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GROUND WATER IN MUSSELSHELL AND GOLDEN VALLEY COUNTIES MONTANA

BY

A. J. ELLIS AND O. E. MEINZER

Prepared in cooperation with the State Engineer; the Department of Chemistry of the Montana State College, Bozeman; and the Water Laboratory of the Montana State Board of Health

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PREFACE.

By O. E. Meinzer.

For several years Arthur J. Ellis was engaged in an investigation of the ground waters of southeastern and south-central Montana. During this time he became thoroughly familiar with the water-supply problems of the region and obtained an intimate knowledge of its successive geologic formations and their character as water bearers. His sudden death on July 22, 1920, brought this valuable work to an abrupt end and removed the only real specialist on the ground-water hydrology of Montana.

At the time of his death he had in preparation a report on ground water in an area which was then Musselshell County but is now divided between Musselshell and Golden Valley counties. For this report, which was based on several months of field work in the fall of 1917 and a few weeks in the fall of 1919, he had completed a geologic map of the area (Pl. I, in pocket), had tabulated the records of about 150 wells, had indicated for each well the geologic formation from which the water is derived, and had compiled a geologic section in which he made statements in regard to the water-bearing character of each formation (pp. 12–14). He had, however, prepared very little manuscript.

In parts of Musselshell and Golden Valley counties it is difficult to obtain satisfactory water supplies even for farm use, and a large number of requests are received by the United States Geological Survey from settlers in these counties for information as to whether they can get water of good quality on their land, and, if so, how deep they will have to drill to find it. In view of the existing need for published information on the ground water of these counties, and in view of the large amount of work that Mr. Ellis had done on this subject, it seemed very desirable to complete his report and to publish it. I have therefore undertaken to perform this task, basing my statements on the geologic map, the tabulated well data, the geologic section given on pages 12–14, Mr. Ellis's field notes, and the geologic reports previously published on this region. The result must be distinctly inferior to what Mr. Ellis would himself have produced. However, the report will doubtless be of practical value to the pioneers who in the face of many difficulties have courageously undertaken to develop this section of the Northwest and for whose welfare Mr. Ellis was deeply concerned.

Fortunately two publications [1] already issued by the Geological Survey give much reliable information on the geology of parts of these counties, and I have taken the liberty to draw extensively on them, though it has not been practicable to give references in each place where material from these publications is used.

The geologic map (Pl. I, in pocket) is published nearly as compiled by Mr. Ellis. The map of the southeastern part of the area, covered by Fort Union and Lance formations, was taken from the map of the Bull Mountain coal field;[2] most of the rest of the area was mapped by Mr. Ellis in the field, but he also made extensive use of maps by Bowen [3] and by Woolsey [4] for parts of the area. The map for the vicinity of the Big Snowy Mountains was left incomplete by Mr. Ellis, and this part has been completed from rather inadequate data furnished by C. H. Clapp, W. R. Calvert, C. F. Bowen, and W. T. Thom, jr. The area contained in Tps. 9, 10, and 11 N., Rs. 24 and 25 E., has recently been studied by Frank Reeves, who has made some revisions in the part of the map covering these townships. Considerable information regarding deep wells was furnished by Messrs. Thom and Reeves, and valuable assistance was given by G. M. Hall, especially in the preparation of the section on artesian water.

The ground-water investigation in Musselshell and Golden Valley counties was made in cooperation with the State of Montana. The chemical analyses were made in the laboratory of the State Board of Health and the Montana State College, at Bozeman, under the supervision of W. M. Cobleigh, director of the laboratory, and the records of some of the wells were collected through correspondence by A. W. Mahon, State engineer.

The report was completed in May, 1921, but its publication has been delayed because of lack of funds for printing.

[1] 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. Bowen, C. F., Anticlines in a part of the Musselshell Valley, Musselshell, Meagher, and Sweet Grass counties, Mont.: U. S. Geol. Survey Bull. 691, pp. 185–209, 1919.

[2] Woolsey, L. H., Richards, R. W., and Lupton, C. T., op. cit., pl. 1.

[3] Bowen, C. F., op. cit., pl. 25; U. S. Geol. Survey Bull. 541, pl. 19, 1914.

[4] U. S. Geol. Survey Bull. 691, pl. 16, 1919.

GROUND WATER IN MUSSELSHELL AND GOLDEN VALLEY COUNTIES, MONTANA.

By A. J. Ellis and O. E. Meinzer.

INTRODUCTION.

Musselshell and Golden Valley counties, Mont., are situated just southeast of the center of the State (Fig. 1). Their combined

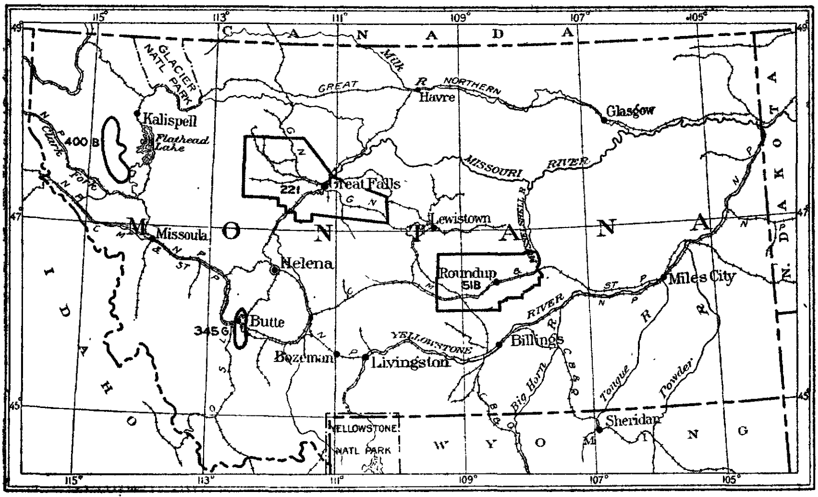

Figure 1.—Index map of Montana showing areas considered in this paper and in other water-supply papers of the United States Geological Survey relating to ground water.

area is about 3,000 square miles. The region considered in this paper includes all of Musselshell County and that portion of Golden Valley County which was included in Musselshell County prior to 1920. It does not include the appendage formed by Tps. 4 and 5 N., Rs. 17 and 18 E. Although essentially a part of the plains region of eastern Montana it lies near the Rocky Mountains and includes many natural features characteristic of the Rocky Mountain region. The Continental Divide is about 150 miles west of the area, but within that distance rise several mountain ranges, one of which, the Big Snowy Mountains, extends into the northwest corner of Golden Valley County.

Musselshell River flows eastward through both counties. The river valley is in part subject to overflow, and it does not contain as much tillable bottom land as is found along most of the rivers farther east in the State, but it nevertheless contains some of the best farms in these two counties. The Chicago, Milwaukee & St. Paul Railway follows the river, and the principal towns have grown up on its route. Hence the population of the area is largely concentrated in Musselshell Valley. Although the parts of the area outside the valley are sparsely populated the land is almost all privately owned. Practically no land sufficiently level for cultivation remains unoccupied.

The area is served by two railroads. The main line of the Chicago, Milwaukee & St. Paul leaves the Yellowstone Valley at Forsyth and crosses the northern part of Rosebud County to the valley of the Musselshell at Melstone, which it follows westward through Musselshell and Golden Valley counties. A branch of the Great Northern Railway running from Great Falls to Laurel, on the main line of the Northern Pacific Railway, crosses the southwest corner of this area. These railroads intersect about halfway between Lavina and Ryegate, but no facilities for the interchange of passengers are maintained at the intersection. In changing from one railroad to the other passengers customarily take an automobile stage that is operated between Lavina, on the Chicago, Milwaukee & St. Paul, and Belmont, on the Great Northern. Automobile stages are operated on regular schedules between Roundup and Billings, which is on the main line of the Northern Pacific Railway.

Nearly all parts of the area are accessible by automobile during the summer season. The roads are generally graded and in good condition. Heavy rains sometimes render them impassable for short periods, expecially in the areas occupied by shale, and heavy snows occasionally block practically all roads.

In 1920 the population of Musselshell County (including the part of Golden Valley County considered in this paper) was 12,030. In that year Roundup had 2,434 inhabitants, Melstone 477, and Ryegate 405.

The principal industries are stock raising, farming, and coal mining. The climate is semiarid, the average annual precipitation being about 15 inches. Formerly the principal industry was cattle and sheep raising, many of the old ranches being situated along Musselshell River. In recent years numerous settlers have come into the area and have undertaken to raise grain and other crops by dry-farming methods. Some valley land is irrigated with water from Musselshell River and produces grain and alfalfa. Coal mining on a commercial scale was begun in 1907, soon after the Chicago, Milwaukee & St. Paul Railway was built through the region. Roundup and Klein are the principal centers of the coal-mining industry.

DRAINAGE.

The entire area lies in the drainage basin of Musselshell River except a portion not exceeding two townships in the southeastern part, which is tributary to the Yellowstone. The valley of the Musselshell ranges in width from less than half a mile to nearly 4 miles. The stream is virtually perennial and generally carries a considerable volume of water. It rises in the mountains to the west. The following table gives the summarized records of its flow at Harlowton, about 20 miles upstream from the west boundary of Golden Valley County and above the point where the American Fork discharges into it. Most of the tributaries of the Musselshell in this area are intermittent streams, but they have deep valleys and carry much water after heavy rains.

Average monthly discharge, in second-feet, of Musselshell River near Harlowton, Mont. (sec. 26, T. 8 N., R. 15 E.), from 1907 to 1918.

[Compiled from data in U. S. Geol. Survey Water-Supply Papers 246, 266, 286, 306, 326, 356, 386, 406, 436, 456, 476. A second-foot is 1 cubic foot per second, or about 449 gallons per minute.]

Month.	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
January	......	......	......	[a]45	[a]45	......	......	......	......	......	......	......
February	......	......	......	[a]45	[a]50	......	......	......	......	......	......	......
March	......	......	......	325	131	[b]58.5	......	......	[c]54.8	[d]238	......	[e]786
April	......	......	[f]144	322	154	303	445	244	124	213	288	380
May	......	643	426	375	534	585	602	710	461	449	960	707
June	......	[g]1,210	888	103	878	458	675	731	603	806	2,470	826
July	[h]471	......	268	15.7	57.1	91.7	217	271	371	255	503	308
August	250	5.56	111	.37	78.1	41.7	51.9	5.19	275	41.6	64.6	174
September	125	21.6	156	35.9	58.0	56.0	30.7	18.1	229	41.0	87.6	213
October	119	......	123	57.8	73.1	86.9	106	47.1	47.1	180	87.8	105
November	107	......	119	85.8	64.0	97.1	103	[i]103	47.4	[j]123	92.3	154
December	......	......	......	49.6	[a]40.0	......	......	......	[k]42.1	......	[l]65.7	[m]162
Maximum	865	2,940	1,360	615	2,540	1,410	1,200	1,390	932	1,200	3,780	1,320
Minimum	95	.4	80	0	8	25	17	1	30	25	43	64

[a] Estimated.
[b] March 15-31.
[c] March 14-31.
[d] March 19-31.
[e] March 19-31.
[f] April 10-30.
[g] June 5-23.
[h] July 11-31.
[i] Partly estimated
[j] November 1-16.
[k] December 1-12.
[l] December 1-23.
[m] December 1-8.

