forms a strip half a mile or more in width in many places. This land is used mostly for alfalfa hay meadows.

The topography of this township is very rough and broken because of the many coulees tributary to Rosebud Creek, but on the intervening divides the rim-rock sandstone at the top of the Lance formation has given rise to flat-topped mesas. In the area of Lebo shale the topography is especially rugged. The western edge of the dissected Rosebud Buttes extends into the northeastern part of this township.

Soft water can be obtained by drilling wells 150 feet deep or more into the Lance formation, but according to reports no flows have been obtained in this township, though several wells have been drilled on Rosebud Creek, which is the most favorable place for prospecting. The well of Walt Kennedy, on the flood plain of Rosebud Creek in the SE. ¼ sec. 8, is 570 feet deep, ends in the Lance formation, and is reported to have a water level within 3 feet of the top. The well on Harry Kennedy's place, in the SE. ¼ sec. 29, on a bench about 10 feet above the flood plain of the creek, is 92 feet deep, yields soft water, and has a water level 15 feet below the surface.

In many of the wells less than 50 feet deep near Rosebud Creek the water, which is derived from the alluvial material on each side of the creek, is not satisfactory for domestic use. The quantity and quality of water in wells of this type depend upon the underflow of the creek, and in summer the water is generally of poor quality. A 20-foot dug well on Walt Kennedy's ranch, in the SE. ¼ sec. 8, yields water that is hard and contains over 2,000 parts per million of total solids. (See analysis 69.) Small supplies of water sufficient for a family can be obtained from dug wells in the Lance sandstone in the coulees tributary to Rosebud Creek.

T. 5 N., R. 43 E.

The Lance formation crops out along Sweeney Creek, and overlying the Lance beds the entire thickness of the Lebo shale member of the Fort Union formation is well exposed along Sweeney Creek and in the northern part of the township. The upper light-colored member (Tongue River) of the Fort Union formation crops out at the surface over the central, southern, western, and southwestern parts of the township. The southern part, especially secs. 20, 27, 28, 29, 32, 33, and 34, is underlain by the soft light-colored shale and sandstone of the Tongue River member. Progressively higher beds of the Fort Union formation crop out toward the west, culminating in the Rosebud Buttes, in the west-central part of this township. These buttes, which are the most prominent topographic feature in the central part of Rosebud County, are due to the resistance to erosion of clinkered sandstone and shale formed by the burning of an underlying coal bed at about the horizon of the Rosebud coal,[94] or perhaps slightly above. The topography of the area adjacent to these buttes, on the north is extremely rugged. Pleistocene terrace gravel is present in abundance on the slopes for several miles west of Sweeney Creek. It was probably deposited by a tributary to the Yellowstone River at the same time that the gravel of the broad terrace in this township was laid down.

Wells drilled 150 feet or more into the Lance formation along Sweeney Creek will yield soft water. The areas of Lebo shale, in general, are unfavorable for water supplies from drilled wells. The Fort Union strata above the Lebo member yield good water in quantities sufficient for domestic use and stock. The water from A. M. Moleworth's dug well, in the SE. ¼ sec. 20, which is 26 feet deep, is typical of that obtained from shallow wells in these Tongue River rocks. This water, though hard, contains less than 700 parts per million of dissolved solids. (See analysis 70.)

Where the terrace gravel is not above the water table it will generally yield water of good quality. Shallow dug wells in the alluvium of Sweeney Creek generally yield water that is hard but otherwise satisfactory for domestic use, drinking, and stock. George Jackson's dug well, 30 feet deep, in the SW. ¼ sec. 24, and J. E. Bott's dug well, 10 feet deep, in the NE. ¼ sec. 33, obtain their water from the alluvium of Sweeney Creek and the underlying Fort Union rocks. The sample for analysis 71 was collected from a well of similar type in the SE. ¼ SW. ¼ sec. 30, T. 5 N., R. 44 E.

T. 5 N., R. 44 E.

The Lance formation crops out in the beds of Iron Jaw, Graveyard, and Sweeney Creeks on the northern and southwestern edges of T. 5 N., R. 44 E. The Lebo shale is exposed at the surface around the northwestern, northern, and western edges of the township, and in the northwest corner the outcrop of this shale is at least 2 miles wide. In the northern part of the township there are considerable beds of clinker, but in the southern part there are fewer burned coal beds and most of the topography is of the smooth undulating type, in many places characteristic of the lowermost strata of the Fort Union formation. Gravel is present in the northeastern part of this township.

Soft water of good quality can be obtained by drilling into the Lance formation. In general the Lebo shale will not yield much water, and the quality at many places is inferior. Water of fairly

[94] Dobbin, C. E., op. cit.

satisfactory quality can generally be obtained from wells 40 feet deep or less in the small coulees in the Fort Union Upland. G. S. Ashman's well in the SE. 1/4 SW. 1/4 sec. 30, which is 19 feet deep, obtains hard water from the alluvial gravel of Sweeney Creek. The water stands 4 feet above the bottom of the well. (See analysis 71.) Lloyd & Ball have a dug well 12 feet deep in the SW. 1/4 sec. 31 which yields hard alkaline water.

T. 4 N., R. 39 E.

Rocks of the Lance formation are exposed at the surface over most of T. 4 N., R. 39 E., but there is a considerable area of Fort Union strata, including the Lebo shale member, in the west central and southwestern parts of the township. Overlying the highest Fort Union rocks is a gravel terrace, the top of which, according to Dobbin,[95] stands at an altitude of 3,650 feet, or about 1,000 feet above the Yellowstone River. Terrace gravel is present also at lower levels in the northern and northeastern parts of the township. The bedrock in this township dips gently southeastward.

Reservation Creek, a tributary to the Yellowstone River, drains the western part of this township, and the tributaries of Armells Creek drain the remainder. Springs and small seepages are common along Reservation Creek, and most of the water is contributed by sandstones of the Lance formation. The relative abundance of springs in the Lance rocks in this township is probably due to the overlying terrace gravel deposits, which absorb much of the rain. Soft water may be had by drilling wells 150 feet or more into the Lance formation. (See analysis 73.)

The Lebo shale either yields no water at all or water of poor quality. The Tongue River member of the Fort Union and the Lance formations yields water of satisfactory quality. The Tongue River member is mostly covered by gravel, which averages 55 feet in thickness,[95] and yields water where it is not above the water table. A 15-foot dug well on W. R. Kinkade's ranch, in the NE. 1/4 sec. 6, yields a pleasant-tasting hard water from the alluvial gravel of Reservation Creek.

T. 4 N., R. 40 E.

In T. 4 N., R. 40 E., Armells Creek has cut a valley several hundred feet deep in which the Lance formation is well exposed. At the top of the Lance formation there is a well-developed escarpment on both sides of the creek. The Lebo shale member of the Fort Union formation is present on the higher divides in the eastern and southern parts of this township. The regional dip of the rocks is less than 1° slightly south of east.

[95] Dobbin, C. E., op. cit.

Armells Creek, which flows northward to the Yellowstone River, is formed by the union in sec. 21 of East Fork and West Fork. These streams and their tributaries have dissected the surface of this township considerably, so that it is rather rough except on some of the divides, where the top sandstone of the Lance formation has resisted erosion and formed a relatively smooth-topped mesa, and along the flood plain of Armells Creek.

Soft water for domestic use and stock can be obtained by drilling into the Lance formation 125 feet or more, or at some places even less. Sample 72 was collected at the Howard Bros. ranch, in the NE. ¼ sec. 5, from a well 102 feet deep and 3 inches in diameter. The analysis shows that this water is slightly hard and that it contains over 1,100 parts per million of total solids. The water from this well tastes good and was used by the crews constructing the railroad along Armells Creek. It is satisfactory for cooking and domestic uses and for stock, but is reported to foam so badly in boilers that it must be changed three times a week. The well is on a bench about 40 feet above the river, and normally the water stands 20 feet below the surface, but under constant pumping for 12 or 18 hours the water level drops to 60 feet below the surface. This well, which is typical of many wells in the Lance formation, supplies ample water for 40 head of stock and 20 or more men and has never gone dry.

A drilled well 129 feet deep on J. T. Carland's ranch, in the SW. ¼ sec. 21, yields a fairly soft water. (See analysis 73.) The water in this well rises within 30 feet of the surface. A similar well 125 feet deep on another tract of Mr. Carland's, near the center of sec. 30, is also reported to yield soft water.

Hard water satisfactory for domestic use, stock, and gardens can be obtained in places by digging shallow wells into the alluvium of Armells Creek. A well of this type is located on the Bauch ranch, in the NE. ¼ NW. ¼ sec. 26. (See analysis 117.) A dug well 14 feet deep in the SE. ¼ sec. 22 supplied water for all the needs of 25 men and 50 head of stock.

T. 4 N., R. 41 E.

The upper beds of the Lance formation are exposed in the deeper ravines in the western and southeastern parts of T. 4 N., R. 41 E. The Lebo shale member of the Fort Union formation crops out around the margin of the township. The light-colored beds of the overlying Tongue River member occupy most of the township and cap the divide between Armells and Rosebud Creeks. Because of its numerous pine trees, this sparsely inhabited upland forms a contrast to the area of Lebo shale, which is treeless. High-level gravel has been mapped by Dobbin[97] in parts of secs. 11, 12, 14, and 15.

[97] Dobbin, C. E., op. cit.

In the area of Lance rocks water can be obtained in coulees by digging wells into a sandstone member of the Lance formation. Soft water is doubtless obtainable by drilling wells 150 feet or more into the Lance formation. The Lebo shale is generally unfavorable for water supplies. The strata of the Tongue River member yield satisfactory water, either hard or soft, according to the depth from which it is obtained. The high-level gravel will yield water in places where it is thick enough to extend below the water table, and the water will undoubtedly be of good quality.

T. 4 N., R. 42 E.

In T. 4 N., R. 42 E., Rosebud Creek and its tributaries have exposed a considerable area of Lance strata. The rim-rock sandstone at the top of the Lance formation occupies most of the divides in the eastern part of this township. The Lebo shale member of the Fort Union formation is present over a considerable area in the western and southern parts, and the overlying light-colored beds of the Tongue River member occupy a relatively small area in the western and southern parts. The rocks dip southeast a few feet to the mile.

The erosion by Cottonwood Creek and its tributaries, South Fork, Middle Fork, and North Fork, and by Sawmill Creek, as well as their numerous smaller branches, has resulted in a very rough topography. The only places where the surface is relatively smooth are on the high divides capped by the top sandstone of the Lance formation, along the flood plain of Rosebud Creek, and along the flood plain of the lower few miles of Cottonwood Creek.

Soft water can be had by drilling in the Lance formation. Several such wells ranging in depth from 128 to 160 feet have been put down along the flood plain of Rosebud Creek; the water in all of them rises within 20 feet of the surface. The well of M. H. Francis, in the SE. ¼ sec. 13, is 128 feet deep and the water rises within 17 feet of the surface. The water in this well, which is representative of other wells in the Lance formation along the flood plain of Rosebud Creek, is pleasant tasting but poor for making coffee and tea. (See analysis 75.)

T. 4 N., R. 43 E.

In T. 4 N., R. 43 E., the outcrop of the Lance formation forms a strip that averages about 2 miles in width in the western part of the township. The rim-rock sandstone at the top of the Tullock member of the Lance forms a prominent bench along the east side of Rosebud Creek. East of the outcrop of the Lance formation there is a belt of the Lebo shale member of the Fort Union formation that is extremely rough and dissected, and east of the Lebo outcrop in the eastern part of the township are the light-colored beds of the overlying Tongue River member. All these strata dip eastward a few feet to the mile. Rosebud Creek flows northwestward across the southwest corner of the township, and its largest tributary here is East Cottonwood Creek, which drains much of the township.

The Lance formation at some depth yields adequate supplies of soft water. On A. C. Stohr's ranch, in the SE. ¼ sec. 30, there is a drilled well 400 feet deep in which the water rises within 20 feet of the surface. On B. R. Crane's ranch, in the NE. ¼ sec. 24, there is a similar well 160 feet deep in which the water rises within 14 feet of the surface. In a few places water from sandstones of the Lance formation gives rise to springs. Water similar to that obtained in the M. H. Francis well (p. 97) may be expected from wells drilled into the Lance along Rosebud Creek.

The Lebo member of the Fort Union formation generally will not yield satisfactory water supplies, but the overlying light-colored rocks of the Tongue River member in the eastern part of the township will in most places yield satisfactory water to either drilled or dug wells. Shallow-dug wells in the alluvium along Rosebud and Cottonwood Creeks will yield hard water of inferior quality at many places.

T. 4 N., R. 44 E.

In the northern part of T. 4 N., R. 44 E., in the valley of Sweeney Creek and in the lower courses of its tributaries, Twelvemile and Bill Creeks, the dark-colored Lebo shale is the surface rock. In the remainder of the township the lower part of the overlying light-colored Tongue River member of the Fort Union formation is exposed. An undulating topography with relatively little roughness is characteristic of most of this township. There is little Fort Union clinker, as most of this area is stratigraphically below the first well-developed clinker bed (Rosebud) of Rosebud County. Because of the relative smoothness of this township a considerable part of it is utilized for agriculture, and it is consequently fairly well settled.

In general, the Lebo shale member does not yield satisfactory water supplies. There are a number of satisfactory shallow dug wells in the sands of the lower 300 feet of the Tongue River member. Wells of this type were noted on Albert Eberhart's ranch, in the NW. ¼ sec. 2 (depth 8 feet); on Arthur Emery's ranch, in the SE. ¼ sec. 6; on D. L. Davis's ranch, in the NE. ¼ SW. ¼ sec. 20; on R. L. Cass's ranch, in the NW. ¼ sec. 24; on J. B. Martin's ranch, near the center of the E. ½ sec. 24; and on Roy Lund's ranch, in the NE. ¼ sec. 30. The water from all these wells is hard but satisfactory for most uses. Springs yielding potable water from the lower Tongue River beds are fairly common in this township.

T. 3 N., R. 39 E.

The Lance formation crops out in the eastern part of T. 3 N., R. 39 E., and stratigraphically above the Lance beds in the east-central and southeastern parts of the township there is a narrow belt of the Lebo shale member of the Fort Union formation. The rocks of the Tongue River member of the Fort Union, which overlie the Lebo member, are at the surface over the remainder of the township. The strata in this township lie almost flat.

The high-level gravel which is present in T. 4 N., R. 39 E., extends southward into this township, where it lies at an altitude of 3,650 feet above sea level. (See fig. 3.) Dobbin[98] reports that this is the highest level at which gravel terraces were found in the area mapped by him, and no terraces were observed by the writer that could be assumed to belong to higher levels.

The West Fork of Armells Creek flows northeastward across the southeast corner of T. 3 N., R. 39 E. The rest of the township is drained by tributaries to the West Fork, the largest of which is Trail Creek.

Except along the West Fork of Armells Creek the areas of Lance and Lebo rocks have a fairly rough topography. The rocks of the Tongue River member in the central part of the township form a broad rolling upland, but in the southwestern part the Tongue River beds are considerably dissected and the topography is rough.