PHYSIOGRAPHY.

PHYSIOGRAPHIC SITUATION AND SUBDIVISIONS.

Musselshell and Golden Valley counties lie near the western edge of the Great Plains Province. Sedimentary formations lie at the surface almost everywhere in the area, and the surface features have been developed through the folding and tilting of these formations and their differential erosion. The area may be divided into three physiographic units: The Big Snowy Mountains, which lie for the most part outside of the area but include about six townships in its northwest corner; the Bull Mountain upland, which occupies the southeast quarter of the area; and the plains, which lie between the other two units, and include most of the area.

BIG SNOWY MOUNTAINS.

The Big Snowy Mountains, which extend into the northwest corner of this area, reach heights of more than 8,600 feet above sea level, according to the United States Geological Survey's topographic map of the Big Snowy Mountain quadrangle. They were formed by an upwarping of the earth's crust and the consequent erosion of the elevated formations, which produced a rugged topography. The erosion has been so great that in the heart of the mountains the younger formations have been entirely removed and some very old rocks are exposed. In spite of the great erosion, however, the crest of the range stands a few thousand feet above the surrounding country.

BULL MOUNTAIN UPLAND.

The Bull Mountains occupy the central part of the southeast quarter of the area (T. 6 N., R. 27 E., and adjacent parts), but the physiographic unit to which they belong includes practically the entire southeast quarter. As compared with the ranges of the Rocky Mountain system, farther west, the Bull Mountains are little more than hills, but they rise prominently above the general level of the surrounding country and reach an altitude of about 4,700 feet above sea level, which is about 1,800 feet above the lowest land in Musselshell County. They consist of a group of mesas that have been brought into relief by the erosion of the plains of which they were formerly a part. Their tops are flat table-lands bordered by steep slopes and cliffs, in which may be seen the edges of the layers of sandstone and shale which underlie the table-lands and which formerly covered the entire region but have now been eroded from the surrounding country. These sandstones and shales owe their preservation in the Bull Mountains to their position in the center of a downwarped area and to the burning of interstratified coal beds, which baked and hardened the sandstone and shale and made them especially resistant to erosion.[5]

The Bull Mountains comprise four principal mesas and a number of outlying buttes. Bridges Butte, Taylor Mesa, and Three Buttes Mesa, named in order from west to east, form the main part of the mountains. Eldridge Mesa, the largest member of the group, lies south of Taylor Mesa. The mesas are separated by deep valleys that have steep sparsely wooded sides. A good idea of the topography may be gained from the topographic map (Fig. 2) and from the views of Eldridge Mesa (Pl. II).

The rest of the Bull Mountain upland—the country surrounding the Bull Mountains proper and occupying the southern part of Musselshell County—is somewhat less rugged but has the same type

[5] Woolsey, L. H., Richards, R. W., and Lupton, C. T. op. cit., p. 15.

of topography. It consists chiefly of table-lands, which are underlain by only gently inclined beds but which are cut up by innumerable steep-sided coulees, such as those in the northern part of the area

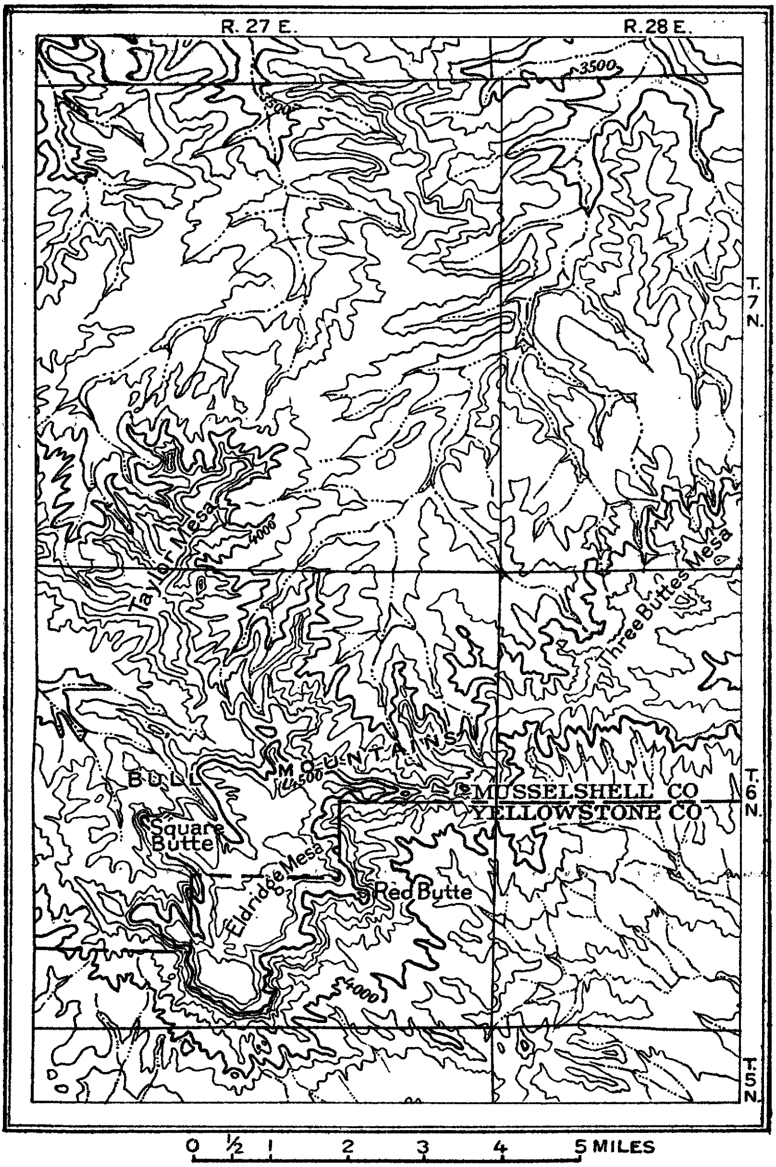

FIGURE 2.—Topographic map of Bull Mountains and adjacent country.

shown in Figure 2. In general the part of Musselshell County south of the river between ranges 24 and 27, inclusive, contains much land that is greatly dissected and only isolated tracts that are adapted for farming, whereas the part south of the river that lies farther east is less rugged and contains much good agricultural land.

THE PLAINS.

The plains that occupy all the area except the northwest corner and the southeast quarter are underlain by alternating beds of sandstone and shale that have been warped in various ways. These folded beds were worn down by the streams to such an extent that the surface, although far from level, has a relief of only a few hundred feet. The sandstones, which are much more resistant to erosion than the shales, were etched into relief as the surfaces underlain by shale were worn down. Consequently the plains are characterized by flat shale lowlands separated by sandstone ridges, as is well shown in Plate III. The Woman's Pocket, the Devils Pocket, and the Devils Basin, are large shale lowlands nearly surrounded by sandstone ridges (Pl. I).

The present surface is apparently the product of several cyles of erosion, in each of which the streams cut down to a lower level. First the area was bevelled to a surface corresponding roughly to the tops of the ridges and buttes; later this surface was dissected, producing the present lowlands. The following statement on this point is made by Bowen:[6]

> Terrace gravels, consisting chiefly of waterworn pebbles of limestone, chert, sandstone, and igneous rock of several types, in places well consolidated by calcareous cements into a true conglomerate, are widespread in this area. The gravel occurs at two or more levels, but the most prominent deposits are at the tops of the highest buttes and ridges. These detached areas rise to about the same elevation, so that if the surface represented by them were restored it would form a plain rising gradually toward the mountains. * * * Below these highest terraces there is at least one other level at which the gravel occurs. No especial study was made of the relation of these two terrace levels, so that it is not known whether those at the lower level represent a reworking and redistribution of those at the higher level or whether they are simply residual products that have settled to their present position during the process of erosion.

The streams follow courses without much regard to the structure of the rocks or the present topography. In several places they flow boldly out of the "pockets" occupied by clay flats, through gorges cut in the sandstone ridges. These are in part antecedent streams. Where they flow over anticlines they have cut into the rocks as fast as the rocks were bowed up, and thus, to a large extent, they have maintained their courses in spite of the earth movements.

[6] Bowen, C. F., Anticlines in a part of the Musselshell Valley, Musselshell, Meagher, and Sweet Grass counties, Mont.: U. S. Geol. Survey Bull. 691, p. 190, 1919.

A.

B.

ELDRIDGE MESA AND ADJACENT PLATEAU.

A, North side; *B*, south side. Photographs bp R. W. Richards.

SHALE LOWLANDS INTERRUPTED BY SANDSTONE RIDGES.

Photograph by A. J. Ellis.

LAKE BASINS.[7]

Among the most interesting and significant physiographic features of this area and the surrounding region are a number of undrained or imperfectly drained basins in which are found small temporary or permanent lakes and larger areas in which stream or lake deposits of gravel, sand, and clay are spread over the eroded surfaces of older rocks.

These lakes lie 75 to 100 miles from the nearest region that shows evidences of glaciation. They are obviously not glacial features. The underlying rocks are of different ages, chiefly shale but partly sandstone. The basins can apparently not be explained as sink holes due to the solution and caving of underlying formations, and they can not be adequately explained by wind erosion alone. There is evidence that they are due to warping and perhaps faulting of the rock formations that occurred in recent geologic times and may be still going on.

One group of these basins, locally known as the "Lake Basin," lies just south of the area covered by this report. In so far as the lakes of this group have any outlets they lie in the drainage basin of Fivemile Creek, which discharges into Yellowstone River (Fig. 3).

As mapped by Hancock[8] and shown in Figure 3, a belt of short faults extends almost coincident with the course of Fivemile Creek from its head to its mouth. In the lower part of its course nine faults actually cross the stream. The dismemberment of this stream to form detached lake basins is apparently due chiefly to recent slight earth movements in the faulted zone.

The largest of the lake beds is that crossed by the Great Northern Railway, near the middle of which Comanche is situated (Fig. 3). It covers about 60 square miles. It does not contain a permanent body of water, but from all sides short perennial or intermittent streams discharge upon the lake bed and fail to reach a trunk stream. Water stands in some places for long periods and is disposed of largely by evaporation. The lake bed is covered by stream and lake deposits of unknown thickness. Hancock suggests that the deposits are probably thin. The north third of these deposits is underlain by the Lance formation (p. 17) and the remainder by the Bearpaw shale (p. 18). The course of Fivemile Creek before the stream and lake deposits were laid down was along the extreme south side of the Comanche basin. The small streams along the north border are twigs of a normal branch that once drained the basin. Good evi-

[7] This section is adapted from an unpublished paper by Mr. Ellis entitled "Quaternary lakes in central Montana."

[8] Hancock, E. T., Geology and oil and gas prospects of the Lake Basin field, Mont.: U. S. Geol. Survey Bull. 691, pp. 101–147, 1919.