By drilling 150 feet or more into the Lance formation soft water can be obtained. A 125-foot well drilled on Carl Gillin's ranch, in the W. ½ sec. 24, is reported to have produced a slight flow for one month, but because of defective construction it soon ceased to flow. The Lebo shale at some places yields water to shallow wells, but this water is hard, highly mineralized, and unpleasant for drinking. A dug well 10 feet deep in the Lebo shale in the SW. ¼ sec. 34 is of this kind. The Tongue River strata of the Fort Union formation, which rest on the Lebo member, yield satisfactory water from both deep and shallow wells; the water from deep wells is soft and that from shallow wells is hard, for example, the water from Fred Law's well, 10 feet deep, in the SW. ¼ sec. 28. (See analysis 76.) In this township there are a number of dug wells of similar character obtaining water from Tongue River strata, among them the wells of J. S. Nelson, in the SE. ¼ sec. 20, 55 feet deep; S. A. Horton, in the NW. ¼ sec. 34, 25 feet deep, and J. B. Johnson, in the SE. ¼ sec. 28, 15 feet deep.

Springs in a number of the coulees furnish further evidence that the water table is relatively near the surface within this area of Tongue River rocks. The water in these springs, though hard, is

[98] Dobbin, C. E., op. cit.

pleasant tasting and is essentially the same in chemical character as the water shown by analysis 76. A spring of this type was observed in the NE. 1/4 sec. 30, on C. L. Thompson's ranch. Potable water may be obtained from the terrace gravel in places where the water table is above the bottom of the gravel.

T. 3 N., R. 40 E.

The oldest surface rocks in T. 3 N., R. 40 E., belong to the Lance formation. These rocks are best exposed in the western part of the township, but they crop out also in the eastern part. The Lebo shale member of the Fort Union formation is present at the surface over much of the northern and northeastern parts of the township, and the overlying light-colored strata of the Tongue River member of the Fort Union formation are confined almost entirely to the central and southern parts. These rocks dip eastward at the rate of a few feet to the mile. The most noteworthy structural feature is a fault in secs. 13 and 14, which strikes southeast. The same belt of faulting continues southeastward into T. 3 N., R. 41 E. The maximum displacement is 50 feet.

The central part of this township is on the divide between the East and West Forks of Armells Creek, and from this divide the drainage goes northwestward into West Fork and northeastward into the East Fork, which flow, respectively, across the northwest and northeast corners of the township. Sevenmile Creek, a tributary to the East Fork, is the next largest stream in this township. The entire township is rough and dissected and is uninviting for settlement.

The ground-water conditions are in no essential respects different from those in T. 3 N., R. 39 E. Soft water can be obtained by drilling 150 feet or more into the Lance formation, and in some places satisfactory water can be obtained by digging shallow wells in the Lance sandstones in some of the coulees. The Lebo shale member will generally not yield satisfactory water to shallow wells. Satisfactory water can be obtained from the rocks of the Tongue River member in wells drilled to a depth of 150 feet or more and in some places from shallow dug wells. Springs yielding water of good quality are fairly common in the southern sections of this township. Such a spring is reported to exist on Arthur Wood's place, in the NE. 1/4 sec. 32.

T. 3 N., R. 41 E.

There are small inliers of Lance strata in the southwestern part of T. 3 N., R. 41 E., and the East Fork of Armells Creek cuts into Lance rocks in the northwest corner of the township. The Lebo shale member of the Fort Union formation is well exposed along

Armells Creek, which flows in a general northwesterly direction across the western part of the township. In the eastern part the overlying Tongue River member of the Fort Union formation is present, and a small outlier of these strata is present in the southwest corner.

The divide between Armells Creek and Rosebud Creek is in the eastern part of the township, and most of the surface run-off goes into Armells Creek.

Soft water can be obtained by drilling 150 feet or more into the Lance formation. The drilled well of David McGillivery, in the NE. 1/4 sec. 20, which is 176 feet deep, draws water from the upper or Tullock member of the Lance formation that is reported to be soft and pleasant tasting.

In this township there are a number of shallow dug wells obtaining water from the Tongue River member of the Fort Union formation; this water is generally slightly hard but always pleasant tasting and satisfactory for most uses. Among these wells are those of E. R. Burleigh, in the NW. 1/4 SE. 1/4 sec. 24, 12 feet deep; J. W. Johnson, in the SE. 1/4 sec. 10, 7 feet deep; J. W. Johnson, in the SE. 1/4 sec. 28, 17 feet deep; and J. E. Kirby, in the NE. 1/4 sec. 28, 15 feet deep. Water of similar quality occurs at a spring on E. R Burleigh's ranch, in the NE. 1/4 sec. 10. It is reported that this spring, which is at the base of a thick ledge of sandstone of the Tongue River member, has never gone dry and is capable of watering several hundred head of sheep at all times.

In general the alluvium along Armells Creek yields hard and rather highly mineralized water, but in the SW. 1/4 sec. 6, at the junction with Sevenmile Creek, there is a spring of considerable magnitude, whose water has an especially pleasant taste. The water issues from the alluvium, but a considerable part of it may come originally from the sandstone at the top of the Tullock member of the Lance formation. When visited this spring served as the source of supply for 45 people, with no apparent tendency toward exhaustion.

T. 3 N., R. 42 E.

The Lebo shale member of the Fort Union formation is exposed in the creek valleys in the eastern and northwestern parts of T. 3 N., R. 42 E., and the overlying Tongue River member of the Fort Union formation is confined to the higher country in the central and southwestern parts. The township is rough and dissected except in the extreme western and southwestern parts. The rocks dip eastward at an angle of a few feet to the mile.

Water from the Lebo shale, where it can be obtained, is generally not satisfactory for drinking. Shallow dug wells in the Tongue River member of the Fort Union formation generally yield water of fairly satisfactory quality, but for some unaccountable reason the water in shallow wells in the Tongue River rocks on the whole seems to be more undesirable for domestic purposes here than elsewhere. The water of Mrs. Martha Beeley's well, in the SW. 1/4 sec. 32, 16 feet deep, is rather unusual on account of the hydrogen sulphide which it contains. (See analysis 77.)

In the western and southwestern parts of this township the country is relatively smooth and the water table is very close to the surface, as indicated by numerous springs and by green spots at the bottom of many of the outcrops of massive sandstone in secs. 20, 28, 29, 30, 31, and 32. Kenneth McKerlich has a spring in the SW. 1/4 sec. 6 in the bed of a coulee that yields pleasant-tasting hard water, and he reports that he has never known it to go dry.

T. 3 N., R. 43 E.

Rosebud Creek flows northward across the west-central part of T. 3 N., R. 43 E., exposing a considerable strip of Lance rocks. The rim-rock sandstone at the top of the upper or Tullock member of the Lance formation is conspicuous on both sides of the creek. Overlying the Lance formation is the Lebo shale member of the Fort Union formation, which crops out in a belt on both sides of the creek. In the eastern part of the township the light-colored rocks of the younger or Tongue River member of the Fort Union are at the surface. All these strata dip eastward a few feet to the mile. Rosebud Creek drains all of this township, and its chief tributaries are Udie, Sprague, Cherry, and Eagle Creeks.

Wells drilled 150 feet or more into the Lance formation will yield soft water that is satisfactory for domestic use and stock. A typical sample of water from a well of this type was collected from Freeman Philbrick's 254-foot drilled well, in the SE. 1/4 sec. 4, T. 2 N., R. 43 E. (See p. 106.) Water from the 520-foot well of Laird & Weaver, in the NE. 1/4 sec. 20 (see analysis 78), is harder than is usual for the deep wells in the Lance formation. It is highly probable that the hard water from the alluvium of Rosebud Creek is seeping into the well and mixing with the lower soft water. The water in this well is reported to rise within 7 feet of the surface. In some of the coulees satisfactory water can be obtained by digging shallow wells into one of the Lance sandstones. In the rough, dissected Lebo shale areas satisfactory supplies of ground water are difficult or impossible to obtain in shallow wells, but in the eastern part of the township ground water of good quality can be had by putting down either dug or drilled wells in the Tongue River member. The alluvial material of the flood plain of Rosebud Creek yields hard water, much of which is inferior in quality, though it differs somewhat in different places.

T. 3 N., R. 44 E.

All the surface strata in T. 3 N., R. 44 E., belong to the Fort Union formation; the Lebo shale member crops out in some of the ravines in the eastern part of the township and along Eagle Creek in the northwest corner, but elsewhere in the township the younger light-colored Tongue River strata are at the surface. In many places in this township the coals of the Tongue River member have been burned, and there is considerable clinker.

The Tongue River member of the Fort Union generally yields water of satisfactory quality, somewhat similar to the water from the same member in near-by townships. (Compare analyses 86 and 77.)

The water of shallow wells will doubtless be hard; the water from wells 150 feet or more deep will be soft.

T. 2 N., R. 39 E.

In the northeast corner of T. 2 N., R. 39 E., in the bed of the West Fork of Armells Creek, there is a small area where the Lebo shale member of the Fort Union formation comes to the surface, but in the remainder of this township all the rocks at the surface belong to the upper or Tongue River member of the Fort Union formation. This township consists for the most part of an undulating upland. West Fork of Armells Creek flows northward across the eastern part and the rest of the township is drained by Trail Creek and the North and South Forks of Donley Creek, all of which are tributaries to the West Fork of Armells Creek.

The Lance formation, though not exposed at the surface, yields soft water which can be obtained by drilling through the Fort Union formation into the Lance.

At C. M. Dowland's ranch, in the SW. ¼ sec. 12, there is a drilled well 222 feet deep which begins in the Fort Union formation and ends in one of the sandstones near the top of the Lance formation, from which it obtains its water. The water level is 65 feet below the surface. The water is soft and contains less than 800 parts per million of dissolved solids (see analysis 81), yet the taste is not altogether pleasant. On Mrs. Maude Robinson's ranch, in the NW. ¼ sec. 6, there is a drilled well 202 feet deep which obtains its water from the Lebo shale member. The water has an unpleasant, bitter taste and is hard and highly mineralized, containing over 3,200 parts per million of total dissolved solids. (See analysis 83.) In contrast is another well on Mrs. Robinson's ranch, less than 100 feet distant, which is 340 feet deep and obtains its water from the Tullock member of the Lance formation. Its water contains less than 900 parts per million of dissolved solids. (See analysis 80.) This water also, however, has a disagreeable taste, probably due to the hydrogen sulphide which it seems to contain, and is turbid, doubtless because certain of the shale members have not been adequately cased off.

Another well in the SW. 1/4 sec. 12, owned by C. M. Dowland, is in the rocks of the Tongue River member. This well is 85 feet deep and 4 inches in diameter. The water, which rises within 16 feet of the surface, is hard and is utilized mostly for stock. The Tongue River beds throughout this township generally yield hard water of satisfactory quality to dug wells. Other wells of this kind are those of R. E. Hay, in the NE. 1/4 sec. 28 (40 feet deep), and R. I. Harold, in the NE. 1/4 sec. 32. In the area of Tongue River rocks in this township there are springs along several of the coulees. The water of these springs comes either from the alluvium or from a sandstone bed. Among those observed are the spring of C. M. Dowland, in the NW. 1/4 sec. 14; and two springs owned by Mrs. Della Harold, one in the SW. 1/4 sec. 28 and another in the W. 1/2 sec. 34. It is estimated that these springs yield from 1 to 2 gallons a minute, and the water is doubtless similar in quality to that obtained in shallow dug wells in this area of lower Tongue River strata—that is, hard but potable and satisfactory for most uses.

T. 2 N., R. 40 E.

The Tongue River member of the Fort Union formation is at the surface in all of T. 2 N., R. 40 E., except a part of sec. 1, where the underlying Lebo shale member of the Fort Union is exposed.

The ground-water conditions in this township are similar to those in T. 2 N., R. 39 E. Supplies of soft water can be obtained by drilling through the Fort Union strata into the Lance formation, care being taken to case off any undesirable water that may be encountered near the surface or within the Lebo shale member. In the localities where the Tongue River member is sufficiently thick soft water can be obtained from drilled wells. Shallow dug wells in the Tongue River member in most places will yield satisfactory supplies of hard water. Several such wells along Stocker Creek were inspected, among them the wells of Elsworth Post, in the SE. 1/4 sec. 2, depth 22 feet; C. V. Chilburg, NE. 1/4 sec. 12, 32 feet; and John McDonald, SE. 1/4 sec. 24. Wells of this type yield ample supplies of water for a family and the necessary stock.

T. 2 N., R. 41 E.

The Tongue River member of the Fort Union formation is exposed at the surface over all of T. 2 N., R. 41 E., except parts of secs. 5 and 6, where the underlying Lebo shale member of the Fort Union is at the surface.

In the south-central part of this township, along Armells Creek, the Northern Pacific Railway plans to work the Rosebud coal[99] by stripping with a steam shovel. In order to obtain adequate water supplies for any community that may spring up as a result of these coal-mining operations, a well of large diameter—at least 6 inches, preferably greater—should be drilled into the Lance formation, and any water from the overlying Lebo shale should be tightly cased off. In this area the bottom of the Lance formation will be encountered within 1,500 feet, but it will doubtless be unnecessary to go to this depth. It was reported that in February, 1926, a rig was engaged in drilling a well for the prospective community on Armells Creek, and that at a depth of about 900 feet the well was yielding 750 gallons an hour, or 18,000 gallons a day.

The water obtained in this township from a depth of 150 feet or more and above the base of the Lance formation will be soft but probably unsatisfactory for steam boilers on account of foaming. C. C. Edwards, in the SE. ¼ NE. ¼ sec. 17, owns a drilled well 177 feet deep extending into the Lance formation, in which the water rises within 20 feet of the surface. This is primarily a soft water (see analysis 118), but probably hard water from near the surface is also being contributed to it. In any drilled well, even one extending to the bottom of the Lance formation, the water would doubtless rise to a considerable height in the casing, but a flowing well is not to be expected. It is possible that considerable supplies of ground water might be obtained by drilling a well of large diameter into the Tongue River member of the Fort Union, but in order to insure an adequate supply it will probably be necessary to drill into some of the sandstones of the Lance formation.

Water of fairly satisfactory quality can be obtained in many places by digging shallow wells into the Tongue River member. This water will be similar in chemical character to waters from shallow wells in T. 1 N., Rs. 40 and 41 E. (See analyses 84, 85, and 86.)

T. 2 N., R. 42 E.

In T. 2 N., R. 42 E., all the surficial rocks belong to the Tongue River member of the Fort Union formation, except in a part of sec. 1, where the Lebo shale member of the Fort Union is at the surface. All the drainage goes eastward into Rosebud Creek, mostly by way of Spring and Pony Creeks, which are the only large tributaries to Rosebud Creek in this township.

By drilling through the strata of the Fort Union formation into the Lance formation soft water can be obtained, and in the western part of the township, where the Tongue River member of the Fort

[99] Dobbin, C. E., op. cit.