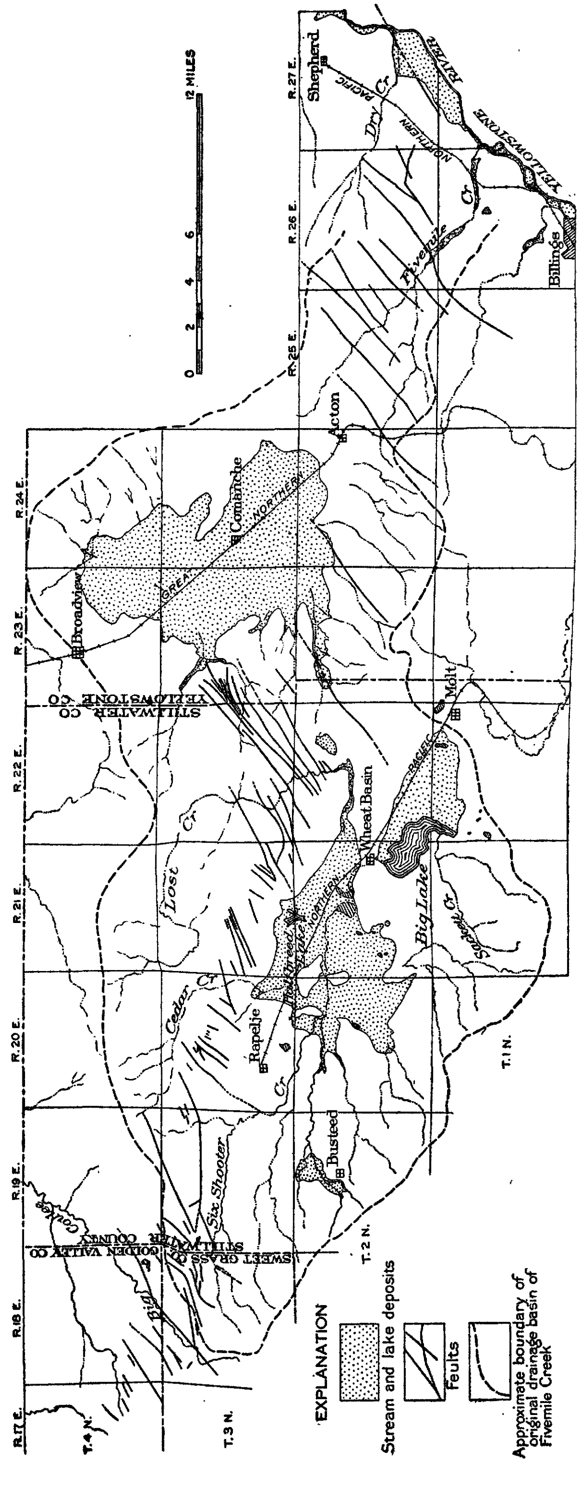

FIGURE 3.—Map of Lake Basin region, south of Musselshell and Golden Valley counties, showing streams, lakes, and recent stream and lake deposits in relation to faults. (After E. T. Hancock.)

dence for this arrangement of the drainage is given by the four confluent creeks on the north border. The basin is bordered on the east and north by gradual slopes of northeastward-dipping beds. On the west it is bordered by the dip slope of a structural dome. On the south it is also bordered by dip slopes.

West of the Comanche basin is the Lake Basin proper. Stream and lake deposits have been laid down in three separate bodies, and nearly a dozen permanent or intermittent lakes are scattered over the basin floor. This basin may, however, be considered as a unit. The stream and lake deposits are underlain for the most part by shale but in some places by sandstone. Fivemile Creek, here a mere trace of the former stream, makes a halting effort to cross the basin. Numerous small streams enter the basin, but they die out or end in lakes and do not reach any trunk stream. The disposition of these streams furnishes ample evidence of a former normal drainage system. This basin is bordered on the north by faulted dip slopes and on the south by hills of the Lance formation. The basin has obviously been formed by a recent disturbance of the grade of Fivemile Creek—a relative elevation where the axis of the fault belt crosses the stream course. The stream and lake deposits are relatively recent, and hardly a beginning has been made in the readjustment of the drainage.

Some of the lakes or ponds in this region occupy depressions that have been formed by the wind which has eroded the recent deposits, as is shown by the mounds on the leeward sides of the depressions. These wind-eroded depressions are, however, only minor features that were developed after the basins had been formed and had been covered with a mantle of water-laid sediments.

In Musselshell and Golden Valley counties there are about a dozen lakes which probably owe their existence to recent earth movements. Some of them are shown in Plate I (in pocket). Mason Lake and the lake near the southeast end of Woman's Pocket are the largest.

Woman's Pocket is an eroded anticline that pitches in both directions with the trend—an elongated area in which the rock formations were warped up and then deeply eroded (Pl. I). It brings up a large area of Colorado shale (see p. 22) completely surrounded by outcropping Eagle sandstone (see p. 21) that presents a steep cliff on the south, west, and east sides. The cliff is practically unbroken except at one place on the east side, where it is cut through by Currant Creek. This creek enters the pocket from the north, and, together with its tributary, Pocket Creek, effectively drains the northern two-thirds of Woman's Pocket. The southern third is, however, practically undrained and contains a lake bed on which water stands except in the driest periods. Here has been laid down a thin stratum of stream and lake deposits not shown in Plate I. About 200 feet of Colorado shale has been eroded from the south end of the pocket, most of which must have been transported by a tributary of Currant Creek that no longer exists. Apparently the south end of Woman's Pocket has been depressed sufficiently to destroy the former drainage grade.

The Mason Lake basin lies in a syncline—an area in which the rock formations have been warped down. On the northeast and southwest sides it is bordered by dip slopes of the Lance formation. Stream or lake deposits are spread over practically the whole basin (Pl. I). The basin is crossed and partly drained by Willow Creek, which enters it from the north and leaves it through a gorge on the east side. Mason Lake is a permanent body of water at the south end of the basin. There are also two alkali flats along the southwest margin which contain water in wet seasons. Apparently this basin, like the Woman's Pocket, has been tilted enough to throw some of its southern part out of reach of a previously effective drainage system.

ROCK FORMATIONS AND THEIR WATER-BEARING PROPERTIES.

GENERAL SECTION.

The surface of Musselshell and Golden Valley counties is underlain in most places by alternating beds of soft shale and somewhat harder sandstone. These beds have an aggregate thickness of several thousand feet. As a rule the sandstones yield water that can be used for domestic and stock supplies, whereas the shales are non-water-bearing or yield only water of poor quality. Most of the water from the shale can not be used for drinking, and much of it is too highly mineralized even for stock. None of the sandstones is likely to furnish enough water for irrigation, except possibly on a small scale, and there may be difficulty in getting large enough supplies from them for public waterworks. Moreover, where the sandstones are thin and shaly or lie below considerable thicknesses of shale the quality of the water may be bad. The best prospect of getting water supplies from the shales is by digging shallow wells in low places.

In some places water can be obtained from gravelly or sandy deposits that are spread over the eroded surfaces of the older rocks. These deposits are of two kinds—the alluvium and lake deposits in the stream valleys and lake basins (Pl. I), and the older alluvium (probably of Miocene age) that mantles the high terraces, especially near the Big Snowy Mountains. The recent alluvium is valuable as a source of water in Musselshell Valley; the older alluvium, or terrace gravel, furnishes some supplies in the vicinity of the Big Snowy Mountains, but in most places where it occurs it is too thin or too much exposed to extend below the water table.

The sandstone and shale formations investigated range in age from Lower Cretaceous to Eocene. Below the rocks investigated are

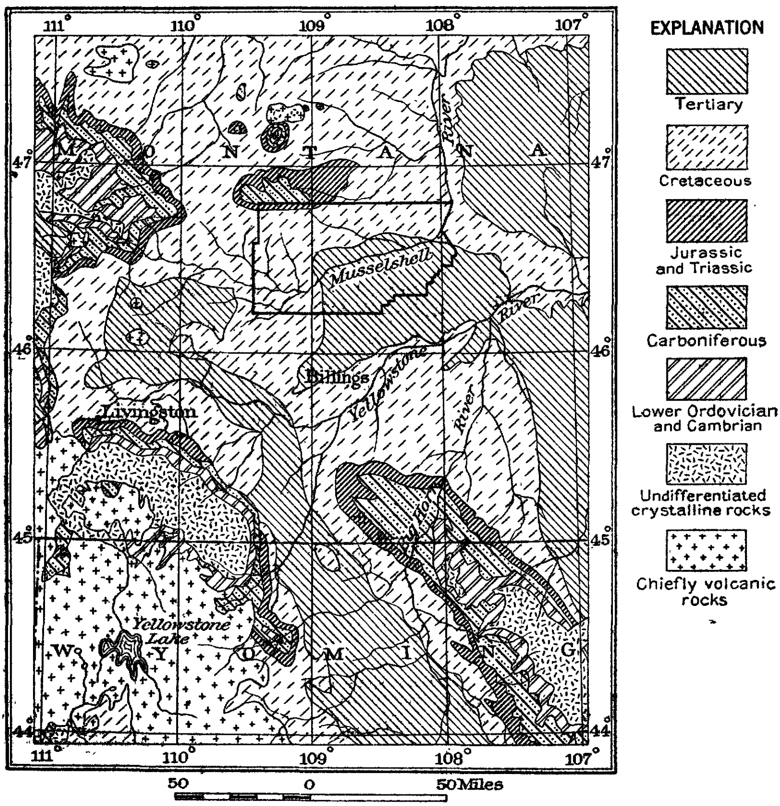

FIGURE 4.—Geologic sketch map of the part of Montana in which Musselshell and Golden Valley counties are situated, showing the relation of the area to the major structural features of the region. After E. T. Hancock.

older sedimentary formations, which are exposed in the Big Snowy Mountains (Fig. 4), but which in other parts of the area lie too deep to be reached in drilling for water. These older formations range in age from Algonkian to Jurassic or Lower Cretaceous (?) and include much massive Carboniferous limestone.

The following generalized section gives information on the formations exposed in the area:

Generalized section of geologic formations in Musselshell and Golden Valley counties.[a]

System.	Series.	Group and formation.		Maximum thickness (approximate).	Lithologic character.	Water supply.
				Feet.		
Quaternary.					Alluvium and lake deposits (gravel, sand, and clay).	Coarser types are water-bearing and supply shallow dug wells; finer types are non water-bearing or yield meager supplies of poor quality. Some municipal supplies are obtained from alluvium. The most abundant yields are obtained in the valley of Musselshell River.
Tertiary.	Miocene(?).	Terrace deposits.		200	Gravel.	Water-bearing where sufficiently thick and not exposed to rapid drainage. Supplies shallow dug wells and drilled wells as mnch as 200 feet deep near base of Big Snowy Mountains.
	Eocene.	Fort Union formation.		2,000	Beds of massive resistant yellowish to buff sandstone, clay, shale, and coal. At the base is the Lebo shale member, consisting of 300 feet of dark olive-green to brown sandy shale and thin-bedded arkosic sandstone with beds of carbonaceous sandstone and coal.	Generally water-bearing, but yields are generally small. Principal sources of water are sandstone lenses and coal beds. Shale lenses are non water-bearing or furnish small supplies of poor quality. Some lenses of fine-grained sandstone present obstacles to finishing wells. Lebo shale member contains nonwater-bearing shale but also some water-bearing sandstone.
Tertiary(?)	Eocene(?).	Lance formation.		1,500	Alternating beds of massive yellowish-brown and gray sandstone and buff to gray shale.	Generally water-bearing. Principal sources of water are sandstone beds, especially the basal member, which in structurally favorable places supplies flowing wells. Shale beds are generally non water-bearing or furnish meager amounts of highly mineralized water.
Cretaceous.	Upper Cretaceous.	Montana group.	Bearpaw shale.	1,000	Dark shale containing calcareous concretions, with some sandstone near base.	Generally non water-bearing. Meager supplies of water, nearly all unsuitable for domestic use, have been obtained in a few places from somewhat sandy layers.
			Judith River formation.	400	Sandstone and shale. Lower part is chiefly sandstone.	Generally yields adequate supplies of water for domestic and stock use. Where the formation is thin supplies from this source resemble those from the Bearpaw and Claggett.