Union formation is sufficiently thick, soft water may be had by drilling 150 feet or more into it. Hard water of a fairly satisfactory quality is obtained in shallow dug wells. Small ravines and coulees are especially desirable places for digging such wells. Shallow wells belonging to the following persons were inspected: J. S. Mitchell, NW. 1/4 sec. 6, depth 32 feet; Pat McKay, center of W. 1/2 sec. 8, 18 feet; and Mrs. Delia Egan, SE. 1/4 sec. 32, 37 feet. In the western part of this township there are numerous places where the grass and other vegetation is very green; the green spots are caused by seepage of water from the base of certain beds of massive sandstone.

The quality of the water in the shallow wells and springs in the Tongue River member is similar to that from wells in similar rocks in near-by townships. (See analyses 76, 77, 84, 85, and 86.)

T. 2 N., R. 43 E.

In T. 2 N., R. 43 E., the top of the Lance formation dips below the level of Rosebud Creek in sec. 4. The Lebo shale member of the Fort Union formation crops out along Rosebud Creek from sec. 4 to a point near the boundary of secs. 29 and 32, where it in turn dips below the creek. In the eastern, western, and extreme southern parts of the township the light-colored upper or Tongue River member of the Fort Union formation is at the surface.

The Lance formation in this township will yield soft water that is satisfactory for domestic use and stock, but the overlying Lebo shale should be cased off so as to prevent any undesirable water that it might yield from entering the well. At Freeman Philbrick's place, in the SE. 1/4 sec. 4, there is a drilled well 254 feet deep, which obtains its water from the Lance formation and in which the water rises within 17 feet of the surface. Analysis 82 shows that this is one of the typical soft waters, containing over 1,300 parts per million total solids. Wells similar in character and yielding water of similar quality have been drilled elsewhere along Rosebud Creek. At A. F. McBride's place, in the NW. 1/4 NE. 1/4 sec. 16, there is a well 230 feet deep, drilled into the Lance formation, in which the water rises within 26 feet of the surface. At Malcolm Philbrick's place, in the SW. 1/4 sec. 21, there is a well 236 feet deep, extending into the Lance formation, in which the water is reported to rise within 18 feet of the surface.

The Lebo shale member is not a satisfactory aquifer. The overlying Tongue River member will generally yield potable hard water to shallow dug wells, and in places where the Tongue River member is sufficiently thick wells 150 feet or more deep will yield soft water. The alluvium in the flood plain along Rosebud Creek yields hard water, much of which is not pleasant to the taste.

T. 2 N., R. 44 E.

The dark-colored Lebo shale member of the Fort Union formation is at the surface in the coulees in the eastern part of T. 2 N., R. 44 E., and along Dry Creek in the central part. Over the remainder of the township the light-colored strata of the upper or Tongue River member of the Fort Union are the surficial rocks. Tributaries to Tongue River drain most of this township.

Soft water can be obtained by drilling through the Fort Union strata into the Lance formation, and in the southeast corner of the township, on the flood plain of Tongue River, flowing wells would be expected within a depth of 500 feet. In places where water is obtainable from the Lebo shale member it will generally be nonpotable. The light-colored strata of the Tongue River member in most places yield water to shallow dug wells that is hard but satisfactory for domestic use and stock, and in the western part of the township, where the Tongue River member is sufficiently thick, it is possible to drill wells 150 feet or more into this member and obtain soft water. The water from shallow wells will doubtless resemble in quality that shown by analyses 76, 77, 84, 85, and 86, and that from deep wells will resemble Nos. 95, 102, 103, and 107. The alluvium along Tongue River generally yields hard water of fairly satisfactory quality.

T. 1 N., R. 39 E.

The 9 sections in the southwest corner of T. 1 N., R. 39 E., are in Big Horn County, and the remaining 27 are in Rosebud County. The Wolf Mountains, the highest part of which stands at an altitude of about 4,780 feet,[1] trend in a general southeasterly direction across the southwestern part of this township. These mountains are composed of a huge mass of nearly horizontal beds of sandstone, shale, coal, and clinker of the upper or Tongue River member of the Fort Union formation. The drainage in this township goes northeastward into the West Fork of Armells Creek and eastward into the East Fork.

In that portion of the northeastern part of the township which is best adapted for habitation soft water (see analyses 102, 103, 105, and 107) may be procured by drilling 150 feet or more into the Tongue River member or by drilling still deeper into the Lance formation. If water supplies from the Lance formation are sought, it may be necessary to case off the water from the lower or Lebo shale member of the Fort Union formation.

In most places shallow dug wells in the Tongue River member will yield fairly satisfactory hard water, and in the coulees near the base

[1] Dobbin, C. E., personal communication.

of the Wolf Mountains springs occur at a number of places. The quality of the water from these near-surface sources in all probability will be similar to that shown by analyses 76, 77, 84, 85, and 86.

T. 1 N., R. 40 E.

All the surface rocks in T. 1 N., R. 40 E., belong to the upper or Tongue River member of the Fort Union formation. Most of this township, especially the southern part, is rough and considerably dissected. In the northern part the drainage goes into Armells Creek by way of East Fork and Stocker Creek. The East Fork of Armells Creek flows eastward across this township in a wide alluvium-filled valley. The southern part of the township is drained by Lee and Richards Coulees, both of which are tributary to Rosebud Creek.

Soft water can be obtained by drilling 150 feet or more into the Tongue River member or by drilling through the underlying Lebo shale member of the Fort Union into the Lance formation. In most places it may be necessary to case off any water contributed from the Lebo member.

On Mrs. Edna Binkert's ranch, in the NW. ¼ sec. 6, there is a dug well 48 feet deep, containing 8 feet of water contributed by a coal bed in the Tongue River member. This water is very hard. (See analysis 84.) Fairly satisfactory hard water can be obtained by digging shallow wells in the Tongue River member or in the alluvium derived from it in many of the coulees and along the East Fork of Armells Creek. Some of these wells are as follows: Levi Taylor estate, SW. ¼ sec. 12, dug well 24 feet deep, containing 5 feet of water; A. L. Taylor, NW. ¼ NW. ¼ sec. 14, dug well 34 feet deep, 9 feet of water; S. A. Post, NW. ¼ sec. 20, dug well 17 feet deep, 2 feet of water; C. A. Smith, NW. ¼ sec. 12, dug well 20 feet deep, 6 feet of water; and R. E. Lane, NW. ¼ NE. ¼ sec. 18, dug well 22 feet deep, 5 feet of water. The water in wells of this type is always hard but generally pleasant tasting and otherwise satisfactory. Analysis 122 represents fairly hard water collected from a coal shaft on Henry Tabert's land, in the SE. ¼ NW. ¼ sec. 3.

Very good springs were noted in the north-central part of this township, the water being contributed by one of the massive sandstones in the Tongue River member. W. L. Cooley pipes the water from a spring in the center of the S. ½ sec. 4 into his house and garage, about 300 yards to the north.

T. 1 N., R. 41 E.

All the surficial rocks in T. 1 N., R. 41 E., belong to the light-colored upper or Tongue River member of the Fort Union formation, and in the eastern and southern parts of the township most of the divides are capped with the red clinker of this member. In the northwestern part of the township the East Fork of Armells Creek flows in a wide valley, and the stripping project of the Northern Pacific Railway along Armells Creek is expected to extend from T. 2 N., R. 41 E., into this township. The possibilities of obtaining a ground-water supply for a railroad community here are similar to those in T. 2 N., R. 41 E. (See p. 105.)

Most of the shallow dug wells in this township yield water of satisfactory quality. L. S. Sherman's dug well, in the SW. 1/4 sec. 8, is 24 feet deep, with 5 feet of water. Thomas Belyea's dug well is 42 feet deep, with 4 feet of water that is pleasant tasting and satisfactory for most uses. L. S. Kimball's dug well, in the SW. 1/4 sec. 6, 50 feet deep, yields a type of water that is unusual in this area. The water comes from a coal bed, and the organic matter derived from the coal gives it a dark-brown color and a rather unpleasant taste. These features are objectionable, but the water is of excellent quality so far as the amount of dissolved mineral constituents is concerned. (See analysis 85.) Perhaps the organic material causes certain salts to be deposited, thereby reducing the concentration.

At C. E. Hafer's ranch, in the SE. 1/4 sec. 12, there is a 65-foot drilled well which obtains its water from a sandstone in the Tongue River member and in which the water rises within 54 feet of the surface. This water is especially palatable, and analysis 86 shows that, though hard, it is about the best in quality of all the waters in the Tongue River member, as it contains only 366 parts per million of total solids. The water for analysis 123 was collected by the engineers of the Northern Pacific Railway from a water hole 6 feet deep in the East Fork of Armells Creek, in the NW. 1/4 sec. 8, T. 1 N., R. 41 E.

T. 1 N., R. 42 E.

In T. 1 N., R. 42 E., all the surface strata belong to the Tongue River member of the Fort Union formation. This township is drained by Rosebud Creek and its tributaries. Rosebud Creek flows northeastward across the southeast corner of the township, and its largest tributaries are the North and South Forks of Cow Creek, Hay Coulee, and Miller Coulee, all of which flow in a general easterly or southeasterly direction across the township. Much of the coal in this township has been burned along the outcrop, and as a result most of the divides are capped with clinker. The surface on the whole is considerably dissected and rather rough.

Along Rosebud Creek the typical soft water of the region is obtained by drilling into the lower beds of the Tongue River member, or deeper into the sandstones at the top of the Lance formation, which in the northern part of the township can probably be reached within 250 feet. J. P. McChristen's well, near the center of the NW. 1/4 sec.

34, is 232 feet deep, and the water rises within 15 feet of the surface. H. H. Huffman, in the SW. 1/4 sec. 33, has a drilled well 205 feet deep, in which the water rises within 18 feet of the surface.

Fairly satisfactory hard water may be obtained from shallow dug wells, especially where such beds encounter coals. At some places coal beds give rise to springs. Soft water similar in chemical character to that shown in analyses 102, 103, 105, and 107 is to be expected in the deeper wells, and hard water similar to Nos. 76, 77, 84, 85, and 86 is to be expected from the shallow wells.

T. 1 N., R. 43 E.

Rocks of the Tongue River member of the Fort Union formation are at the surface over all of T. 1 N., R. 43 E., and much of the coal in this member has been burned near the outcrop, forming clinker beds. Rosebud Creek flows northeastward across the northwestern part of the township. Its largest tributaries are Sand Coulee, Bean Coulee, and Greenleaf Creek, which enter Rosebud Creek from the east, and Cow Creek, which enters from the west.

Soft water can be obtained by drilling into the Tongue River member or to a greater depth into the Lance formation. Although as a rule there is not sufficient head to obtain a flowing well in this township, there is at least one notable exception. On Freeman Philbrick's land, in the NW. 1/4 sec. 8, in the valley of Rosebud Creek, there is a drilled well about 140 feet deep, obtaining its water from a sandstone lens in the Lebo shale member of the Fort Union formation, which flows at the rate of three-eighths of a gallon a minute, yielding the characteristic soft water of this region. With the exception of the flowing wells along the Tongue River in T. 1 N., R. 44 E., this is the only flowing well south of T. 6 N. in Rosebud County.

On Thomas Roberts's ranch, in the SW. 1/4 sec. 4, there is a drilled well 350 feet deep, in which the water level is reported to be 90 feet below the surface. On G. W. Bradley's ranch, in the NW. 1/4 sec. 30, there is a soft-water well 147 feet deep, in which the water rises within 30 feet of the surface. Shallow dug wells along Rosebud Creek and its tributaries, most of which are in the alluvium, yield hard water that in many places, though drinkable, is not particularly palatable. Water of this kind was noted in the dug wells of Mrs. L. A. Brown, in the NW. 1/4 sec. 20, depth 17.5 feet; S. W. Stuart, SW. 1/4 sec. 28, 30 feet; and Van Sant Trust Co., NE. 1/4 sec. 32, 33 feet. The water in George W. Parkins's 60-foot drilled well, in the SW. 1/4 sec. 19, yields a very pleasant-tasting water, the source of which is a sandstone in the Tongue River member.

T. 1 N., R. 44 E.

The Tongue River flows northeastward across T. 1 N., R. 44 E., entering in sec. 33 and leaving in sec. 1. The lower or Lebo shale member of the Fort Union formation is exposed along the river north of the mouth of Beaver and Lee Creeks, which are the largest tributaries of the Tongue River in this township. The Tongue River and its tributaries drain the entire township. With the exception of the Lebo shale outcrop and a fairly wide strip of alluvium along the Tongue River, all the surface rocks belong to the upper or light-colored Tongue River member of the Fort Union formation.

Along the flood plain of the Tongue River flowing wells have been obtained by drilling into the Lance formation, but there is apparently not sufficient head to predict with certainty that a flow can be obtained at any particular place. On A. M. Ball's ranch, in the SW. ¼ sec. 12, on a bench about 30 feet above the river, there is a well 216 feet deep, in which the water, which was encountered at 210 feet, comes within 60 feet of the surface. Analysis 87 shows that this is one of the typical soft waters of the region. On M. W. Milligan's ranch, in the SW. ¼ sec. 22, a well 365 feet deep flowed at the rate of 10 gallons a minute in 1923. It is reported to have flowed at the rate of 30 gallons a minute in 1916, when first drilled. Analysis 88 shows that the water from this well also is typical of the soft waters of the region.

In contrast to this well is another well owned by Mr. Milligan in the NE. ¼ SE. ¼ sec. 22, which is 460 feet deep but with a flow of only 1 gallon a minute or less. On the same ranch, in the SW. ¼ SE. ¼ sec. 15, there is a well 522 feet deep, in which the water does not reach the surface but is raised by a gas engine and centrifugal pump. The water of all these wells comes from the Lance formation and is doubtless similar in chemical character to that shown by analysis 88. Back from the river, where the Tongue River strata are sufficiently thick, soft water similar to that obtained from the Lance formation will be encountered, but flowing wells are not to be expected. Mr. Milligan also owns a soft-water well in the SE. ¼ sec. 9, which is 151 feet deep and obtains water from the Lebo (?) shale that rises within 25 feet of the surface.

The alluvium along the Tongue River yields hard but potable water to dug or driven wells, which are utilized by many people as a source of domestic supply. Among such wells are those of M. R. Geist, dug well, NW. ¼ sec. 12, depth 35 feet; schoolhouse, SE. ¼ sec. 28; N. W. Goodale, driven well, NW. ¼ sec. 12, 40 feet; R. R. Hart's driven well, NW. ¼ sec. 14, 20 feet; and T. T. Orr's driven well, SW. ¼ sec. 14, 14 feet.

T. 1 S., R. 39 E.

Only the eastern half of T. 1 S., R. 39 E., is in Rosebud County. All the rocks seen at the surface belong to the Tongue River member of the Fort Union formation. The North and South Forks of Big Cottonwood Creek, tributary to Rosebud Creek, are the principal streams draining this township. There is a considerable amount of clinker, and erosion has formed many steep-walled coulees, especially in the western part of the half of the township that is in Rosebud County.

Soft water can be obtained from the Fort Union formation by drilling 150 feet or more. Hard but fairly satisfactory tasting water can be procured from the Tongue River rocks at relatively shallow depths, especially from the coal and clinker beds. The coal and clinker beds in this township no doubt give rise in many places to springs yielding satisfactory water, but no search was made for springs.

T. 1 S., R. 40 E.

All the surface rocks in T. 1 S., R. 40 E., belong to the light-colored upper or Tongue River member of the Fort Union formation. In this township much of the Fort Union coal has been burned along the outcrop, producing the characteristic red clinker, which forms flat-topped mesalike divides between the streams.

This township is drained by Richards Coulee, Slough Grass Creek, Little Cottonwood Creek, Big Cottonwood Creek, and their tributaries, all of which are tributary to Rosebud Creek. The run-off is therefore toward the east and southeast. Near their mouths the streams in this township have cut wide valleys flanked by steep cliffs that are capped by clinker.

In the western part of the township, which is considerably higher than the eastern part, there is more grass and vegetation, and pine trees are fairly plentiful, conditions being intermediate between those of the semiarid country along Rosebud Creek and those of the pine-forested Cheyenne Indian Reservation, where there is more rainfall.

By drilling 150 feet or more into the Fort Union formation or still deeper into the Lance formation soft water can be obtained. The abundance of green reed grass and the numerous seepages in the coulees adjacent to the outcrops of massive sandstone in the western part of the township show that ground water is close to the surface in many places. Hard but fairly good tasting water can be obtained by digging shallow wells in many of the coulees, the source of the water being the massive sandstone, the coals, or the clinker beds of the Tongue River member.

The soft water from deeper wells will be similar in character to that shown by analyses 102, 103, 105, and 107, and the hard water from shallow wells may be similar to any of the waters shown by analyses 93, 98, 99, or 104.

T. 1 S., R. 41 E.

The light-colored strata of the upper or Tongue River member of the Fort Union formation are at the surface over all of T. 1 S., R. 41 E. Rosebud Creek flows northeastward across this township. Its principal tributaries are the North and South Forks of Richards Coulee, Sloughgrass Creek, Little Cottonwood Creek, and Big Cottonwood Creek from the west and northwest and Ryegrass Creek from the southeast. Much of the coal in the Fort Union formation in this township has been burned along the outcrop, and many of the intervalley areas are flat-topped tablelands underlain by erosion-resisting red clinker.

The valleys of the streams tributary to Rosebud Creek in this township are typical coulees—that is, wide-mouthed steep-walled valleys, the size of which is out of proportion to the small amount of water now flowing through them.

By drilling into the Tongue River member soft water can be obtained at a depth of 150 feet or more. Several of the ranches along Rosebud Creek obtain their water supplies in this manner. On John McKay's ranch, in the SE. 1/4 sec. 28, there is a drilled well 235 feet deep in which the water comes within 20 feet of the surface. On the ranch of Mrs. E. Davidson, in the NE. 1/4 sec. 33, there is a drilled well 170 feet deep which yields soft water that rises within 11 feet of the surface. Mrs. Davidson owns another drilled well in the same quarter section, which is 80 feet deep and yields hard water of satisfactory quality from the Tongue River member. This water is vastly superior to that from Frank E. Westlake's 35-foot drilled well in the alluvium along Rosebud Creek, which is nonpotable and very hard (see analysis 91), and which may be regarded as more or less typical of the water from the alluvium.

Springs yielding potable hard water from the coals, sandstones, and clinker beds of the Tongue River member are fairly common; a spring in a coal bed in the SE. 1/4 sec. 8 is representative.

T. 1 S., R. 42 E.

The light-colored beds of the upper or Tongue River member of the Fort Union formation are at the surface over all of T. 1 S., R. 42 E., and the coals in these beds have been burned along the outcrop over much of the township. The township is drained by Rosebud Creek, which flows northeastward across the northwest corner, and its tributaries, the largest of which is Lee Coulee. Along Rosebud Creek the topography is much the same as it is along the same creek in T. 1 S., R. 41 E.

The Tongue River member will yield supplies of soft water within a depth of 150 feet or more, and along the flood plain of Rosebud Creek in this township there are several wells that obtain their water from this source. Ira Snider, in the NE. ¼ SE. ¼ sec. 8, has a well 200 feet deep, in which the water was reported to rise within 11 feet of the surface. This water, as shown by analysis 90, is soft and typical of the soft waters of this county. On another tract of Mr. Snider's, in the NE. ¼ sec. 10, there is a well of good-tasting soft water reported to be 236 feet deep, with the water level 26 feet below the surface. Hugh Lynch, on his ranch, in the SW. ¼ sec. 8, has a drilled well 170 feet deep with the water level 14 feet below the surface. From a history of the construction of this well and a study of analysis 89, which shows hard water, it seems that the near-surface hard water has not been effectively cased off and that the water obtained from the well doubtless represents a mixture of the near-surface hard water and the deeper soft water. On J. D. Carpenter's ranch, in the NE. ¼ sec. 10, there is a drilled well 94 feet deep in which the water level is within 14 feet of the surface. The water in this well is hard. Supplies of potable hard water can be had from shallow wells in the Fort Union rocks. (See analyses 84, 86, and 92.) A. J. and Mike Kuharski have bored a well 20 feet deep in the Fort Union rocks, in the SW. ¼ sec. 12, and analysis 92 shows that this water, as might be expected, is hard. From the débris about the well it seems probable that this well derives its water in part from a clinker bed. The alluvium along Rosebud Creek generally yields water of poor quality.

At a number of places, especially in the southern part of the township, coals and clinker beds of the Fort Union formation yield springs of pleasant-tasting hard water, and several ranches depend on such springs for their domestic supplies, among them A. J. and Mike Kuharski, in the SW. ¼ sec. 12; John Bradley, in the NE. ¼ sec. 24; and George Wood, near the center of sec. 26.

Springs from the Tongue River member that yield hard water of different grades of potability were noted on the land of Mike Hole, in the NE. ¼ sec. 12; Bud Schafer, in the SW. ¼ sec. 20; Horton Brothers, in the NE. ¼ sec. 25; William Parkin, in the SW. ¼ sec. 34; and along the road in the SW. ¼ sec. 24.

T. 1 S., R. 43 E.

In T. 1 S., R. 43 E., all the rocks cropping out at the surface belong to the Tongue River member of the Fort Union formation. The township is drained by Greenleaf Creek and other smaller tributaries to Rosebud Creek and by Leigh Creek, which is the largest tributary to Tongue River in this township. The coals of the Tongue River member have been considerably burned on the high ground between Rosebud Creek and the Tongue River and in the extreme southern part of the township. Pine trees are plentiful on these high red-soil areas.

Wells drilled 150 feet or more into the Fort Union formation will yield soft water similar to that obtained under like conditions in the townships near by. (See analyses 102, 103, and 104.) The water from the coal beds issues as springs at numerous places in the southern part of the township. Such water is hard. Shallow wells at most places yield water that is of satisfactory quality, especially where it comes from coal, sandstone, or alluvial gravel derived from clinker. These waters are invariably hard and are similar to those shown by analyses 76, 84, and 93. Tom Wood, in the NE. ¼ sec. 28, has a dug well 25 feet deep, in which the water is potable but hard, and on Earnie Sprague's place, in the SE. ¼ sec. 30, there is a well 30 feet deep that yields meager supplies of similar water.

T. 1 S., R. 44 E.

The Tongue River, which next to the Yellowstone River is the largest stream in Rosebud County, flows northward across T. 1 S., R. 44 E. Along the river there is a strip of Recent alluvium, which averages about half a mile in width and which is cultivated in most places. Back from the river the steep bluffs are capped by red clinker resulting from the burning of coals.

Along the flood plain of the river—at least in the northern part of the township—it may be necessary to drill through the Fort Union formation into the Lance formation in order to obtain the best quality of soft water. S. A. Hotchkiss, in the SW. ¼ sec. 2, has a well 260 feet deep that is reported to have had a flow of 5 gallons a minute when first drilled in 1913, which decreased to a small trickle within two weeks. This report leads to the inference that the well was improperly constructed. Most of the water in this well probably comes from the Lance formation and is similar to the other soft waters of Rosebud County. (See analyses 87 and 88.)

Although flows can not be predicted with certainty, the northern part of this township, along the flood plain of the Tongue River, is a favorable place for prospecting for artesian wells.

Gravel beds in the alluvial fill of the flood plain of the Tongue River yield hard water that is very satisfactory for drinking. A sample representative of this type of water was collected from James L. Foster's well, in the NW. ¼ sec. 14, which is 14 feet deep, in gravel. (See analysis 94.) Springs deriving their water from the Fort Union coals yield water which is hard but satisfactory for drinking.

T. 2 S., RS. 39 AND 40 E.

In T. 2 S., R. 39 E., only secs. 1, 2, and 3 are in Rosebud County, and in T. 2 S., R. 40 E., only secs. 1 to 12. Because of the relatively small area and the similarity of their ground-water conditions these two fractions of townshps are described together. All the rocks cropping out at the surface belong to the Tongue River member of the Fort Union formation. Much of the coal has been burned, with the development of considerable beds of clinker. These townships are drained by Lynch Coulee and Big Cottonwood Creek. The western part of this area is considerably higher than the eastern part, and its pine trees and other vegetation indicate that the conditions of precipitation approach those in the Wolf Mountains and in the upland of the Northern Cheyenne Indian Reservation rather than those in the lower country to the north. In general the ground-water conditions in these townships are similar to those in T. 1 S., Rs. 39 and 40 E., which adjoin on the north.

On Charles G. Farr's ranch, in the SE. ¼ sec. 6, T. 2 S., R. 40 E., there is a well 117 feet deep, in which the water comes within 62 feet of the surface. This water is hard and has a very unpleasant taste. Analysis 95 shows that it is much more highly mineralized than the average waters from the Tongue River member. It is highly probable that most of this water is derived from a clinker bed that contains considerable mineral matter, and there is little doubt that if this highly mineralized water is sealed off potable soft water can be obtained by drilling the well 100 feet deeper. On F. A. Cooley's ranch, in the SE. ¼ sec. 8, T. 2 S., R. 40 E., there is a drilled well 38 feet deep with the water level 22 feet below the surface. The water in this well is hard, and though it contains almost 3,000 parts per million of dissolved solids, is pleasant tasting. (See analysis 96.) A deposit of white alkali on the trough leading from the pump indicates the high amount of dissolved material.

T. 2 S., R. 41 E.

T. 2 S., R. 41 E., includes part of the Northern Cheyenne Indian Reservation, which is described on pages 126 to 129. Secs. 1 and 6 and the northern part of secs. 7 to 12, which are outside the reservation, are described here.

Soft water can be obtained at approximately the same depths in this township as in T. 1 S., R. 41 E., and other ground-water conditions are similar. In the NE. ¼ SW. ¼ sec. 8, on Martin Lennom's ranch, there is a drilled well 84 feet deep, with the water standing 15 feet below the surface. This water is fairly palatable but is hard, as the well is not sufficiently deep to penetrate the zone of soft water. It is utilized with satisfactory results for irrigating a garden. The deeper soft water is unsatisfactory for irrigating.

Springs are fairly common. In the NW. ¼ sec. 10 Henry N. Bayley has a spring of especially palatable water. (See analysis 97.) He has built adjacent to the spring a concrete collecting box 8 by 8 by 4 feet with intake and overflow pipes. The water from this box is piped by gravity about 1½ miles to his residence, near the center of sec. 4, where it is used for all domestic purposes.

T. 2 S., RS. 42 AND 43 E.

Most of T. 2 S., Rs. 42 and 43 E., lies within the Tongue River Northern Cheyenne Indian Reservation, which is described on pages 126 to 129. Only the narrow belt across the northern part of these townships outside the reservation is considered here. In this area all the surface rocks belong to the Tongue River member of the Fort Union formation, and much of the coal has been burned along the outcrop, producing the characteristic red clinker. The northern part of these townships is transitional between the open sparsely vegetated townships to the north and the heavily forested lands of the reservation. As in the townships to the north, soft water can doubtless be procured by drilling 150 feet or more into the Fort Union strata. (See analyses 102, 103, and 105.)

At many places in this area there are springs which yield hard but pleasant-tasting water. (See analyses 97 and 101.) Shallow dug wells will no doubt yield water similar in character to that from springs.

T. 2 S., R. 44 E.

The Tongue River flows northward across T. 2 S., R. 44 E., through an alluvium-filled valley, bordered on each side by rocks of the Tongue River member of the Fort Union formation, in which much of the coal has been burned, thereby producing considerable thicknesses of red clinker.

All of the country in this township south of the 40-mile limit of the railway grant and west of the Tongue River is within the Northern Cheyenne Indian Reservation. The largest tributaries to the Tongue River in this township are Stebbins Creek and Home Coulee from the west, and Cook Creek, Northrop Coulee, and Colbert Coulee from the east.

Soft water will doubtless be encountered within 150 feet or more, and although there are no flowing wells in this township it is believed that flows could probably be obtained along the flood plain close to the Tongue River by drilling to a depth of 500 feet or less; the southern part of the township would be the most favorable. In the SE. ¼ sec. 4, on R. P. Colbert's ranch, there is a well 118 feet deep with a water level 28 feet below the surface, which yields good-tasting soft water. The coals and clinker beds in places give rise to springs of potable hard water. Such a spring was noted at Jack Johnson's, in the NW. ¼ sec. 6. Hard but potable water can be obtained by digging shallow wells into the intercalated gravel beds in the alluvium along the Tongue River, and less satisfactory water can be obtained from shallow wells in coulees tributary to the river.

Representative of the shallow dug wells in the alluvium along the Tongue River which yield hard water are R. P. Colbert's well, in the SE. ¼ sec. 4, which is 28 feet deep and contains 4 feet of water, and Thomas Horton's well, in the NE. ¼ sec. 4, which is 22 feet deep and contains 3 feet of water.

T. 3 S., R. 44 E.

The Tongue River member of the Fort Union formation is at the surface over all of T. 3 S., R. 44 E., except along the Tongue River and some of its tributaries, where there is a considerable deposit of alluvium. The Tongue River member in this township contains a considerable amount of red clinker. Otter Creek, from the east, and Logging Creek, from the west, are the largest tributaries to the Tongue River in this township. The country east of the river, which is outside the Northern Cheyenne Indian Reservation, is discussed here. Much of the coal in the Tongue River member has been burned along the outcrop, and on the red soil derived from this clinker there is a considerable forest growth near the eastern and western margins of the township.

Ashland, a village of several hundred inhabitants, outside the reservation, is the largest community in Rosebud County south of the Yellowstone River. In the vicinity of Ashland, along the flood plain of the Tongue River and its tributary Otter Creek, there are several soft-water artesian wells ranging in depth from 200 to 250 feet, which obtain their water near the base of the Tongue River member. These wells, all of which are gas-bearing, yield between 1½ and 5 gallons a minute. Some of the best of these artesian wells are described below.