[a] Bowen, C. F., Anticlines in a part of the Musselshell Valley, Montana: U. S. Geol. Survey Bull. 691, pp. 188 and 189, 1918; 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; and unpublished material. The section below the Kootenai formation is from unpublished data by W. R. Calvert. The water-supply data are chiefly by Ellis.

Generalized section of geologic formations in Musselshell and Golden Valley counties—Continued.

System.	Series.	Group and formation.		Maximum thickness (approximate).	Lithologic character.	Water supply.
				Feet.		
Cretaceous.	Upper Cretaceous.	Montana group.	Claggett formation.	470	Dark concretionary shale and a little sandstone similar to Bearpaw shale.	Generally non water-bearing in Musselshell and Golden Valley counties but contains sandstone members in Stillwater County that are probably water-bearing.
			Eagle sandstone.	300	Chiefly sandstone, but considerable shale lies in its middle part.	Generally water-bearing. Supplies flowing wells in structurally favorable places.
		Colorado shale.		2,200	Chiefly shale, but carries several beds of sandstone and conglomerate.	Generally non water-bearing. Water has been obtained in a few places from sandy layers, but it is generally unfit for domestic use. In the northeastern part of this area the "First Cat Creek sand," at the base of the Colorado, may yield artesian flows of satisfactory water.
	Lower Cretaceous.	Kootenai formation.		500	Maroon, drab, greenish-gray, and white sandy shales with some beds of sandstone in the upper part.	Some sandstone beds yield water. Water has been obtained from the Kootenai by drilling through the Colorado.
Cretaceous (?)	Lower Cretaceous (?)	Morrison (?) formation (non-marine beds).			Alternating beds of sandstone, varicolored shales, and thin nodular limestone.	These formations lie too deep to be reached in drilling for water except in the vicinity of the Big Snowy Mountains. A few deep wells drilled in search of oil are believed to have found water in a sandstone belonging to the Morrison formation and at the top of the Quadrant formation.
Jurassic.	Upper Jurassic.	Ellis formation (marine Jurassic).		300+	Alternating beds of tan-colored sandstone, red shale, and thin dove-colored limestone. The sandstone contains great numbers of oyster shells.	
Carboniferous.	Pennsylvanian.	Quadrant formation.		1,300	Red and green shale, reddish sandstone, and either massive limestone or sandstone at the top. Contains carboniferous fossils which indicate that these strata are chiefly Mississippian but in part Pennsylvanian.	
	Mississippian.	Madison limestone.		2,000	Limestone which forms the main mass of the Big Snowy Mountains. The upper half contains four massive chert-bearing members. The basal part is thin-bedded limestone.	

Generalized section of geologic formations in Musselshell and Golden Valley counties—Continued.

System.	Series.	Group and formation.	Maximum thickness (approximate).	Lithologic character.	Water supply.
			Feet.		
Devonian.			200	Chocolate-colored limestone which gives fetid odor when struck with a hammer.	These formations lie too deep to be reached in drilling for water except in the vicinity of the Big Snowy Mountains.
Cambrian.				Limestone conglomerate composed of flat pebbles with calcareous cement. It has the appearance of beach shingle.	
			750	Greenish micaceous shale with thin limestone members from which Middle Cambrian fossils were obtained. Trilobites occur in the shale.	
			70	Hard reddish sandstone or quartz conglomerate, composed almost entirely of silica with quartz pebbles.	
Algonkian.	Belt.		300+	Dark, highly indurated, calcareous shales, with well-developed joints and bedding planes.	

QUATERNARY ALLUVIUM.

Alluvium ranging from clay or silt to gravel generally underlies the valleys of Musselshell River and its tributaries and yields water to shallow dug wells in many places, not only in the Musselshell Valley but also in the smaller valleys. In some places, however, the alluvium consists so largely of clayey material that it does not yield water in practicable amounts or its water is of poor quality.

The city of Roundup formerly obtained its public water supply from a well in the Musselshell Valley, 8 by 16 feet in cross section and 35 feet deep, which extends through 15 feet of sand and 20 feet of gravel and ends in blue shale that underlies the alluvium. This well is reported to have been pumped at about 500 gallons a minute and to have yielded as much as 500,000 gallons in a day. The water is hard but otherwise of satisfactory quality so far as its mineral content is concerned. (See analysis No. 22, p. 41.)

The waterworks of Melstone are supplied from a well in the valley about 600 feet from Musselshell River. The well is 20 feet in diameter and 20 feet deep and is sunk in gravel. Its water level fluctuates considerably. On or about December 11, 1920, a pumping test was made by the engineer in charge, who reports the following results: Depth of water level below surface before pumps were started, 10 feet 8 inches; after pumping 1 hour, 13 feet 6 inches; after pumping 4 hours 40 minutes, 19 feet 10 inches. The pumps were then stopped, and in 1 hour 30 minutes the water level rose 5 feet 6 inches. The rate of pumping was not reported, but the data given show that in the period of 1 hour 30 minutes after the pumps were stopped the percolation into the well averaged nearly 150 gallons a minute, with a drawdown ranging between about 9 feet and 3½ feet. The rate of pumping was doubtless greater. In November, 1920, the pumpage was reported to be about 11,000 gallons a day.

The wells at Roundup and Melstone seem to indicate that water could be recovered in large quantities from the alluvium and suggest the possibility of irrigation with well water in the Musselshell Valley.

MIOCENE (?) TERRACE GRAVEL.

Gravelly alluvial deposits occur extensively on the uplands, especially in the northwestern part of the area. In many places they are too thin to be water-bearing, and where they are thick they are likely to be in such elevated and exposed positions that they allow the water to drain out of them and thus do not afford a source of supply for wells. Near the Big Snowy Mountains, however, where they are thickest and underlie the largest areas, they furnish supplies to both dug and drilled wells, some of the drilled wells being between 100 and 200 feet deep. In some places where water-bearing sandstones are not available it may be possible to get small supplies from this upland gravel, even where it is not thick, by digging wells at points where there is the least opportunity for the ground water to drain out, and where there is therefore some prospect that the water table is near the surface and that the lower part of the gravel is saturated.

FORT UNION FORMATION.

The Fort Union formation underlies a large part of eastern Montana and is a very valuable water-bearing formation, especially in the southeastern part of the State. It extends into the southeastern part of the area under consideration, including most of the country south of the river and east of Dean Creek (Pl. I, in pocket). In this area it attains its greatest thickness in the Bull Mountains, where Woolsey measured a section nearly 2,000 feet thick (Pl. IV). It consists of many beds of sandstone, shale, and coal, which change from place to place, as is well shown in the sections in Plate IV.

Water is obtained from sandstone beds that are not too fine or clayey and that lie far enough below the surface to be saturated. Beds of fine incoherent sand may not only fail to supply water but may seriously interfere with drilling on account of the quicksand running into the well. In some parts of Montana coal beds are also recognized water bearers. Because of the changeable character of the formation it is often impossible to predict at what depth a water supply will be found. Thus a sandstone struck in one well may be absent in a well not far away, although the second well is likely to penetrate some other water-bearing sandstone before it reaches a great depth.

As many settlers can not afford to drill wells, it becomes important to find places in which ground water can be obtained by digging to moderate depths. Many settlers who fail to find such supplies have used surface water or have been obliged to haul water for domestic use from wells as much as 10 miles distant. Before digging in a place where there is any doubt as to the presence of water near the surface other wells in the vicinity should be examined, even if they are as much as a mile or two distant, not necessarily with a view to obtaining water under exactly similar conditions, but especially to observe the depths at which water is obtained, the sort of material encountered in digging, the quality of water obtained, and, finally, with regard to the immediate surroundings of each well, the slope of the surface, the proximity and character of drainage channels, and, from the character of the ground or from any near-by exposures, the approximate thickness and character of the beds that lie beneath the surface. By exercising adequate care in these observations one may acquire a familiarity with the appearance of areas where the water is near the surface that will prove helpful in selecting new well sites. Certain plants are believed to afford evidence of the occurrence and even the quality of ground water, but too great reliance must not be placed on such evidence. Evaporation areas—areas characterized generally by moist soil, alkali crusts, or rank vegetation—usually indicate ground water. The extensive area underlain by Fort Union rocks, with its irregularity in surface features and underlying beds, furnishes a good opportunity for locating shallow water supplies by observing surface conditions. These methods can, however, be used only for locating water at depths less than about 25 feet below the surface.

As soon as a settler in the area underlain by the Fort Union formation can afford to do so, it will be advisable for him to have a well drilled, unless he has a satisfactory spring or dug well. Owing to the roughness of the surface in the area underlain by the Fort Union formation and the diversity and discontinuity of the beds that make up this formation, great variety in the occurrence of water is to be

A. CONTRASTING TOPOGRAPHY OF BEARPAW AND LANCE FORMATIONS.

Photograph by C. T. Lupton.

B. CONTRASTING TOPOGRAPHY OF LEBO SHALE MEMBER OF THE FORT UNION FORMATION AND UPPER PART OF THE FORT UNION.

Photograph by C. T. Lupton.

expected, but the drill is likely to encounter a water-bearing bed within a depth of 300 feet almost anywhere in the area.

Most of the drilled wells in the Fort Union are 6 inches in diameter and range in depth from 50 to 350 feet. They commonly yield fairly satisfactory supplies of water for domestic use and for stock. The largest yields reported are from the well of Mr. Jack Davies, which has been pumped at 25 gallons a minute, and the well of the Roundup Coal Mining Co., which is pumped at 40 gallons a minute. The Davies well may be described in detail as a somewhat typical Fort Union well. It is situated near Roundup, in the SE. ¼ sec. 28, T. 8 N., R. 25 E. It is a drilled well, 6 inches in diameter and 50 feet deep and is cased to a depth of 27 feet. It struck water of poor quality at a depth of 22 feet, which was cased out, and a larger quantity of better water at 45 feet, which rose to a level 8 feet below the surface and which forms the present supply. The well of the Roundup Coal Mining Co., in the SW. ¼ sec. 14, in the same township, is 250 feet deep and is lined with 5-inch casing to a depth of about 20 feet. It gets its principal supply from sandstone at a depth of 150 feet. The water normally stands about 30 feet below the surface, and when the well is pumped at 40 gallons a minute the water level in the well is drawn down about 20 feet—that is, to a level about 50 feet below the surface. The water is used in steam boilers.

At the city waterworks in Roundup three 7-inch wells have been drilled, 150, 175, and 200 feet deep. They pass successively through about 35 feet of alluvium, 35 feet of blue shale, 5 feet of water-bearing coal, 20 feet of non water-bearing hard white sandstone, and 10 feet of soft water-bearing sandstone. At a depth of a little more than 100 feet they pass into dense sticky clay, and they all end in this clay. The 150-foot well, which is the strongest of the three, is reported to have flowed into a pit 22 feet deep at the rate of 90 gallons a minute under a head of 7 feet.

At the base of the Fort Union is the Lebo shale, which is somewhat less likely to yield supplies of water than the rest of the formation, although it also contains some sandstone (Pl. IV). Its distribution at the surface is shown in Plate I (in pocket). Plate V, *B*, shows the contrast between the surface of the Lebo shale, which is soft and easily eroded down to flat lowlands, and the higher parts of the Fort Union, which contain numerous beds of sandstone that are more resistant and hence form hills or ridges.

LANCE FORMATION.

The Lance formation underlies the Fort Union and is at the surface throughout a considerable tract, especially on the west side of the Fort Union area, where it forms a belt averaging about a township in width (Pl. I, in pocket). As measured by Richards northeast of

Roundup, it has a maximum thickness of about 1,500 feet (Pl. IV). It is similar to the Fort Union formation in the character of its beds and in its water-bearing properties, but it probably contains a larger proportion of sandy beds and yields water somewhat more freely. In its upper part it also contains beds of coal. Nearly all the general statements that have been made regarding the Fort Union formation will also apply to this formation.

The township descriptions on pages 49–90 contain the records of 32 drilled wells that are known to get their supply from the Lance formation. These wells range in depth from 62 feet to about 250 feet and have an average depth of 120 feet. The levels to which the water normally rises in these wells range from above the surface, in a few flowing wells, to 160 feet below the surface and average 36 feet below the surface. About two-thirds of them yield ample supplies for the purposes required—usually domestic or general farm use. A number of them yield as much as 10 gallons a minute. A few, however, yield less than 1 gallon a minute, and one drill-hole, 250 feet deep, is dry. Most of the water is of fairly satisfactory quality and some of it is rather soft, but the water from some wells is too highly mineralized to be satisfactory.

BEARPAW SHALE.

The formations below the Lance, taken as a whole, contain a larger proportion of shale than do the Lance and Fort Union. Hence the ground-water conditions are in general less favorable in the western and northern parts of this area, where these older formations are at the surface, than in the southeastern part, where the Fort Union and Lance are at the surface (Pl. I, in pocket).

Immediately below the Lance is the Bearpaw shale—a dense soft dark-gray or black shale containing many large calcareous concretions but almost devoid of sandstone, except perhaps near its base. The striking contrast which its flat lowlands make with the rugged uplands of the adjacent Lance areas is well shown in Plate V, *A*. The significance of this contrast should be understood by every driller who operates in the region. The Bearpaw shale is about 1,000 feet thick, and in its entire thickness contains no good water-bearing beds. It yields no water except in some places meager supplies from materials very near the surface or from deeper sandy layers which generally contain bad water.

The wells drilled into the Bearpaw shale are nearly all unsatisfactory. Almost invariably the little water that they yield is of bad quality, although the water from some of the wells is used for live stock or even for household purposes. Examples of the futility of drilling deep into this shale without going through it into underlying sandstone are afforded by the 517-foot hole drilled in Melstone, in the SW. ¼ sec. 30, T. 10 N., R. 31 E., and by the 600-foot hole in the

SW. ¼ sec. 28, T. 8 N., R. 20 E. The Melstone well did not have enough water for drilling and that little was reported to be unfit for drinking; the other well is all in shale and all dry except for a little bad water near the top.

There are three possible ways of obtaining water supplies in the Bearpaw areas—by drilling to underlying sandstones, by developing supplies from very shallow sources (either in superficial gravelly deposits or in the loose upper part of the shale formation itself), or by impounding rain or stream water.

According to the geologic map (Pl. I, in pocket), both the 517-foot hole and the 600-foot hole mentioned above must reach somewhere near the bottom of the Bearpaw shale. If they had been drilled a few hundred feet deeper they would have reached the underlying Judith River sandstone, and it is possible, although by no means certain, that they would have struck a supply of potable water.

In some localities in the Bearpaw area small supplies of water good enough for stock and even for human use can be obtained from shallow dug wells in low places where there is an alluvial deposit or where the surface layer of the shale is sufficiently uncompacted to be somewhat permeable and lies low enough to be saturated. The dug well in the NW. ¼ sec. 27, T. 9 N., R. 21 E. (p. 58) is apparently an example of this type of well. It is only 12 feet deep and ends in shale, but it has water that stands sometimes within 4 feet of the surface and is used for watering stock. Analysis No. 4 (p. 41) shows that this water is highly mineralized but better than many other waters in the county that are used for drinking and household purposes.

On pages 43–47 are described methods of impounding storm run-off for stock use and of storing in cisterns rain water from roofs and from specially constructed water catches for drinking, cooking, and washing. In some places in the Bearpaw areas it may be necessary to depend on such surface sources for water supplies.

JUDITH RIVER FORMATION.

The Judith River formation, which lies below the Bearpaw shale, has a maximum thickness in these counties of about 400 feet or possibly somewhat more. It consists of alternating beds of sandstone and shale, the sandstone beds predominating. Its lower part consists of a medium-grained sandstone that is hard enough to form ledges where it crops out. The formation generally yields water of fair quality and in amounts adequate for domestic use. In some places, however, its water supplies resemble those of the Bearpaw shale in being meager and of bad quality.

The Judith River wells mentioned in the township descriptions, except a few, yield water that is used for domestic purposes and is regarded as satisfactory. Most of these are drilled wells less than 100 feet deep; and only one is more than 200 feet deep. Most of them are in localities where the Judith River formation is at the surface, and therefore they do not throw much light on the very practical question whether this formation will yield potable water where it is deeply buried below Bearpaw shale. The well of R. L. Hamilton, in the N.½ sec. 24, T. 10 N., R. 28 E., is, however, somewhat promising in this respect. It is situated in an area of Bearpaw shale and passes through 190 feet of shale, which yields a little bad water that was cased off. The well ends in sandstone of the Judith River formation, which yields an ample supply of satisfactory water. Just what results can generally be obtained by drilling through great thicknesses of Bearpaw shale into sandstone of the Judith River formation can be determined only by actual drilling. The prospects are good enough, however, to warrant making a thorough test.

CLAGGETT FORMATION.

The Claggett formation has a known maximum thickness in this area of somewhat less than 500 feet and consists chiefly of soft shale like the Bearpaw shale. Bowen [10] has shown, however, that near the west edge of Golden Valley County two thin sandy zones appear, making low ridges in the middle part of the Claggett outcrop, and that 20 miles farther west about half of the Claggett consists of sandstone. The following section was measured by Bowen in the western part of the county, where the two sandy zones were observed:

Section of Claggett formation measured by C. F. Bowen in sec. 11, T. 7 N., R. 19 E.

Base of Judith River formation.	
Claggett formation:	Feet.
Sandstone, platy	7
Shale, mostly concealed	146
Shale, sandy, and sandstone, thin-bedded	55
Concealed, probably concretionary shale	90
Sandstone, thin-bedded	6
Shale, sandy	5
Sandstone	3
Shale, concretionary, drab	155
Eagle sandstone.	
	467

The records on pages 49–90 show that wells have been drilled into the Claggett formation to a depth of 225 feet and that the results have been very unsatisfactory. The meager supplies of water obtained in these wells are all highly mineralized; nearly all are too bad for domestic use and they are largely too bad for live stock.

[10] Bowen, C. F., Anticlines in a part of the Musselshell Valley, Musselshell, Meagher, and Sweet Grass counties, Mont.: U. S. Geol. Survey Bull. 691, pp. 192, 193, 1919.

Deep drilling seems to be more promising in the Claggett areas (Pl. I, in pocket) than in the Bearpaw areas because the Claggett formation is hardly half as thick as the Bearpaw shale, and the Eagle sandstone, which underlies the Claggett, is perhaps a more dependable source of water than the Judith River formation, which underlies the Bearpaw. Some wells should be drilled in the Claggett areas deep enough to pass through the Claggett formation and to the base of the Eagle sandstone, if necessary, in order to test the possibility of getting potable water from the Eagle sandstone where it lies buried by the Claggett formation.

EAGLE SANDSTONE.

In Musselshell and Golden Valley counties the Eagle sandstone is the most important water bearer below the Lance formation. It is about 300 feet thick and consists chiefly of sandstone. The middle part of the formation consists largely of shale, and the largest body of relatively clean porous sandstone is near the bottom. The largest yields of water are therefore to be expected from the lower part of the formation. In some places where the formation is at the surface it forms two parallel ridges—one produced by the sandstone in the upper part of the formation and the other by the sandstone in the lower part—with an intervening depression underlain by the shaly beds of the middle part of the Eagle.

The following section was measured by Bowen[11] in the rim of the Woman's Pocket:

Section of Eagle sandstone on south side of Woman's Pocket, in the SE. ¼ sec. 33, T. 8 N., R. 21 E.

	Feet.
Claggett formation.	
Eagle sandstone:	
Sandstone, brown, thin-bedded	18
Shale, partly concealed	118
Sandstone, thin-bedded, with some interbedded shale	40
Shale, sandy	26
Sandstone, white, massive to thick-bedded, cross-bedded	101
Colorado shale.	
	303

The descriptions on pages 49–90 contain information regarding 22 wells that obtain their water from the Eagle sandstone. Practically all of these are successful wells. The drilled wells in the Eagle sandstone described in this paper are nearly all 6 inches in diameter. They range in depth from 43 feet to 550 feet and have an average depth of 158 feet. They include three flowing wells. Most of them yield water that is regarded as fairly satisfactory for domestic and general farm use and in quantities sufficient for these purposes, though some yield bad water. The largest yield reported is 15 gallons a minute.

[11] Op. cit., p. 194.

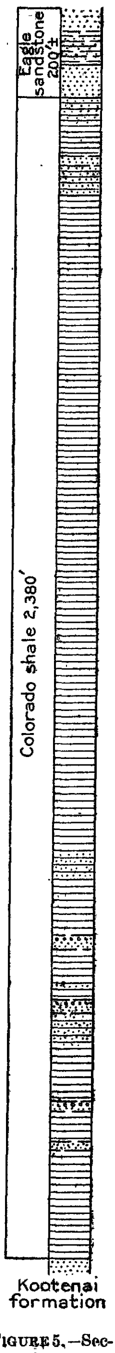

FIGURE 5.—Section of Colorado shale in Devils Pocket. (By C. F. Bowen.)

It is uncertain whether the Eagle sandstone will yield water that is good enough for use at considerable distances from its outcrops and where it is covered by shale that contains bad water. This important practical question should be answered by sinking test wells in such localities to the base of the Eagle sandstone.

COLORADO SHALE.

Below the Eagle sandstone is the Colorado shale, which is the most unfavorable formation in the area with respect to water supplies. It is about 2,200 feet thick and consists chiefly of black fissile shale that does not yield water. In the northeastern part of the area the so-called "First Cat Creek sand," about 15 to 30 feet thick, lies at the base of the Colorado. It consists of more or less clayey sandstone which yields to several deep wells artesian water that is good enough for use. At several other horizons the Colorado shale contains sandy beds, but the little water which they yield is commonly unsatisfactory for domestic use, and some of it is too bad for stock.