At the St. Labre Mission, in the NE. ¼ sec. 3, there is an artesian well 178 feet deep that flows at the rate of 9 gallons a minute. The water is of very good quality, containing approximately 1,000 parts per million of total solids. (See analysis 102.) Mrs. Vess Newell's well, in the SE. ¼ NW. ¼ sec. 11, which supplies many of the residents of Ashland, is 240 feet deep and flows at the rate of 2 gallons a minute. The water is soft and contains less than 1,000 parts per million of dissolved mineral constituents. (See analysis 103.) Other flowing wells from which samples for analysis were collected are the well in the SE. ¼ sec. 3, which is 240 feet deep; Thomas Wood's well, in the SE. ¼ NW. ¼ sec. 11, which is 235 feet deep and flows at the rate of 1¼ gallons a minute; the schoolhouse well, in the SW. ¼ NW. ¼ sec. 11, which is 235 feet deep; T. G. Wagner's well, near the center of the NE. ¼ sec. 13, which is 263 feet deep and flows at the rate of 3 gallons a minute. In the SW. ¼ sec. 18 of the adjoining township (T. 3 S., R. 45 E.) H. S. Trusler has a well 230 feet deep which is reported to flow at the rate of 15 gallons a minute. All these flowing wells seem to derive their water from the Tongue River member. The water is similar in quality to that represented by analyses 102 and 103, being satisfactory for drinking, domestic purposes, and stock but unfit for irrigation. Hard water that is satisfactory for irrigating lawns and gardens and is generally palatable can be had by digging or boring shallow wells into the alluvium along the Tongue River or by penetrating the rocks of the Tongue River member to depths of about 50 feet. D. A. Scallend, in the NE. ¼ sec. 22, has an 18-foot dug well ending in Fort Union sandstone. J. Scandel, in the SE. ¼ sec. 28, has a dug well 18 feet deep in the alluvium of the Tongue River the water of which is reported to taste of "alkali." Wells of this type will yield water varying in chemical character, similar to that shown by analyses 76, 86, 109, and 110. In general, the water from the Tongue River member will be of better quality than that obtained in the alluvium.

At many places in the Tongue River strata there are springs coming from coal, clinker, and sandstone beds.

T. 4 S., RS. 43 AND 44 E.

The Tongue River flows northeastward across the southeast corner of T. 4 S., R. 43 E., and the northwest corner of T. 4 S., R. 44 E. In these townships only a small strip along the river was examined. All the country west of the river is within the Northern Cheyenne Indian Reservation. Except for valley fill along the Tongue River the rocks belong to the Tongue River member of the Fort Union formation, and the dip is northeast at less than 1°.

Ground-water conditions are essentially the same in the two townships. Soft water can be obtained by drilling into the Fort Union rocks. The flood plain of the river can be regarded as favorable for prospecting for flowing wells. The water obtained from either flowing or nonflowing wells at depths greater than 150 feet will be similar in quality to the water of the deeper wells in adjoining townships. (See analyses 102, 103, and 107.) The clinker and coal beds yield potable hard water in springs. On A. J. Powers's land, east of the Ashland-Birney road, in the SE. 1/4 SW. 1/4 sec. 8, T. 4 S., R. 44 E., there is a spring in a coal and clinker bed, the water of which flows by gravity into the house, several hundred feet to the west. Analysis 104 shows that this water, though hard, contains less than 550 parts per million of total solids. Hard water satisfactory for domestic use can be obtained in many places from shallow wells sunk into the Fort Union strata in coulees and, in many of the unirrigated tracts, from the alluvium along the Tongue River. (See analysis 106.)

T. 5 S., R. 41 E.

Only the part of T. 5 S., R. 41 E., south of Cook Creek is outside the Northern Cheyenne Indian Reservation. All the rocks exposed at the surface belong to the Tongue River member of the Fort Union formation, and the ground-water conditions are the same as in the adjoining townships to the east and south (T. 5 S., R. 42 E., and T. 6 S., R. 41 E.).

T. 5 S., RS. 42 AND 43 E.

All the rocks at the surface in T. 5 S., Rs. 42 and 43 E., belong to the Tongue River member of the Fort Union formation, which in this region contains well-developed clinker beds. The Tongue River flows northeastward across the southeast corner of T. 5 S., R. 42 E., and the northwest corner of T. 5 S., R. 43 E. A fertile alluvial flood plain borders the river. A considerable part of these two townships has not been surveyed. All the country west of the Tongue River and north of Cook Creek is in the Northern Cheyenne Indian Reservation.

The ground-water conditions are in no important respect different from those in T. 4 S., Rs. 43 and 44 E. Soft water can be obtained from wells 150 feet or more deep, and hard water from shallow wells in the alluvium or in the Tongue River beds. The soft deep water will be similar in character to Nos. 102, 103, 105, and 107, and the shallow water to Nos. 106, 99, 111, and 112. Owing to the gentle northeastward dip of the strata, conditions are favorable for artesian wells along the flood plain of the river. Flowing wells can not be predicted in this area with certainty. The sample of water for analysis 106 was collected from the dug well 17 feet deep at the Indian school in the SW. 1/4 sec. 7, T. 5 S., R. 43 W. Albert Knoblock, in the SW. 1/4 sec. 17, T. 5 S., R. 43 E., has a dug well 18 feet deep, containing 3 feet of water. The water in this well is contributed from a coal bed, and the water level fluctuates with the rise and fall of Tongue River, as the well is within 100 feet of the stream.

T. 5 S., R. 44 E.

Only the northern part of T. 5 S., R. 44 E., has been examined. All the rocks cropping out in this area belong to the Tongue River member of the Fort Union formation. Odell Creek flows northwestward across this township into the Tongue River and with its tributaries drains the area. Most of the slopes in the eastern and southern parts of the township are covered with a considerable growth of timber. All of the township is within the Custer National Forest.

Hard water can be obtained along Odell Creek within 50 feet of the surface in most places, and soft water at a depth of 150 feet or more. In the forested region in the southern part of the township, where the water table is relatively close to the surface, the groundwater conditions are similar to those in Tps. 6 and 7 S., R. 44 E. The hard water obtained from shallow depths will doubtless be similar in chemical character to Nos. 100, 109, and 110, and the deeper soft water will be similar to Nos. 102, 103, and 107.

Roy Pittman, in sec. 9, in the valley of Odell Creek, has a dug well 75 feet deep which is reported to yield hard water.

T. 6 S., R. 41 E.

In T. 6 S., R. 41 E., all the rocks at the surface belong to the Tongue River member of the Fort Union formation. The drainage goes southeastward to the Tongue River by Bull, Prairie Dog, and Canyon Creeks and their tributaries.

The ground-water conditions characteristic of this part of Rosebud County prevail in this township. Supplies of soft water can be obtained by drilling 150 feet or more. Potable hard water issues as springs from coal beds and clinker, and hard water somewhat similar in character is obtained from shallow dug wells. Analyses of waters obtained from shallow and deep wells in southern Rosebud County are given in the table.

T. 6 S., R. 42 E.

The Tongue River flows across T. 6 S., R. 42 E., from the southwest to the northeast corner. A relatively narrow but fertile belt of alluvium borders the river. The principal tributaries in this township are Browns Gulch, Zook, Whitten, and Bull Creeks from the northwest and Butte Creek from the southeast. All the surface rocks in this township belong to the Tongue River member of the Fort Union formation, which in this region contains a great deal of clinker.

Here, as elsewhere in the area of Tongue River rocks, the water obtained from a depth of 150 feet or more is soft, and that occurring relatively near the surface is hard.

At the Three Circle ranch, in the SW. ¼ SE. ¼ sec. 1, there is a drilled well 246 feet deep, the top of which is about 25 feet above the river. This well, which flows at the rate of three-fourths of a gallon a minute, is the only flowing well south of Ashland. Its water is soft (see analysis 107), a quality which is to be expected. At the G. W. Brewster estate, in the SW. ¼ sec. 23, soft water containing only about 500 parts per million of total solids is obtained from a well 80 feet deep. (See analysis 108.) This well, which is 4 inches in diameter, is reported to have gone through 20 feet of sandstone to the water-bearing bed. The water level is normally 14 feet below the surface. The water is pumped with a gas engine to a storage tank, from which it is drawn to serve all domestic needs of 30 or more people. The pump delivers 33 gallons a minute and is reported to lower the water level in the well 1 foot a minute for 12 minutes, after which there is no change. This well is indicative of the ground-water supplies that can be had by drilling into the Fort Union rocks.

Several shallow wells that obtain their water from the alluvium along the Tongue River in this township were also inspected, including those of A. E. Peterson, dug well, in the SW. ¼ sec. 32, depth 14 feet; Thomas Salverson, dug well, NW. ¼ sec. 32, 12 feet; Thomas Salverson, driven well, NW. ¼ sec. 32, 12 feet. The water level in all these wells fluctuates with change in level of the Tongue River. The water is hard and similar in chemical character to that of other shallow wells in southern Rosebud County.

T. 6 S., R. 43 E.

In T. 6 S., R. 43 E., all the strata belong to the Tongue River member of the Fort Union formation. The coals in this member have been burned along the outcrop in many places, and there is a great amount of clinker. The Tongue River flows across a part of sec. 7, and Hanging Woman Creek, the East Fork of Hanging Woman Creek, Roberts Gulch, and Timber Creek are the principal other streams draining this township. The western part of the township is in the Custer National Forest.

In this township, as in all the rest of southern Rosebud County, soft water is obtained from the deeper wells and hard water from the shallower wells. The chemical character of the water obtained from the deeper wells is shown by analyses 102, 103, 105, and 107, and that of the water from the shallower wells by analyses 94, 99, 109, and 110. On Gilbert Woodard's land, in the NE. ¼ sec. 19, there is a well 235 feet deep in which the water level is reported to be 20 feet below the surface. This well yields soft water, and is equipped with a gasoline engine for pumping. A well 20 feet deep in the same quarter section yields fairly good-tasting hard water. At the Bones Bros.'s ranch, on the bank of Hanging Woman Creek, in the SW. ¼ sec. 20, there is an 11-foot dug well, in which the water stands 7 feet below the surface. This water is very pleasant tasting, and there is an ample supply for 25 or 30 people and a large ranch. There is a strong flow of ground water here, and the well is in reality a spring which has been deepened to a well. The water is lifted by an automatic-pressure pump. In general, the water obtained from other shallow dug wells in the alluvium along the streams in this township is much less satisfactory than that obtained from this well.

T. 6 S., R. 44 E.

The surface strata throughout T. 6 S., R. 44 E., belong to the Tongue River member of the Fort Union formation, in which there are at least two well-developed clinker beds. In 1923 this township had not been surveyed by the United States General Land Office. All of the township is within the Custer National Forest, and over most of it there is a considerable forest growth. The township is on the divide between the Tongue River and Otter Creek drainage basins.

Soft water can be obtained by drilling wells 150 feet or more into the Tongue River strata. Good tasting but hard water is obtained in springs from coal and clinker beds. Sample 109 was collected from A. J. Jackson's dug well in sec. 30 (unsurveyed), which is 25 feet deep and ends in alluvial gravel. The water is pleasant tasting but hard, and the analysis shows that it contains less than 600 parts per million of total solids. Analysis 102, 103, 105, and 107 of samples collected from wells in near-by townships, show the chemical character of water that is to be expected from deeper wells here.

TPS. 7 AND 7½ S., R. 41 E.

All the rocks in Tps. 7 and 7½ S., R. 41 E., belong to the Tongue River member of the Fort Union formation. A considerable amount of the coal in these beds has been burned along the outcrop, producing red cliffs of striking appearance. Tongue River and its tributaries, the largest of which are Spring Canyon and Fourmile Creek, from the west, and Dead Mans Gulch and Harris Creek, from the southeast, drain this township.

Soft water (see analyses 102, 103, 105, and 107) in sufficient quantities for domestic use can be obtained by drilling 150 feet or more. Hard water (see analyses 106 and 109) is obtained from shallow wells in the Tongue River strata or in the alluvium derived from it. The water in Bernt Hanson's well, in sec. 11, is representative of the quality of water that may be expected from wells dug into the alluvium. (See analysis 111.)

At the Flying V ranch, in the SW. ¼ sec. 22, there is a well 90 feet deep, with the water level 12 feet below the surface, which yields good-tasting water. On Paul Paulson's place, in the NW. ¼ sec. 27, there is a 20-foot dug well in river alluvium which was reported to contain hard water of satisfactory taste.

T. 7 S., R. 42 E.

In T. 7 S., R. 42 E., all the surface strata belong to the Tongue River member of the Fort Union formation. The drainage in this township goes westward and northwestward by Wall Creek, Dead Mans Gulch, and Harris Creek to the Tongue River and eastward by Van Meter and Locey Gulches to Hanging Woman Creek, a northward-flowing tributary of the Tongue River. The divide between these two drainage systems runs approximately south, west of the center of the township.

Soft water can be obtained from the Tongue River strata by drilling wells 150 feet or more deep, and soft water can be obtained at shallower depths from the same rocks or from the alluvium derived from them.

In the NW. ¼ sec. 6, at the 4 D ranch, owned by the Brown Land & Cattle Co., there is a dug well 20 feet deep, which is reported to obtain its water from alluvial quicksand. This well is between an irrigation ditch and the river, and it is reported that when the ditch is empty the well also empties. The tract in proximity to the well is not extensively irrigated. The water is potable, and analysis 110 shows that it is hard but less mineralized than the water from the Fort Union formation in this region. Another well in the NW. ¼ sec. 6 is 260 feet deep and yields soft water. The well is equipped with a gasoline engine which pumps water for household use.

T. 7 S., R. 43 E.

The surface strata in T. 7 S., R. 43 E., belong to the Tongue River member of the Fort Union formation. Hanging Woman Creek, with its tributaries Van Meter Gulch, Locey Gulch, and Strout Creek, drain the southern and western parts of this township and Lee Creek, another large tributary to Hanging Woman Creek, drains the northeastern part. On the whole, the township is dissected and rough. Twelve sections in the northeast corner are within the Custer National Forest.

There are clinker beds of at least two horizons, which can be traced over most of the township. The upper one caps the divide and is probably the equivalent of the Smith clinker.[2]

[2] Baker, A. A., The Northward Extension of the Sheridan Coal Field, Big Horn and Rosebud Counties, Mont.: U. S. Geol. Survey Bull. 806, p. 56, 1929.

Along Hanging Woman Creek and the lower part of Lee Creek hard water is encountered within 25 feet of the surface in most places, but such water is not so palatable as the soft water obtained by drilling to greater depths. On F. C. Rolls's ranch, in the NE. ¼ sec. 13, there is a soft-water well 427 feet deep, in which the water stands 142 feet below the surface. Analyses 102, 103, 105, and 107 indicate the chemical character of the soft water that is to be expected from the deeper wells. Hard water is obtained from shallow wells in the Tongue River rocks, or in alluvium derived from these rocks. (See analyses 99, 106, 109, and 110.)

Springs yielding hard but potable water from the gravel along Lee Creek and from the coal and clinker beds are not uncommon. A spring examined at F. C. Rolls's place, in the NE. ¼ sec. 13 is reported to fail during dry seasons.