The following details of the stratigraphy of the Colorado shale given by Bowen[12] are applicable to Musselshell and Golden Valley counties. (See Fig. 5.)

This shale is for the most part black and fissile, somewhat sandy in the lower part of the section, more concretionary and argillaceous in the upper part. Beginning about 250 feet above the base is a zone about 300 feet thick in which there are at least three sandstones 5 to 20 feet thick. Each of these sandstones contains small pebbles of black chert at the top and fragments of fish remains. This zone is overlain by 10 to 30 feet of fissile indurated sandy shale, which contains an abundance of fish scales and bones and weathers white on exposure. About 250 to 300 feet above this is another sandy zone, 30 or 40 feet thick, with a calcareous sandstone at the top. This sandy zone forms a very low inconspicuous ridge. The remainder of the section is chiefly shale, with about 75 feet of thin-bedded sandstones and sandy shales about 100 feet below the top of the formation.

A well 2,018 feet deep was drilled by the Seventy-nine Oil Co. in or near sec. 36, T. 5 N., R. 19 E. (Pl. I, in pocket). In regard to this well the following statements are made by W. R. Calvert,[13] geologist:

The well was drilled as a test for oil in 1914. A little water was encountered at shallow depth at the base of the valley fill; otherwise the hole was dry throughout. The well was started at a horizon approximately 300 feet below the Eagle sandstone and was in Colorado shale to a depth slightly exceeding 1,800 feet, when the Kootenai formation was encountered. The bottom of the hole is in Kootenai.

[12] Op. cit., p. 195.
[13] Written communication from Mr. Calvert.

Drilling in the areas of Colorado shale can not be encouraged except near the margins, where the formation thins out and there is a prospect of finding water in sandstone underlying the thick shale. Unless a chance is taken on deep drilling, water supplies in these areas must be developed from very shallow sources, as shown in the description of the areas of Bearpaw shale (p. 19), or by storing rain or surface water, as described on pages 43–47.

KOOTENAI FORMATION.

Below the Colorado shale is the Kootenai formation, which comes to the surface in only small tracts in the northwestern part of the area (Pl. I in pocket). It consists largely of shale of maroon and other rather striking colors, but it also includes beds of sandstone, some of which are fairly coarse. In some places in this general region the Colorado shale is underlain by water-bearing sandstone at about the horizon of the Kootenai, and in these counties water-bearing beds will probably also be found below the Colorado shale.

The following description of the Kootenai formation in the Big Snowy Mountains in Golden Valley County, is given by W. R. Calvert[14]:

> The Kootenai formation, which is of Lower Cretaceous age, is of special interest in that it carries the coal of the well-known Great Falls and Lewistown fields. This formation is about 500 feet thick, the lower 60 feet of which is composed mainly of sandy shale. Next above is a massive gray conglomeratic sandstone about 50 feet thick that is the most persistent member of the entire geologic section. This sandstone immediately overlies the coal wherever coal is present. The upper 400 feet of the formation is composed of alternating sandstone and maroon-colored shale, the latter greatly predominating.

The water-bearing properties of the Kootenai formation in an area around Great Falls, Mont., which extends within about 45 miles of the westernmost Kootenai outcrop in this area, are described by Fisher[15] as follows:

> The water-bearing rocks of the Great Falls region are confined mainly to the basal Colorado and Kootenai formations, where a number of sandstone beds occur which are porous and imbibe water freely when conditions are favorable. In the Kootenai formation several water-bearing horizons are found. The massive gray sandstone overlying the coal, which ranges in thickness from 25 to 80 feet, is the source of a number of springs, and wherever the coal is mined, especially where the sandstone forms the roof, considerable difficulty is encountered with water from this formation. Above the sandstone overlying the coal there are a number of massive sandstones interbedded with red shale, which, when they occupy summits of plateaus, have numerous small springs issuing from their base. These Kootenai sandstone beds are the sources of numerous small springs wherever they are exposed.

According to Calvert, the hole drilled by the Seventy-nine Oil Co. (p. 22) extended about 200 feet into the Kootenai formation without

[14] Unpublished manuscript.

[15] Fisher, C. A., Geology and water resources of the Great Falls region, Mont.: U. S. Geol. Survey Water-Supply Paper 221, p. 35, 1909.

finding water. On the other hand, the 96-foot well of W. H. Kaercher, in the SW. ¼ sec. 4, T. 11 N., R. 24 E., ends in sandstone apparently belonging to the Kootenai formation and yields an ample supply of water that is used for domestic supplies and for stock. (See analysis No. 20, p. 41.) Water has also been reported in other wells in this region from the Kootenai or the basal beds of the Colorado.

RELATION OF ROCK STRUCTURE TO WATER SUPPLIES.

The rock formations that underlie Musselshell and Golden Valley counties do not as a rule lie horizontal but have been tilted and warped. After being tilted and warped they were extensively eroded, and their eroded edges are now exposed at the surface. Where the sandstones come to the surface they generally form

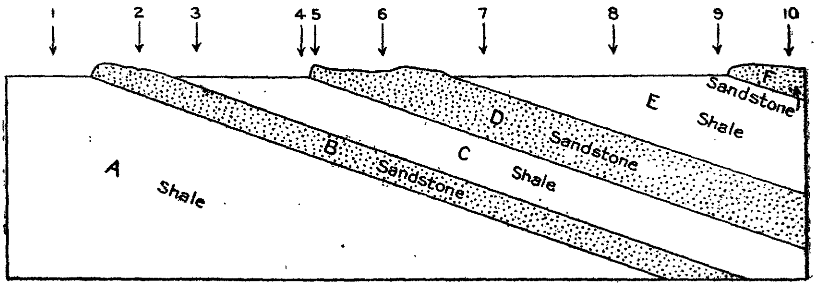

FIGURE 6.—Hypothetical section illustrating relation of ground water to rock structure in Musselshell and Golden Valley counties. Alternate beds of sandstone and shale (A to F, inclusive) are tilted and their eroded edges are exposed at the surface. The shale is worn down to form flat lowlands; the sandstone is more resistant to erosion and hence stands up in ridges and hills. As a general rule, the shale yields only meager supplies of poor water, whereas the sandstone yields somewhat larger supplies of better water. There are, however, many exceptions to this rule. Nos. 1 to 10 are well sites discussed in the text.

ridges, and where the shales come to the surface they generally form flat lowlands. The sandstones are in general more favorable than the shales as sources of potable water. These rather simple facts of the geology ought to be understood by every driller who operates in these counties, because they will help him to act intelligently and to avoid much fruitless drilling. Their application is illustrated in Figure 6.

The prospects of drilling at sites 1 to 10, in Figure 6, are as follows: At site 1 the drill will be in shale to a great depth, and the prospects of getting a good well, even by deep drilling, are poor. At site 2 a satisfactory supply will probably be obtained at a moderate depth, but if the drill should pass through sandstone B and enter shale A without finding a satisfactory supply the prospects of finding a supply by drilling deeper would be very poor. At site 3 the drill will first encounter shale C, but without going to very great depth it will penetrate sandstone B, in which a satisfactory supply will probably be found. At site 4 the drill will enter shale at the surface and will have to penetrate, obliquely to the bedding, virtually the entire thickness of shale C before it reaches a sandstone. A very deep well would reach sandstone B, where it would probably find water, but the water might not be good enough for use. At site 5 the drill will penetrate considerable sandstone before it reaches shale C. The lower part of the sandstone may here be saturated and furnish a satisfactory well or the formation may be drained dry from the top down to the shale below. At site 6 the sandstone extends to a greater depth than at site 5, and the prospects are accordingly better. At site 7 the conditions are similar to those at site 3. At site 8 the drill will be in shale to a great depth. It would have to penetrate about half of shale E before it would reach the underlying sandstone D, in which it might perhaps find a satisfactory supply. At site 9 the conditions are like those at site 8 except that about twice as great a thickness of shale would have to be penetrated before the underlying sandstone would be reached, and moreover the prospects of getting satisfactory water from the sandstone would be poorer. At site 10 the surface formation is a sandstone that is not found at any of the other nine sites. However, if this sandstone, F, has water-bearing characteristics similar to those of the other sandstones, B and D, the conditions found at site 10 will be much like those at sites 2 and 6.

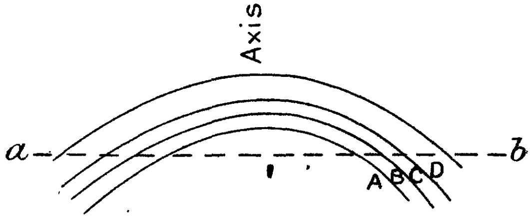

FIGURE 7.—Section showing a series of beds (A to D inclusive) that have been arched up to form an anticline. If they are eroded down to the broken line (*a–b*) the oldest formation, A, is at the surface along the axis of the anticline, and successively younger beds appear at the surface on both sides.

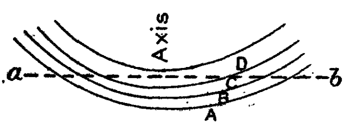

FIGURE 8.—Section showing a series of beds (A to D, inclusive) that have been bent down to form a syncline. If they are eroded down to the broken line (*a–b*) the youngest formation, D, is at the surface along the axis of the syncline, and successively older beds appear at the surface on both sides.

Where the formations have been warped up they form anticlines, as shown in Figure 7. In these places there has been much erosion, and hence the oldest formations are likely to be at the surface along the axes of the anticlines. (See Fig. 7.) Where the formations have been warped down they form synclines, and the youngest formations are likely to be at the surface along the axes, as shown in Figure 8.

In the region in which Mussellshell and Golden Valley counties are situated most of the mountains occupy areas in which the formations have been warped up and deeply eroded, so that old formations are exposed, whereas in the intervening areas the formations have as a rule sagged down and have been relatively protected from erosion. The sketch map in Figure 2 shows that if a section were constructed across these counties from the Big Snowy Mountains on the northwest, to the Big Horn Mountains on the southeast, it would in a general way reveal a syncline, as is shown in Figure 6. In the area comprising these counties the formations in general rise toward the northwest—in the direction of the Big Snowy Mountains—and pass to great depths in the opposite direction. Thus, the oldest formations are at the surface in the Big Snowy Mountains in the northwestern part of the area, and the youngest are at the surface in the Bull Mountains in the southeastern part. The geologic map (Pl. I) shows this general transition from older to younger formations toward the southeast. For example, the Colorado shale causes very unfavorable ground-water conditions in many places in the western and northern parts of the area, but it does not in the southeastern

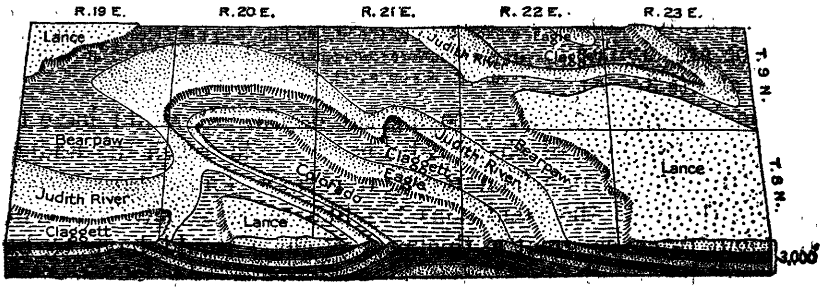

FIGURE 9.—Stereogram of ten townships in Musselshell and Golden Valley counties drawn to show relation of structure to ground-water conditions. The formations shown by stipples contain water-bearing sandstones; the others chiefly shales that yield almost no potable water.

part, where it lies several thousand feet below the surface and where water-bearing beds are found in the Fort Union and Lance formations much nearer the surface.

The formations do not, however, descend regularly toward the southeast but have been irregularly warped into a number of smaller anticlines and synclines. The most prominent of these anticlines is the so-called Woman's Pocket, which is well shown in the section in Plate I. Other anticlines are the Devils Pocket, the Devils Basin, the anticline extending into T. 7 N., R. 19 E., and the anticline extending along the Big Coulee. These last two are nearly at right angles to the Woman's Pocket. Synclines or structural basins generally occupy the belts between the anticlines. A prominent syncline lies between the Woman's Pocket and the Devils Pocket, and extends eastward to the Bull Mountains. The section shown in Plate I passes through this syncline in T. 8 N., Rs. 24 and 25 E. A well-developed triangular basin occurs southwest of Woman's Pocket and between the anticlines along the Big Coulee and in T. 7 N., R.

19 E. From the Woman's Pocket to this basin the formations at the surface range, within about a mile, from the Colorado shale to the Lance formation. Another syncline is flanked on the south by the anticline in T. 7 N., R. 19 E., and on the north by the Big Snowy Mountains, and is to some extent bifurcated by the Woman's Pocket.

The irregular structure of the rock formations in this county causes great variations in the ground-water conditions from place to place within short distances. To how large an extent this is true can best be appreciated by reading the township descriptions (see pp. 49–90) and examining Plate I and Figure 9.

ARTESIAN CONDITIONS.

The stratigraphy and structure of Musselshell and Golden Valley counties are somewhat favorable for producing artesian conditions. The water-bearing sandstones alternate with nearly impervious shales, so that wherever a sandstone passes far beneath the surface it is overlain by an effective confining bed which holds the water in the sandstone under artesian pressure. If a well is drilled through the shale into the underlying water-bearing sandstone the water from the sandstone is likely to rise in the well to a level far above that at which it is encountered. In most of the wells described in this report the normal water level is far above the beds from which the water is derived.

If a well that reaches a given sandstone is situated at a considerably lower altitude than the outcrop of the sandstone, where the water is absorbed from streams or rain, the water from the sandstone may rise to the surface and produce an artesian flow. The permeable formations that crop out in the Big Snowy Mountains or in the adjacent highlands doubtless contain water under artesian pressure where they extend below the other parts of the area, but as a rule they pass so far below the surface that they can not be reached by drilling except at great cost. The numerous folds in the rock formations, however, doubtless produce local artesian structure that will supply flowing wells in certain low places, especially in synclinal areas.

In recent years many wells have been drilled in Musselshell and Golden Valley counties in an endeavor to obtain petroleum in commercial quantities. Most of these wells have yielded some water, and a few have overflowed. Practically all of them show the presence of considerable artesian pressure, the water rising in the casing far above the level of the stratum from which it comes.

In the SW.¼ sec. 24, T. 7 N., R. 18 E., the E. C. Lewis Oil & Development Co. drilled a well 1,910 feet deep, which ended in the Kootenai formation. The log reports a hard sandstone from 825 to 848 feet which yielded 60 gallons of water a minute. The water from a hard shale between the depths of 906 and 920 feet rose 500 feet in the casing. At 1,900 feet the water from "red rock" filled the hole.

In the NE. ¼ sec. 15, T. 8 N., R. 20 E., the Tri-City Oil Co. drilled a well 1,917 feet deep. The well is in Colorado shale to 1,545 feet and probably ends in the Kootenai, which usually yields some water, but no mention of any water is made in the log. The Foster well No. 1 in T. 8 N., R. 20 E., obtained a small artesian flow from a sandstone in the Colorado between the depths of 468 and 475 feet. This well reached a depth of 1,365 feet, but no further mention of water was made in the log. The well drilled by the Tri-City Oil Co. in the SW. ¼ sec. 21, T. 8 N., R. 21 E., reached the depth of 2,145 feet. Artesian flows were obtained from a sandy limestone between the depths of 550 and 570 feet, a gray sandstone between 1,450 and 1,500 feet, a hard limestone between 1,605 and 1,608 feet, and a stratum of white sand between 1,787 and 1,790 feet. The third artesian horizon produced "sulphur water," and the fourth produced some gas. The first two flows were probably from the Colorado shale and the other two from the Kootenai formation.

In sec. 2, T. 9 N., R. 22 E., the well of the E. C. Lewis Oil & Development Co. is 445 feet deep. It passed through Eagle sandstone from the surface to 255 feet and ends in the Colorado shale. It did not produce any artesian flow.

The Roundup Oil & Gas Co. drilled a well, 1,235 feet deep, in the southwest corner of sec. 14, T. 11 N., R. 24 E. This well is reported to have obtained a small flow from a sandstone in the Kootenai formation between the depths of 270 and 290 feet and to have struck water and gas at the top of the Quadrant formation, at a depth of 1,123 feet. In the same quarter section, only 500 feet away, the Montill Oil Co. drilled a well in which the water conditions are about the same as those in the well of the Roundup Oil & Gas Co. In the NE. ¼ sec. 16, T. 11 N., R. 24 E., a well obtained fresh water at six different horizons, but from none did the water rise to the surface. The well of the Tri-City Oil Co., in the NW. ¼ sec. 23, T. 11 N., R. 24 E., is 1,236 feet deep, but struck no artesian flows. The well of the Van Duzen Oil Co., in the SW. ¼ sec. 24, T. 11 N., R. 24 E., obtained an artesian flow at 750 feet from a sandstone believed to be in the Morrison. In the NE. ¼ sec. 9, T. 11 N., R. 25 E., the Spokane-Roundup Oil Co. drilled a well 1,510 feet deep, which obtained an artesian flow from a sandstone between the depths of 1,500 and 1,510 feet. This sandstone is the "First Cat Creek sand" at the base of the Colorado shale.

The Ohio Oil Co. drilled a well 2,450 feet deep, in sec. 24, T. 10 N., R. 26 E. The "First Cat Creek sand," which contained some water, was penetrated between 1,660 and 1,690 feet, but no flows are mentioned in the log. The Romar Oil Co. drilled a well 1,900 feet deep in the NE. ¼ sec. 20, T. 10 N., R. 27 E. Some water was obtained at 820 feet, and the hole filled with water from the "First Cat Creek sand," but did not overflow.

The Northern Pacific well No. 1, in Howard Coulee, in sec. 13, T. 11 N., R. 27 E., reached a depth of 2,455 feet, but no mention is made in the log of any flows. The Ragged Point well, in sec. 5, T. 11 N., R. 30 E., is 2,355 feet deep. Several water-bearing sands were noted in it, but no flows are mentioned.

The record of these wells is not encouraging to any one seeking artesian water. Most of the wells were drilled near the axes of anticlines in an endeavor to obtain oil, and some of the wells are situated so little below the altitude of the intake of the strata yielding the water that there is not enough head to cause the water to rise to the surface. In the synclines, particularly where the synclines and deeply eroded valleys coincide, the chances for obtaining flowing wells are better. However, the depth to the "First Cat Creek sand" (at the base of the Colorado shale) and the Kootenai formation is generally considerable in the synclines, making it very expensive to obtain water from these horizons. The "First Cat Creek sand" does not seem to be so well developed south of the Big Snowy Mountains as it is to the east and northeast, being less sandy, and hence not so good a water bearer. The Kootenai also is less well developed to the south of the mountains. In general, the beds south of the Big Snowy Mountains are more shaly, which makes them poorer water bearers.

Because of the marked change in geology from place to place within short distances the areas in which flowing wells could be obtained are probably small and irregular, although there may be a number of such areas. As these counties are not covered by detailed topographic maps it is impracticable to make any very specific statements as to prospective areas of artesian flow. Flowing wells could probably be obtained in some places in the valleys of Musselshell River and its tributary streams between the west boundary of Golden Valley County and the vicinity of Lavina from the Eagle sandstone, which crops out at somewhat higher levels to the south. The small flows at Lavina are apparently supplied by the Eagle sandstone. Flowing wells could probably also be obtained in various parts of the Musselshell and tributary valleys from the Fort Union and Lance formations, especially in the synclinal area southwest of Roundup and in the one in the vicinity of Delphia and Musselshell. There are at least two flowing wells in low places just west of Musselshell, one of which is 265 feet deep (p. 85). Flowing wells could perhaps also be obtained by drilling in certain low localities in the northern part of the county on the dip sides of outcrops of the

Kootenai formation, the Eagle sandstone, the Judith River formation, or sandstone members of other formations.

QUALITY OF WATER.

AVAILABLE DATA.

A large number of samples of water from wells and springs collected by the United States Geological Survey in southeastern and south-central Montana have been analyzed in the laboratory of the State Board of Health and the Montana State College, at Bozeman, Mont., under the supervision of W. M. Cobleigh, director of the laboratory. Thirty-four of these samples were collected in or near Musselshell and Golden Valley counties, and their analyses are given in the table on pages 40–41.

Many analyses have also been furnished by George M. Prentiss, chief chemist of the Chicago, Milwaukee & St. Paul Railway Co., of waters from wells, springs, and streams along that railway in Montana. In the table on page 42 are given analyses, furnished by Mr. Prentiss, of 17 well waters in or near Musselshell and Golden Valley counties. In the table on page 43 are given 10 typical analyses of filtered water from Musselshell River at different stages. These analyses were made by the railway company under the direction of Mr. Prentiss.

In addition to the analytical results certain computed quantities are given in the table on page 41 and the waters are classified as to their chemical character, suitability for irrigation, and mineral content. These computations and classifications are made by the methods and standards used in a number of earlier publications of the United States Geological Survey.[16]

The inhabitants of these counties contributed information showing their opinion of the quality of the water from their wells and the use that is made of the water. This information is valuable in connection with the analyses and also in determining which formations generally yield potable water and which generally yield water that is too poor to be used or that can be used only for stock. For the waters that were analyzed this information is also given on page 40.

QUANTITY AND CHARACTER OF DISSOLVED SOLIDS.

Most of the ground waters of Musselshell and Golden Valley counties are highly mineralized—that is, they contain relatively large amounts of dissolved mineral matter. The 34 waters whose analyses are given in the table on page 41 range from 288 to 17,092 parts of dissolved mineral matter in 1,000,000 parts of water, by weight.

[16] Stabler, Herman, Some stream waters of the western United States: U. S. Geol. Survey Water-Supply Paper 274, pp. 165–181, 1911. Mendenhall W. C., Dole, R. B., and Stabler, Herman, Ground water in San Joaquin Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 398, pp. 50–82, 1916.

Only 9 of the waters have less than 1,000 parts per million, 13 have between 1,000 and 4,000, and 12 have more than 4,000 parts per million. More than half the waters have more than 2,000 parts per million of total dissolved solids.