T. 7 S., R. 44 E.

Lee Creek and its several forks drain most of T. 7 S., R. 44 E. All the rocks at the surface belong to the Tongue River member of the Fort Union formation. The northern part of this township, which is within the Custer National Forest, is timbered, but the southern part is a broad, open undulating upland. The upland is underlain by a heavy clinker bed, probably the equivalent of the Smith clinker[3] that caps the divide west of Tongue River. A clinker which is less pronounced but occurs over much of this region crops out along Lee Creek in the eastern part of the township.

The clinker beds in this township are especially conducive to springs. In the places where ground water issues from the clinker beds there is usually a considerable deposit of white alkali. A sample of this material was collected from the large clinker bed that crops out along Lee Creek in sec. 18. The analyses of this material (A–16, A–16a, pp. 48 and 49) show that it is almost entirely calcium and magnesium carbonates, but that it contains some calcium, magnesium, and sodium as sulphate and bicarbonate. The water from the clinker beds here, as elsewhere in the county, is good-tasting hard water. At N. W. Snider's ranch, in the NW. ¼ sec. 33, a sample of hard water of this type was collected from a spring issuing from the highest clinker bed in the township. Analysis 112 shows that the water contains about 1,250 parts per million of total solids. This spring yields about 2½ gallons a minute.

All the springs shown on the map (pl. 1) yield harder water, including those of William Munson, in the valley of Lee Creek in the northern part of the SE. ¼ sec. 20, and George Knoblock, in the

[3] Baker, A. A., op. cit.

SE. ¼ sec. 21. Supplies of soft water, similar to that obtained elsewhere in southern Rosebud County (see analyses 102, 103, 105, and 107) can be had in this township by drilling 150 feet or more, and hard water similar to that shown by analyses 98, 99, 109, and 110 can be had from shallow wells.

NORTHERN CHEYENNE INDIAN RESERVATION

LOCATION AND EXTENT

The Northern Cheyenne Indian Reservation, on the Tongue River, which was set aside by the Government in 1886, lies partly in Rosebud County and partly in Big Horn County. It is bounded on the north by the 40-mile limit of the Northern Pacific Railway grant; on the east by the Tongue River; on the south by Cook Creek in Rosebud County and the line between Tps. 5 and 6 S. in Big Horn County; and on the west by the Crow Indian Reservation, about 15 miles west of Rosebud County. The part of the reservation in Rosebud County embraces all of T. 3 S., Rs. 41, 42, 43 E., and T. 4 S., Rs. 41 and 42 E.; and parts of T. 2 S., Rs. 41, 42, 43, and 44 E., T. 3 S., R. 44 E., T. 4 S., Rs. 43 and 44 E., and T. 5 S., Rs. 41, 42, and 43 E. The part in Big Horn County embraces six townships and parts of six others. In 1923, when the field work for this report was done, most of the Northern Cheyenne Reservation had not been surveyed by the General Land Office. Because of this fact and because of the similarity in geology and ground-water conditions over most of the reservation, the part in Rosebud County is described as a whole instead of by individual townships.

TOPOGRAPHY AND VEGETATION

The altitudes within the reservation range from about 4,800 feet on the crest of the divide between Lame Deer Creek and the Tongue River to about 2,930 feet on the Tongue River, giving a maximum relief of about 1,870 feet.

Along the Tongue River, which forms the eastern boundary of the reservation, there are several terraces that seem to be due more to the type of rock than to erosion by the river. One terrace can be readily traced from Ashland, where it is about 150 feet above Otter Creek, to a point about 8 miles north of Ashland, where it descends to river level. Throughout this distance the top of the terrace conforms to the northward dip of a thick clinker bed, which is very resistant to erosion. West of the river the general surface slopes gradually up, away from the river, for several miles to the foot of a steep bluff, probably 1,200 feet or more in height. The roughest topography within the reservation is found in this stretch between Tongue River and the bluff. As exposed in the face of the bluff the red rocks formed by burning of the underlying coal, with the interbedded rocks of lighter hue, form a striking picture.

The central part of the reservation is a broad undulating upland intersected on the east and west drainage slopes by steep-walled ravines. The vegetation on this upland consists mostly of yellow pine. On the divide that separates Lame Deer Creek from Cook Creek and the Tongue River there is a dense forest growth, which decreases somewhat toward the lower country nearer the streams and practically ceases several miles west of the Tongue River.

GEOLOGY AND GROUND WATER

All the rocks in the Northern Cheyenne Reservation belong to the Tongue River member of the Fort Union formation, which in general dips a few feet to the mile northeastward. There are at least two thick clinker beds. The upper bed caps the divide between the Tongue River and Lame Deer Creek and is probably the equivalent of the Smith clinker.[4] There are also numerous thin beds of clinker. The weathering of the clinker produces a red soil, which occurs over most of the reservation.

In the forested parts of the reservation the numerous springs give testimony to the proximity of the water table to the surface, the clinker beds being especially conducive to seepage and springs. A sample of water was collected from a spring about 150 feet northwest of the Ashland-Lame Deer road 10¼ miles west of the Tongue River. The water from this spring is very cool (47° F.), and the yield is at least 10 gallons a minute and may be considerably more. The water issues from a talus accumulation of clinker and probably has its source in a clinker bed. Analysis 101 shows that this water, though hard, contains less than 300 parts per million of total dissolved solids and is therefore better than most of the other waters in Rosebud County.

Soft water can be obtained in the Northern Cheyenne Reservation by drilling 150 feet or more, and the area along the flood plain of the Tongue River is regarded as favorable for prospecting for soft-water artesian wells, though flowing wells can not be predicted with certainty. The soft water obtained from the deeper horizons will no doubt resemble Nos. 102, 103, 105, and 107 in chemical composition. The ground water encountered nearer the surface, whether in the Tongue River strata or in the alluvium derived from it, is always

[4] Baker, A. A., op. cit., p. 35.

hard. The sample for analysis 106, which is representative of the shallow wells in the alluvium, was collected from a dug well 17 feet deep in the SE. ¼ sec. 7, T. 5 S., R. 43 E. This water is very hard but is utilized for domestic purposes and for stock.

GROUND-WATER CONDITIONS AT LAME DEER

The Indian agency is at Lame Deer, on Lame Deer Creek, in secs. 33 and 34, T. 2 S., R. 41 E.; the center of the village is about the mouth of Alderson Creek. (See pl. 6, *B*.) There is considerable alluvium at the junction of Alderson and Lame Deer Creeks, a good share of which consists of red gravel derived from the Tongue River clinker beds in the near-by hills. Almost all the inhabitants obtain their water by digging shallow wells into this alluvial material, in which the water table is encountered within 20 to 30 feet of the surface. The water from these shallow wells, though hard, does not have an unpleasant taste. A sample of water was collected at the residence of the Indian agent, H. M. Boggess, in the NE. ¼ sec. 33, from a well 30 feet deep containing 8 feet of water. Analysis 98 shows that this water is hard and contains less than 650 parts per million of total dissolved solids. The water is used for all domestic purposes and stock. A sample of water was collected from A. C. Stohr's bored well, which is 66 feet deep and 6 inches in diameter and when visited contained about 36 feet of water. Analysis 100 shows that this water contains about 850 parts per million of total solids and is hard. Sample 99 was collected from William Knoblock's well, 18 feet deep, near the agency, in the NE. ¼ sec. 33. These samples are representative of the quality of water which is to be expected from shallow wells in the vicinity of Lame Deer. Soft water may be had by drilling 150 feet or more, and such water will resemble Nos. 102, 103, 105, and 107.

Because of the proximity of outhouses to many shallow wells at Lame Deer the bacteriologic quality of the water may be questionable, but so far as could be ascertained the village has never suffered from epidemics of typhoid or other malady caused by drinking impure water. The risk of pollution would be less if water for domestic purposes and drinking were obtained from deeper wells drilled down to the horizons of soft water.

GROUND-WATER SUPPLIES FOR IRRIGATION

For any contemplated irrigation projects along the principal streams diversion ditches leading the water from the stream itself would probably be the most satisfactory method of obtaining water. However, there are numerous relatively flat stretches of country in the higher parts of the reservation, away from Tongue River, that are cultivated at the present time, and these areas could doubtless be made more productive by additional water supplies. The deeper soft water is not serviceable for irrigation, but the hard water obtained from shallow wells is of satisfactory quality. Supplies of hard water sufficient for irrigating tracts of several acres can probably be obtained in the higher parts of the reservation by putting down wells of large diameter, preferably 50 feet or less in depth.

ANALYSES

Analyses of waters in Rosebud County, Mont.

[Analyzed by H. F. Riffenburg, except as otherwise noted. Parts per million]

No.	Location	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Water-bearing formation	Water level above or below surface (feet)	Use of water [a]
1	NE. ¼ SE. ¼ sec. 23, T. 10 N., R. 34 E.	Northern Pacific Ry.	Dug	7.7	5 feet	Gravel from Lance formation	−2.6	S.
2	NE. ¼ NE. ¼ sec. 26, T. 10 N., R. 34 E.	Mrs. A. Henderson	do	53	6 feet (top); 4 feet bottom)	Lance formation	−51	D.
3	NE. ¼ NW. ¼ sec. 28, T. 9 N., R. 35 E.	Ernest McCollum	do	23	5 feet	Sandstone of Judith River formation.	−21.7	D, S.
4	NE. ¼ NW. ¼ sec. 28, T. 9 N., R. 35 E.	W. J. Johnston	do	51	4 feet	Upper part of Judith River formation.		D, S.
5	NW. ¼ NE. ¼ sec. 34, T. 9 N., R. 35 E.	J. A. Bookman	do	60	3 feet	Judith River formation	−45	D, S.
6	NE. ¼ NW. ¼ sec. 34, T. 9 N., R. 35 E.	Roy Byerley	Drilled	75	6 inches	do	−50 to −60	D, S.
7	NE. ¼ SE. ¼ sec. 33, T. 9 N., R. 37 E.	L. Schmoeller	Dug	69	4 feet	Judith River and Claggett formations.	−64.5	D, S.
8	SW. ¼ sec. 2, T. 8 N., R. 37 E.	Amelia Manser	do	8	5 feet	Sandstone in Judith River formation.	−4.5	D, S.
9	SW. ¼ SE. ¼ sec. 20, T. 8 N., R. 38 E.	Martin Schow	Drilled	60	6 inches	do	−25	D, S.
10	SW. ¼ sec. 24, T. 8 N., R. 38 E.	C. W. Johnson	Dug	28	6½ feet	Claggett shale and alluvium	−20	S.
11	SW. ¼ SW. ¼ sec. 4, T. 8 N., R. 44 E.	Zeno Ottinger	do	16	6 feet	Alluvium from Lebo member	−10	D, S.
12	NE. ¼ NW. ¼ sec. 5, T. 7 N., R. 38 E.	S. Sigman	Bored	40±	12 inches	Sandy shale of Judith River	−32	D.
13	NW. ¼ sec. 5, T. 7 N., R. 38 E.	City of Vananda	Drilled	225	8 inches	Claggett shale	−4 to −15	D, S.
14	SW. ¼ sec. 35, T. 7 N., R. 41 E.	F. V. H. Collins	do	255	2½ inches	Sandstone of Lance formation	Flows 30 feet above river.	D, S.
15	NE. ¼ sec. 8, T. 7 N., R. 43 E.	Joe Barley	do	652	do	Lance formation and Bearpaw shale.	About −73	S.
16	SW. ¼ sec. 36, T. 7 N., R. 44 E.	C. W. Wilson	do	434	1½ inches	Lance formation	Flows	D, S.
17	NE. ¼ sec. 8, T. 6 N., R. 38 E.	Fred McCormack	Dug	12	5 feet (top), 3 feet (bottom).	River gravel	−10	D.
18	SW. ¼ sec. 14, T. 6 N., R. 38 E.	George Mace	do	33	About 5 feet	Alluvium from Reservation Creek.	About −17	D, S.
19	Sec. 17, T. 6 N., R. 38 E.	Mellon Lewis estate	do	20		Alluvium		S.
20	SW. ¼ SW. ¼ sec. 2, T. 6 N., R. 39 E.	Bert Hammond	do	22	16 feet	Alluvial gravel	−16	D, S.
21	SE. ¼ sec. 12, T. 6 N., R. 39 E.	James McGraw	do	16	3 feet	do		D, S.
22	SW. ¼ sec. 14, T. 6 N., R. 39 E.	Andersen & Tadsen	do	39	do	do	−34	D, S.
23	SW. ¼ sec. 18, T. 6 N., R. 39 E.	Sam Newnes	Bored	22	15 inches	Alluvial gravel and sand	−19	([b])
24	SE. ¼ sec. 19, T. 6 N., R. 39 E.	Dennis Myerhoff	Dug and drilled	50	5 feet (top), 3 inches (bottom).	Alluvial gravel	−32	S.
25	SE. ¼ sec. 21, T. 6 N., R. 39 E.	E. F. Myerhoff	Dug	30	4 feet	Alluvium of Yellowstone River		S.

[a] D, domestic; Dr., drinking; I, irrigation; S., stock.

[b] Water is so highly mineralized that stock will not drink it.

Analyses of waters in Rosebud County, Mont.—Continued

No.	Date of collection	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Remarks
1	Oct. 8, 1923	370	16	0.40	57	27	46	0	366	40	2.0	1.5	253	
2	....do.......	640	10	.20	61	29	134	0	444	165	12	10	271	
3	....do.......	1,584	13	.30	82	37	394	0	378	840	20	5.0	357	
4	....do.......	3,724	16	2.3	35	15	1,220	0	878	1,944	28	7.2	149	
5	....do.......	676	16	.20	27	7	213	0	395	190	22	3.0	96	
6	....do.......	512	16	.60	41	13	128	0	298	165	10	3.0	156	
7	Aug. 15, 1923	2,800	6.4	2.1	199	281	184	0	154	1,833	22	Trace.	1,650	
8	....do.......	880	12	.20	212	34	14	0	332	400	3.0	3.0	669	
9	Aug. 16, 1923	328	11	.40	58	25	24	0	217	88	5.0	20	248	
10	....do.......	3,436	11	1.2	342	123	532 24	0	586	1,889	71	.25	1,359	
11	Sept. 25, 1923	926	15	.20	101	45	175 12	0	732	208	5.0	13	437	
12	Aug. 15, 1923	4,542	14	15	322	192	814	0	673	2,658	17	Trace.	1,592	
13	Aug. 14, 1923	6,896	10	3.8	40	27	2,172	0	610	4,230	28	11	211	
14	Sept. 8, 1923	2,916	12	Trace.	13	4.4	957 24	14	527	1,594	34	Trace.	50	No hydrogen sulphide noted in sample when collected.
15	Aug. 7, 1923	3,676	20	4.2	22	9	1,279	0	1,591	1,486	14	7.8	92	
16	Aug. 8, 1923	1,081	11	.20	4.0	2.9	433	72	927	3.3	64	.67	22	
17	Sept. 27, 1923	....	....	....	2.7	192	[c] 544	0	473	1,979	46	....	1,330	In irrigated area.
18	....do.......	....	....	....	25	13	[c] 66	0	122	147	4.0	....	116	In irrigated area. Receives water from underflow of Reservation Creek.
19	Sept. 16, 1916	3,791	31	[d] 5.8	179	152	[c] 785	0	564	2,183	29	.08	1,071	Analyzed by W. M. Cobleigh.
20	Sept. 27, 1923	....	....	....	78	22	[c] 199	0	368	379	16	....	285	In irrigated area. Of unusually good quality.
21	....do.......	2,294	39	1.0	204	73	380 45	0	508	1,184	34	Trace.	809	In irrigated area.
22	....do.......	....	....	....	192	168	[c] 1,290	0	722	3,193	42	....	116	Do.
23	Sept. 11, 1923	10,260	30	Trace.	343	317	2,369	0	1,057	5,531	492	Trace.	2,157	Do.
24	Sept. 27, 1923	....	....	....	175	118	[c] 1,150	0	476	2,772	104	....	921	Do.
25	Sept. 11, 1923	6,430	....	....	430	201	[c] 1,063	0	412	3,628	68	....	1,899	Do.

[c] Calculated.

[d] Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).

Analyses of waters in Rosebud County, Mont.—Continued

No.	Location	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Water-bearing formation	Water level above or below surface (feet)	Use of water
26	SE. ¼ sec. 23, T. 6 N., R. 39 E.	Wellington Payne	Dug	19	3 feet	Lance formation, basal sandstone		D, S.
27	SE. ¼ sec. 23, T. 6 N., R. 39 E.	G. W. Longley	Driven	49	2 inches	Alluvial gravel and quicksand	+10	D, S.
28	NE. ¼ SW. ¼ sec. 7, T. 6 N., R. 40 E.	Cold Springs Livestock Co.	Dug	16.7	3.5 feet	Alluvium	−13.4	D, S.
29	SE. ¼ SW. ¼ sec. 13, T. 6 N., R. 40 E.	Paul Hoffman	do	24	4 feet	do	−21	D, S, I.
30	Eleventh Avenue bet. River and Park Streets, Forsyth, T. 6 N., R. 40 E.	Maj. J. E. Edwards	Drilled	146	2½ inches	Lance formation	−6	D.
31	SE. ¼ sec. 15, T. 6 N., R. 40 E., near center of Yellowstone River about 500 feet south of bank.	Chicago, Milwaukee, St. Paul & Pacific Ry.	Dug	25±		Alluvial river gravel	Varies with river level.	R.R.
32	Corner of Willow Street at end of Seventh Avenue, Forsyth, T. 6 N., R. 40 E.	Northern Pacific Ry	River water, from sedimentation tank.					R.R.
33	NE. ¼ sec. 16, T. 6 N., R. 40 E.	Coal Springs Ranch Co.	Spring			Basal sandstone of Lance formation and terrace gravel.		D, S.
34	NE. ¼ sec. 17, T. 6 N., R. 40 E.	Cold Springs Livestock Co.	Dug	10.6	3 feet	River alluvium	−7.9	D, S.
35	NE. ¼ sec. 20, T. 6 N., R. 40 E.	E. J. Cline	Driven	14	1½ inches	Alluvial gravel		D.
36	SE. ¼ SE. ¼ sec. 22, T. 6 N., R. 40 E.	C. C. Edwards	Dug	16	4 feet	Alluvial river gravel	−12	D, S.
37	Sec. 23, T. 6 N., R. 40 E.	City of Forsyth	River water, filtered.					City.
38	SW. ¼ SW. ¼ sec. 23, T. 6 N., R. 40 E.	Ben Arnold	Dug	18–20	4 feet	Alluvium	−13 to −15	D, S.
39	College Street midway between Prospect and Vine, Forsyth.	John Wachholz	do	20	6 feet	Alluvial gravel	−11	D.
40	SE. corner Cedar and Tenth Streets, Forsyth.	Mrs. Inez Coleman	do	25	4 feet	Alluvium		D.
41	Corner Fifth and River Streets, Forsyth.	W. H. Kelley	Drilled	156	4 inches	Lance formation	−13	D.
42	NW. ½ NW. ¼ sec. 24, T. 6 N., R. 40 E.	H. W. Renicke	Dug	15	3 feet	Lance formation, sand, and alluvium.	−10	D, I.
43	NW. ¼ sec. 28, T. 6 N., R. 40 E.	Public roadside	Spring			Lance formation	Flows	Dr.
44	SE. ¼ sec. 8, T. 6 N., R. 41 E.	Peter Jacobi	Driven	15	1¼ inches	Alluvium	−10	D.
45	NW. ¼ NW. ¼ sec. 10, T. 6 N., R. 41 E.	Mr. Stevens	do	20	1½ inches	Alluvium of Yellowstone River		D, S.
46	SW. ¼ sec. 10, T. 6 N., R. 41 E.	Peter Jackson	Drilled	243	2½ inches	Lance formation	Flows	D, S.
47	SW. ¼ sec. 16, T. 6 N., R. 41 E.	John Borer	Dug	39	4 feet	Terrace gravel	−36	D, S.
48	SW. ¼ sec. 17, T. 6 N., R. 41 E.	B. A. Thomas	do	40	do	do	−38	D, S.
49	SE. ¼ sec. 2, T. 6 N., R. 42 E.	White Cow Bassett estate	Drilled	502	2½ inches	Lance formation	Flows	D, S.
50	NE. ¼ sec. 9, T. 6 N., R. 42 E.	L. D. Crockett	do	260	do	do		D, S.
51	NE. ¼ NE. ¼ sec. 12, T. 6 N., R. 42 E.	Polzin Brothers	Dug	10	2½ feet	Alluvial gravel	−5	D, S.
52	SW. ¼ sec. 14, T. 6 N., R. 42 E.	Joseph Muggli	do	30	3 feet	River gravel	−26 to −29.5	D, I.
53	SW. ¼ sec. 14, T. 6 N., R. 42 E.	do	Drilled	402	2½ inches	Lance formation		D.
54	NE. ¼ SE. ¼ sec. 16, T. 6 N., R. 42 E.	Freeman Philbrick	do	130	do	do	Flows	D, S.

Analyses of waters in Rosebud County, Mont.—Continued

No.	Date of collection	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Remarks
26	Aug. 20, 1923	477	8.8	.40	12	6.1	155	0	381	66	3.0	Trace.	55	
27	Sept. 11, 1923	1,612	19	.13	56	34	460	0	644	696	14	.50	279	East of irrigated tract.
28	Oct. 9, 1923				452	170	[c] 854	0	451	3,062	89		1,827	In irrigated area.
29	do				58	35	[c] 162	0	459	249	4.0		288	
30	Oct. 6, 1923	1,100	12	.20	15	3.1	430	0	996	56	64	Trace.	50	Borate radicle (BO_3) 5 parts per million (colorimetric). Phosphate radicle (PO_4) trace.
31	Sept. 29, 1923				77	20	[c] 63	0	266	175	8.0		274	
32	do				52	18	[c] 83	0	154	236	9.0		204	
33	Aug. 13, 1923	580	16	.40	49	32	125	0	447	139	8.0	1.0	254	
34	Oct. 9, 1923	1,716	28	.40	88	51	430	0	622	778	26	4.2	429	In irrigated area.
35	Sept. 27, 1923	684	24	.20	58	23	147	0	378	226	10	Trace.	239	Not within irrigated area.
36	Oct. 6, 1923	1,675	25	.20	52	13	550	0	927	539	50	1.3	183	
37	1916	390	0	[d] 2.4	53	18	[c] 47	0	146	164	12	.20	206	Analyzed by W. M. Cobleigh. Yellowstone River water, filtered; compare with 31 and 32.
38	Oct. 3, 1923	2,016	20	.20	23	6.8	730	0	1,232	565	40	50	85	
39	Oct. 6, 1923	1,570	23	.20	22	6.1	545	0	915	457	14	3.6	80	
40	do	820	26	.20	50	19	210	0	376	296	24	7.5	203	
41	Aug. 29, 1923	860	10	.40	3.6	1.6	329	48	549	144	34	1.3	16	
42	Oct. 6, 1923	1,244	21	Trace.	16	3.9	460	0	952	231	24	1.2	56	
43	Sept. 27, 1923	720	16	.20	11	3.7	260	0	508	169	8.0	1.3	43	
44	Oct. 6, 1923	560	18	.48	4.8	2.1	195	0	303	176	8.0	.75	21	
45	Sept. 8, 1923				18	5.7	[c] 241	0	339	288	10		68	In irrigated area.
46	Oct. 6, 1923	2,102	12	.20	6.0	4.2	740 24	24	669	979	48	Trace.	32	Hydrogen sulphide (H_2S) 5.5 parts per million.
47	Sept. 5, 1923	385						0	259	94	9.0	4.5		Similar to No. 4–8.
48	Aug. 28, 1923	382	21	.40	42	18	72	0	261	95	10	10	179	
49	Oct. 1, 1923	1,250	16	.30	4.0	3.1	500	12	1,147	2.3	116	Trace.	23	
50	do	1,202	11	.27	3.6	1.7	504	36	1,074	.7	120	Trace.	16	
51	Oct. 3, 1923				79	29	[c] 141	0	420	259	6.0		316	In irrigated area.
52	Aug. 8, 1923	726	15	.40	57	32	165	0	525	187	7.0	.75	274	
53	Oct. 3, 1923	1,403	16	.20	2.6	3.0	561 24	43	1,127	1.0	204	Trace.	19	Sample collected for hydrogen sulphide test; none found.
54	do	1,442	14	.27	2.8	3.1	575	0	1,115	2.3	242	Trace.	20	

[c] Calculated.

[d] Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).

Analyses of waters in Rosebud County, Mont.—Continued

No.	Location	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Water-bearing formation	Water level above or below surface (feet)	Use of water
55	SW. ¼ sec. 24, T. 6 N., R. 42 E.	B. H. Droegemueller	Dug	1½	2½x1½ feet	Lance formation		D.
56	NW. ¼ NW. ¼ sec. 3, T. 6 N., R. 43 E.	Fred Frederickson	Drilled	61	1½ inches	Alluvial gravel		D, S.
57	SW. ¼ sec. 4, T. 6 N., R. 43 E.	Matt Barley	do	486	2½ inches	Lance formation	Flows	D, S.
58	SE. ¼ sec. 5, T. 6 N., R. 43 E.	G. W. Berry	Driven	22	1½ inches	Alluvium		S.
59	SE. ¼ sec. 6, T. 6 N., R. 43 E.	Henry Schleuter	Drilled	590	2½ inches	Lance formation		D, S.
60	NW. ¼ sec. 11, T. 6 N., R. 43 E.	Charles Baird	do	305		Sandstone in Lance formation	Flows	D, S.
61	Sec. 11, T. 6 N., R. 43 E.	E. E. Hatch	do	501	2½ inches	do	do	D, S.
62	NW. ¼ sec. 11, T. 6 N., R. 43 E.	G. E. Burgess	do	525	do	Lance formation	do	D, S.
63	NE. ¼ sec. 12, T. 6 N., R. 43 E.	W. L. Hawley	Dug	20	5 feet	Alluvial gravel	−19.5	S.
64	NW. ¼ sec. 14, T. 5 N., R. 38 E.	H. J. Chapin	do	42	3 feet	Bearpaw shale	−40	S.
65	NE. ¼ sec. 26, T. 5 N., R. 39 E.	W. H. Hardy	do	23	2 feet (top), 6 feet (bottom).	Alluvial gravel of Lance formation	−20	D, S, I.
66	SW. ¼ sec. 20, T. 5 N., R. 40 E.	B. M. Hamre	Spring			Coal of Lance formation		D, S.
67	NE. ¼ sec. 7, T. 5 N., R. 41 E.	J. A. Kenealy	do			Sandstone of Lance formation and terrace gravel.		D, S.
68	NE. ¼ SE. ¼ sec. 28, T. 5 N., R. 41 E.	J. P. Mitchell	Dug	32	3 feet	Coal of Lance formation	−29 to −26	D, S.
69	SW. ¼ sec. 8, T. 5 N., R. 42 E.	Walt. Kennedy	do	20	4½ feet	Alluvium	−16	Dr, S.
70	SE. ¼ sec. 20, T. 5 N., R. 43 E.	A. M. Moleworth	do	26	4 feet	Fort Union formation above Lebo shale and below first clinker.	−22	D.
71	SE. ¼ SW. ¼ sec. 30, T. 5 N., R. 44 E.	G. S. Ashman	do	19	6 feet	Alluvial stream gravel	−15 to −16	D, S.
72	NE. ¼ sec. 5, T. 4 N., R. 40 E.	Howard Bros. ranch	Drilled	102	2½ inches	Lance formation	−17 to −57	D, S.
73	SW. ¼ sec. 21, T. 4 N., R. 40 E.	J. T. Carolan	do	129	do	Lower part of Lance formation	−25 to −30	D, S.
74	NE. ¼ sec. 12, T. 4 N., R. 42 E.	Sherman Hunt	do	180	do	Lance formation	−13	D, S.
75	SE. ¼ sec. 13, T. 4 N., R. 42 E.	M. H. Francis	do	128	do	do	−17	D, S.
76	SW. ¼ sec. 28, T. 3 N., R. 39 E.	Fred Law	Dug	14	4 feet	Near bottom of Fort Union formation.	−12	D.
77	SW. ¼ sec. 32, T. 3 N., R. 42 E.	Martha Beeley	do	16	do	Sand in Fort Union formation		D, S.
78	NE. ¼ sec. 20, T. 3 N., R. 43 E.	Laird & Weaver	Drilled	520	6 inches (top), 2½ inches (bottom).	Lance formation	−7	D, S.
79	Sec. 20, T. 3 N., R. 43 E.	H. Bollmeier	do	510	2½ inches	do		Farm.
80	NW. ¼ sec. 6, T. 2 N., R. 39 E.	Mrs. Maude R. Robinson	do	340	do	Tullock member of Lance formation.		D.
81	SW. ¼ sec. 12, T. 2 N., R. 39 E.	C. M. Dowland	do	220	do	Top sandstone of Lance formation.	−85	D.
82	SE. ¼ sec. 4, T. 2 N., R. 43 E.	Freeman Philbrick	do	254	do	Lance formation		D, S.
83	NW. ¼ sec. 6, T. 2 N., R. 39 E.	Mrs. Maude R. Robinson	do	202	do	Lebo member of Fort Union formation.		S.
84	NW. ¼ sec. 6, T. 1 N., R. 40 E.	Edna Binkert	Dug	48	5 feet	Coal of Fort Union formation	−40	Dr, S.
85	SW. ¼ sec. 6, T. 1 N., R. 41 E.	L. S. Kimball	do	50	6 feet	do	About +6	D, S.
86	S E. ¼ sec. 12, T. 1 N., R. 41 E.	C. A. Hafer	Drilled	65	6 inches	Fort Union formation	−54	D, S.

Analyses of waters in Rosebud County, Mont.—Continued

No.	Date of collection	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Remarks
55	Aug. 6, 1923	296	22	.20	42	17	42	0	288	23	4.0	1.0	175	
56	Oct. 3, 1923	3,830	29	3.6	63	36	1,126 136	0	1,227	1,830	30	Trace.	305	
57	----do-------	1,182	11	.20	3.6	2.3	474 18	24	1,086	3.0	92	Trace.	18	Sample collected for hydrogen sulphide test; none found.
58	Aug. 8, 1923	6,168	25	.50	146	114	1,731	0	1,198	3,062	106	343	832	In irrigated area.
59	Oct. 1, 1923	1,268	15	.20	4.0	1.9	516	9.6	1,169	.8	118	Trace.	18	
60	1916	1,293	10	[d] 1.6	5.9	3.6	[c] 496	18	1,165	.0	86	.06	29	Analyzed by W. M. Cobleigh.
61	Sept. 15, 1916	1,226	36	[d] 1.2	6.3	1.5	[c] 503	0	1,205	3.3	86	.06	22	Do.
62	Oct. 3, 1923	1,220	17	.30	3.6	2.5	490	7.2	1,139	2.1	96	Trace.	19	
63	----do-------	--------	--------	--------	185	91	[c] 742	0	1,247	1,294	56	--------	836	In irrigated area.
64	Aug. 11, 1923	7,501	44	2.1	303	275	1,544 73	0	410	4,787	19	7.5	1,885	
65	Aug. 31, 1923	4,888	22	.20	244	145	1,121	0	976	2,545	96	80	1,204	
66	Aug. 22, 1923	874	19	1.4	90	71	131	0	749	166	8.0	1.0	516	
67	Aug. 18, 1923	518	35	Trace.	50	32	90	0	398	114	6.0	1.0	256	
68	----do-------	1,691	52	3.1	18	10	574	0	842	618	12	.75	86	
69	Sept. 5, 1923	2,008	24	1.6	50	26	637	0	810	848	38	Trace.	232	
70	Aug. 6, 1923	692	11	.20	53	45	134	0	473	148	22	30	317	
71	Aug. 5, 1923	1,926	23	.20	82	80	450	0	644	918	16	5.0	533	
72	Aug. 31, 1923	1,142	12	1.1	29	14	360	0	432	513	6.0	Trace.	130	
73	July 29, 1923	2,097	19	8.0	14	5.5	702	22	583	986	15	2.5	58	
74	Aug. 2, 1923	1,202	11	2.0	5.2	1.8	490	0	1,049	2.1	144	.80	20	
75	----do-------	1,264	15	.30	4.0	2.6	510	24	1,013	1.8	173	1.0	21	
76	July 29, 1923	769	15	.40	74	59	110 13	0	544	212	7.0	Trace.	427	
77	Sept. 14, 1923	1,454	23	2.5	148	160	63	0	464	716	8.0	5.0	1,026	Hydrogen sulphide (H_2S) 2.1 parts per million.
78	Aug. 2, 1923	1,910	22	2.6	53	51	531	0	664	858	26	2.4	342	Upper water probably not cased off.
79	Mar. 16, 1910	1,314	11	[d] 1.8	3.1	1.4	[c] 587	0	1,251	29	157	0	13	Analyzed by W. M. Cobleigh.
80	Aug. 24, 1923	884	12	Trace.	8.0	2.6	342	24	764	76	16	Trace.	31	Turbid when collected. Odor of hydrogen sulphide (H_2S).
81	July 30, 1923	732	9.2	.40	4.4	2.4	305	36	732	2.8	18	Trace.	21	
82	Sept. 17, 1923	1,324	19	.10	13	5.2	474 32	0	883	205	138	.50	54	
83	Aug. 24, 1923	3,266	12	2.4	134	177	618	0	683	1,749	18	5.0	1,061	
84	July 30, 1923	1,351	28	5.3	144	135	92	0	517	634	11	1.5	914	
85	July 31, 1923	334	38	6.9	13	17	20	0	63	56	6.0	24	102	Color dark brown, due to organic matter.
86	July 22, 1923	366	14	Trace.	54	45	16	19	320	49	3.0	Trace.	220	

[c] Calculated.

[d] Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).

Analyses of waters in Rosebud County, Mont.—Continued

No.	Location	Owner or name	Type of well or source	Depth of well (feet)	Diameter of well	Water-bearing formation	Water level above or below surface (feet)	Use of water
87	SW. ¼ sec. 12, T. 1 N., R. 44 E.	A. M. Ball	Drilled	216	2½ inches	Lance formation and Lebo member.	Flows	D, S.
88	SW. ¼ sec. 22, T. 1 N., R. 44 E.	M. W. Milligan	do	365	do	Lance formation	do	D, S.
89	SW. ¼ sec. 8, T. 1 S., R. 42 E.	Hugh Lynch	do	170	8 inches (top), (?) (bottom).	Fort Union formation and alluvial gravel.	−14	D, S.
90	SE. ¼ sec. 8, T. 1 S., R. 42 E.	Ira Snider	do	200	6 inches (top), 2½ inches (bottom).	Sandstone of Fort Union formation.	−11	D, S.
91	SE. ¼ sec. 14, T. 1 S., R. 41 E.	Frank E. Westlake	do	35	2 inches	Alluvium	−29	S.
92	SW. ¼ sec. 12, T. 1 S., R. 42 E.	A. J. and Mike Kuharski	Bored	20	6 inches	Alluvial gravel	+6	D.
93	NE. ¼ sec. 27, T. 1 S., R. 43 E.	A. Ed. Peterson	Spring			Coal of Fort Union formation	Flows	D, S.
94	NW. ¼ sec. 14, T. 1 S., R. 44 E.	James L. Foster	Dug	14	4 feet	Alluvial gravel	−12	D, S.
95	SE. ¼ sec. 6, T. 2 S., R. 40 E.	Charles G. Farr	Drilled	117	6 inches (top), 4 inches (bottom).	Fort Union formation	−105	D, S.
96	SE. ¼ sec. 8, T. 2 S., R. 40 E.	F. A. Cooley	do	38	4 inches	Alluvium	−22	D, S.
97	NW. ¼ sec. 10, T. 2 S., R. 41 E.	Henry N. Bayley	Spring			Fort Union formation	Flows	D, S.
98	NE. ¼ sec. 33, T. 2 S., R. 41 E.	H. M. Boggess	Dug	30	8 feet (top), 4 feet (bottom).	Alluvium	−22	D.
99	NE. ¼ sec. 33, T. 2 S., R. 41 E.	Wm. Knoblock	do	18	4 feet	do		D.
100	NW. ¼ sec. 34, T. 2 S., R. 41 E.	A. C. Stohr	Bored	66	4 inches	Fort Union formation		D.
101	Cheyenne Indian Reservation, 150 feet northwest of road between Ashland and Lame Deer, 10¼ miles west of Tongue River by road.	Cheyenne Indians	Spring			Clinker and coal of Fort Union formation.		Dr, S.
102	NE. ¼ sec. 3, T. 3 S., R. 44 E.	St. Labre Mission	Drilled	178	2½ inches	Base of Fort Union formation	Flows	D, S.
103	SE. ¼ NW. ¼ sec. 11, T. 3 S., R. 44 E.	Mrs. Vess Newell	do	240	do	Near Lebo-Tongue River contact of Fort Union formation.	do	D, S.
104	SE. ¼ SW. ¼ sec. 8, T. 4 S., R. 44 E.	A. J. Power	Spring			Fort Union (?) formation		
105	Sec. 18, T. 4 S., R. 44 E.	Jud McKelvy	Drilled	318	2½ inches	Fort Union formation		D.
106	SE. ¼ sec. 7, T. 5 S., R. 43 E.	U. S. Indian Service	Dug	17	3 feet	Alluvium	+13	D.
107	SW. ¼ SE. ¼ sec. 1, T. 6 S., R. 42 E.	Three Circle ranch	Drilled	246	2½ inches	Fort Union formation, below Rosebud coal.	Flows	D, S.
108	SW. ¼ sec. 23, T. 6 S., R. 42 E.	Brewster Estate	do	80	1¼ inches	Fort Union formation	−14	D, S.
109	Sec. 30(?), T. 6 S., R. 44 E.	A. J. Jackson	Dug	25	3 feet	Alluvial gravel	−22 to −13	D.
110	NW. ¼ sec. 6, T. 7 S., R. 42 E.	Brown Land & Cattle Co.	do	20	5 feet	Alluvial quicksand		D.
111	Sec. 11, T. 7 S., R. 41 E.	Bernt Hanson	do			Alluvium		D, S.
112	NW. ¼ sec. 33, T. 7 S., R. 44 E.	M. W. Snider	Spring			Clinker of Fort Union formation		D, S.

Analyses of waters in Rosebud County, Mont.—Continued

No.	Date of collection	Total dissolved solids at 180° C.	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Carbonate radicle (CO_3)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$ (calculated)	Remarks
87	July 23, 1923	1,397	7.8	.20	4.4	2.6	557	19	1,017	146	152	1.0	22	
88	....do........	1,204	12	Trace.	5.2	2.3	488	43	932	3.3	166	1.5	22	
89	July 15, 1923	1,884	13	1.2	104	92	346	0	390	1,008	9.0	2.2	637	A mixture of hard shallow water and soft deeper water.
90	....do........	1,160	10	Trace.	14	9.1	380	19	371	531	8.0	1.9	72	
91	....do........	2,488	18	8.0	194	172	296	0	547	1,300	20	1.0	1,190	
92	July 20, 1923	1,304	32	.80	90	122	148	0	593	537	6.0	2.0	725	
93	July 19, 1923	2,242	22	.30	134	162	373	0	756	1,123	9.0	1.2	999	
94	July 21, 1923	1,557	23	Trace.	158	97	164	0	400	752	12	.50	793	
95	Sept. 18, 1923	3,736	15	.20	336	215	531	0	373	2,440	10	3.8	1,722	
96	....do........	2,988	17	.80	146	261	388	0	527	1,744	11	3.0	1,435	
97	July 16, 1923	447	21	Trace.	28	33	77	12	173	191	4.0	6.0	205	
98	....do........	638	27	1.0	66	51	43 / 5.4	0	459	87	4.0	2.3	374	
99	Sept. 4, 1916	555	25	[d] 3.0	63	55	[c] 40	0	445	94	3.8	1.5	383	Analyzed by W. M. Cobleigh.
100	....do........	854	30	[d] 3.2	75	86	[c] 84	0	555	250	4.7	2.0	540	Do.
101	Sept. 21, 1923	294	31	.40	39	21	10 / 6.4	0	239	8.2	2.0	1.7	184	
102	July 24, 1923	1,010	13	.40	5.2	1.8	401 / 12	0	964	7.2	78	Trace.	20	
103	....do........	989	9.6	.10	4.0	1.2	405	0	927	2.6	88	.50	15	
104	———, 1916	534	24	[d] 1.2	38	42	[c] 66	0	183	238	8.5	.72	267	Analyzed by W. M. Cobleigh.
105	Sept. 2, 1916	1,397	14	[d] 19	8.0	1.6	[c] 571	0	1,427	28	47	.00	27	Do.
106	Aug. 25, 1923	1,232	31	6.0	182	66	107	0	554	457	9.0	7.5	726	Bad odor; not used recently.
107	Sept. 21, 1923	1,198	20	.20	5.2	2.9	477 / 20	0	1,308	2.8	7.0	Trace.	25	Flowing wells have not been obtained south of this place.
108	July 26, 1923	519	14	.40	12	7.9	167 / 5.9	17	354	107	2.0	3.9	62	
109	....do........	593	22	.10	57	66	71	0	500	159	7.0	1.7	413	
110	July 25, 1923	816	25	Trace.	79	67	58	0	442	211	2.0	2.2	472	Influenced by river. Sample collected when river was high.
111	Sept. 3, 1916	2,014	36	[d] 3.6	108	119	[c] 364	0	476	1,091	16	.50	758	Analyzed by W. M. Cobleigh.
112	Sept. 20, 1923	1,253	30	.20	60	56	300	0	625	481	12	3.8	380	

[c] Calculated.

[d] Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).

Analyses of waters from Rosebud County, Mont., furnished by the Northern Pacific Railway

[Parts per million. Recalculated from hypothetical combinations in grains per United States gallon furnished by H. G. Burnham, engineer of tests of the Northern Pacific Railway Co. Samples collected in 1923]

No.	Location	Total dissolved solids[a]	Silica and oxides of iron and aluminum (SiO_2, Fe_2O_3+Al_2O_3)	Calcium (Ca)	Magnesium (Mg)	Sodium and potassium (Na+K)	Bicarbonate radicle (HCO_3)	Sulphate radicle (SO_4)	Chloride radicle (Cl)	Nitrate radicle (NO_3)	Total hardness as $CaCO_3$[a]	Remarks
113	NE. ¼ NW. ¼ sec. 11, T. 5 N., R. 31 E.	1,275	--------	5.0	3.0	236	1,102	476	12	--------	23	Drilled well 180 feet deep, 2½ inches in diameter.
114	NE. ¼ NW. ¼ sec. 14, T. 5 N., R. 39 E.	1,237	--------	8.6	5.7	422	398	593	12	--------	55	Drilled well near creek, 143 feet deep, 2½ inches in diameter, owned by J. T. Carland.
115	SW. ¼ NW. ¼ sec. 25, T. 5 N., R. 39 E.	1,261	82	72	12	636	631	1,022	12	14	229	Spring owned by Mr. Hardy
116	SE. ¼ NE. ¼ sec. 5, T. 4 N., R. 39 E.	1,166	17	29	11	365	443	505	10	11	118	Drilled well 102 feet deep, 2½ inches in diameter.
117	NE. ¼ NW. ¼ sec. 26, T. 4 N., R. 40 E.	2,061	99	123	62	455	550	1,018	19	14	562	Dug well on ranch of Karl Bausch.
118	SE. ¼ NE. ¼ sec. 17, T. 2 N., R. 41 E.	2,029	46	67	12	233	1,210	1,045	20	10	219	Drilled well 177 feet deep, 2½ inches in diameter, on Edwards ranch.
119	NE. ¼ sec. 27, T. 2 N., R. 41 E.	718	66	114	51	38	357	268	5	--------	494	Spring.
120	SW. ¼ NW. ¼ sec. 34, T. 2 N., R. 41 E.	1,558	30	136	103	244	337	684	--------	24	762	Bored test hole, Northern Pacific Railway Co.
121	SW. ¼ NW. ¼ sec. 34, T. 2 N., R. 41 E.	2,446	212	114	238	258	426	1,343	35	36	1,261	Test hole for coal, Northern Pacific Railway Co.
122	SE. ¼ NW. ¼ sec. 3, T. 1 N., R. 40 E.	1,102	104	98	87	153	794	259	10	--------	601	Coal shaft about 40 feet deep at Henry Tabert's.
123	NW. ¼ sec. 8, T. 1 N., R. 41 E.	962	128	106	35	146	497	295	7	--------	408	Water hole 6 feet deep in Armells Creek.

[a] Calculated.

INDEX

O