The dissolved solids consist chiefly of the basic radicles calcium (Ca), magnesium (Mg), and sodium (Na) and the acid radicles carbonate (CO_3), bicarbonate (HCO_3), sulphate (SO_4), and chloride (Cl). Potassium (K) is included with the sodium in most of the analyses. In accordance with general practice in reporting analyses made with reference to the use of water for boilers, the railroad analyses give the carbonate and bicarbonate together as carbonate, although carbonate if present at all is usually much less than the bicarbonate. The waters in these counties derive their calcium chiefly from calcium carbonate (limestone) and from calcium sulphate (gypsum), their magnesium chiefly from magnesium carbonate and from magnesium sulphate (Epsom salt), and their sodium largely from sodium sulphate (Glauber salt) and in small amounts from sodium chloride (common salt), sodium bicarbonate (baking soda), and sodium carbonate (washing soda). These soluble minerals occur in the rock formations, especially in the more shaly beds, and are taken up by the water as it percolates through the formations.

The calcium in the 34 waters whose analyses are given in the table on page 41 ranges from only 6.8 parts per million to 536 parts and averages 146 parts. Nearly half the waters have more than 100 parts of calcium, but a few are notably low in this constituent. Calcium makes the water hard and causes it to form scale in steam boilers and teakettles.

The magnesium in the 34 waters ranges from only 2.2 parts per million to 367 parts and averages 104 parts. In all but one of these waters there is less magnesium than calcium, and in about half the waters the magnesium content is between one-half and three-fourths that of calcium. Magnesium, like calcium, makes water hard and causes it to deposit scale. It is also likely to make the water corrosive in steam boilers. If present in large amounts as a sulphate (Epsom salt) it gives the water a laxative effect.

The alkali bases—sodium, potassium, etc.—are given together in the analyses. As a rule, in natural water sodium is present in very much larger quantities than potassium and the other alkali bases. In the 34 samples these constituents range from 8.4 parts per million to 4,945 parts and average 869 parts. The amount of sodium and other alkali bases is greater than that of calcium in 29 of the 34 samples; the average amount is about six times that of calcium, and the maximum in any sample is nearly 10 times that of calcium. There is no relation between the content of sodium and that of calcium, as there is between magnesium and calcium. A water that is high in sodium may also be high in calcium (as Nos. 10, 23, 26, and 32), it may be intermediate in calcium (as Nos. 2 and 19), or it may be low in calcium (as Nos. 5 and 6). The much greater abundance of sodium than of calcium and magnesium in the highly mineralized waters is in general due to the greater solubility of the sodium salts. These relations between the contents of calcium and magnesium and of calcium and sodium are not peculiar to this area but are the general rule for highly mineralized waters.

The sodium salts do not make water hard, but they may cause foaming in steam boilers, and when present in excessive quantities they make the water unsuitable for drinking or for use in irrigation. Sodium sulphate (Glauber salt), if present in considerable quantity, has a laxative effect and gives the water an undesirable taste.

The bicarbonate radicle in these waters ranges from 147 parts per million to 1,358 parts and averages 512 parts. The bicarbonate radicle is derived largely from calcium carbonate and magnesium carbonate, together with carbonic acid of atmospheric origin, which renders these carbonates soluble. In part, however, it is probably derived, in the waters of this region, from sodium bicarbonate.

These waters are as a group especially high in the sulphate radicle. In the 34 samples this constituent ranges from 19 parts per million to 10,487 parts, and averages 2,034 parts. In 23 of the samples the sulphate content is more than 500 parts per million and in 18 it is more than 1,000 parts. In about half the samples the sulphate radicle comprises one-half or more of the total dissolved solids, and in only a fourth of the samples does it comprise notably less than one-half. The sulphate radicle is derived chiefly from sodium sulphate, but in part also from calcium sulphate and magnesium sulphate. In the highly mineralized waters the proportion derived from sodium sulphate is especially large. The sulphates are chiefly responsible for the poor quality of many of the waters of this area.

These waters, with a few exceptions, are not high in chlorides. In comparison with the sulphate radicle the chloride radicle as a rule is notably low. In the 34 samples the chloride radicle ranges from 6.1 parts per million to 1,014 parts. This maximum, however, seems to occur in a rather exceptional water, for only three others of the 34 samples contain more than 100 parts of chloride, and more than half of the samples contain less than 35 parts. The chloride radicle is doubtless derived chiefly from sodium chloride. In not more than four of the 34 samples is it present in large enough amounts to be perceptible to the taste.

CLASSIFICATION OF WATERS.

Of the 34 samples whose analyses are given in the table on page 41, 18 are classed as sodium sulphate waters, 8 as calcium sulphate waters, 4 as calcium carbonate waters, and 4 as sodium carbonate waters.

About two-thirds of these waters (including nearly all of those classed as sodium sulphate or calcium sulphate waters) are of the same general type—they are highly mineralized, and their mineral matter consists predominantly of the sulphates of sodium, calcium, and magnesium. They are hard waters, of inferior quality for most uses.

The few samples that are classed as calcium carbonate waters are of a different type. They are much less mineralized and of much better quality for practically all uses. They contain relatively little sulphate or chloride and not very much sodium. Their moderate mineral content consists chiefly of the bicarbonates of calcium and magnesium, which makes them somewhat hard, but otherwise good waters. No. 1 is the best example of this class.

Two waters (Nos. 5 and 6) are remarkably low in calcium and magnesium. They are soft waters. In comparison with the average of the area 6 others (No. 11, 17, 18, 27, 33, and 34) would be considered soft. In addition to being less hard than the average, these waters have the further advantage that the hardness is carbonate hardness, which can largely be removed by heating the water. The very hard waters have largely noncarbonate hardness, which is not affected by heating but can be removed only by the use of an alkali, such as washing soda or lye, or by some commercial softening process.

RELATION OF QUALITY TO WATER-BEARING MATERIALS.

The formations of this area consist chiefly of shale and sandstone. As a rule the shaly formations yield poorer water than the sandstones. This fact was established by the field survey and is corroborated by the chemical data given in the table on page 41 and graphically shown in Figure 10. The waters from shale and from sandy strata in formations that are predominantly shale are generally very rich in sulphates. Many of these waters are too highly mineralized to be fit for any ordinary use. The water in some shallow dug wells ending in shale, such as No. 4. is better than the water from deep wells in shale and is used for drinking and for other domestic purposes. Some of the waters from sandstones are of fairly satisfactory quality (for example, Nos. 1, 9, 16, 17, 20, and 33), but others are very poor (for example, Nos. 11, 13, 14, and 18). As shown in Figure 10, however, all the sandstone waters that were analyzed are used for drinking and for other domestic purposes. The great range in the mineralization of the sandstone waters is doubtless due not only to differences in the character of the sandstones and in the freedom with which water percolates through them but also to the mingling of shale and sandstone waters as they percolate.

The sand and gravel in the alluvium of the present valleys and the gravelly deposits that mantle the bedrocks in some places on the

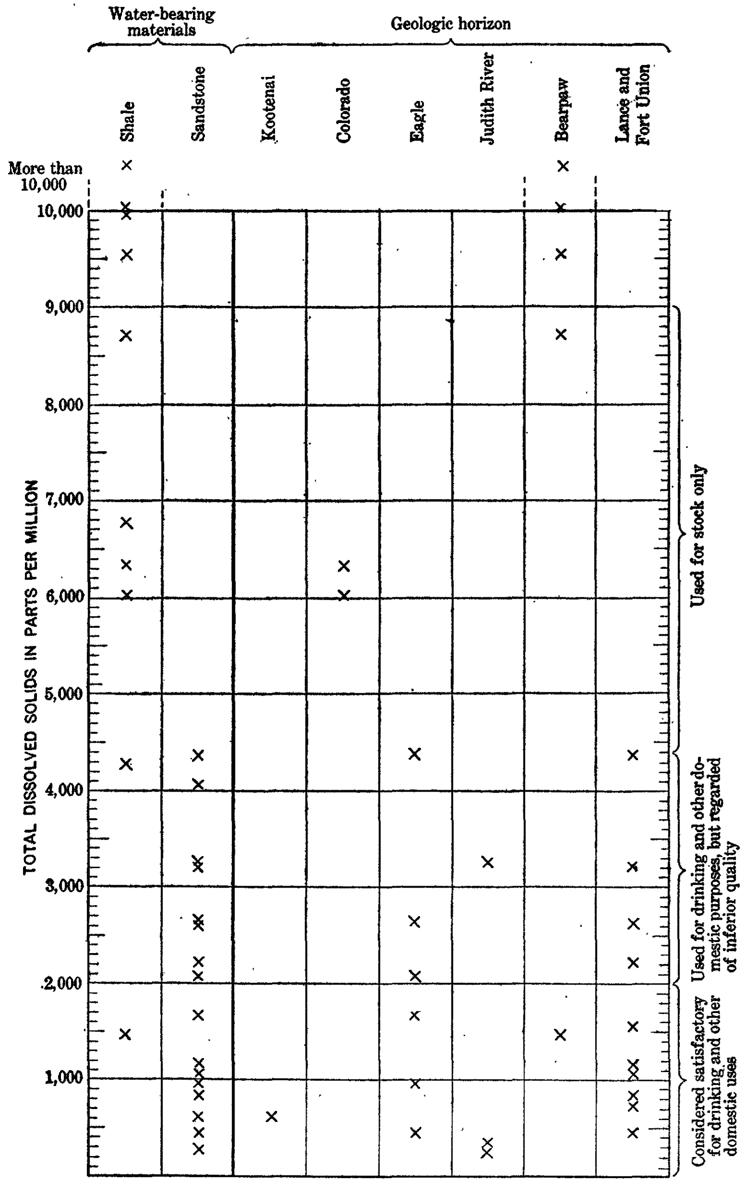

FIGURE 10.—Diagram showing relations of total dissolved solids in ground waters in Musselshell and Golden Valley counties to the water-bearing materials and to the geologic horizons at which the waters occur; also the relation of total dissolved solids to use.

uplands generally yield somewhat hard but otherwise fairly satisfactory water. The clayey alluvium and lake deposits may yield poor water.

RELATION OF QUALITY TO GEOLOGIC HORIZONS.

The character of certain samples of water from the different formations is shown in the table on page 41 and in Figure 10, and general information on the quality of other supplies derived from these formations is given in the township descriptions (pp. 49–90). The available data do not clearly indicate any distinct differences in the types of water from the different formations. The principal generalization that can be made on the basis of the present information is that as a rule, the formations which consist chiefly of sandstone, such as the Fort Union, Lance, Judith River, and Eagle, yield less mineralized water than those which consist chiefly of shale, such as the Bearpaw, Claggett, and Colorado. Figure 10 suggests that this difference is the more noticeable because the waters from the first group fall chiefly within the limits of potability, whereas those from the second group do not. The waters from the Fort Union and Lance formations are probably more generally satisfactory than those from the Judith River formation and the Eagle sandstone, because the Fort Union and Lance lie above the prominent shale formations and their waters are entirely isolated from them, whereas the Judith River formation and the Eagle sandstone are interbedded with prominent beds of shale, and their waters are doubtless mixtures derived in part from the shales.

The two samples (Nos. 5 and 6) which contain very small quantities of calcium and magnesium are believed to come from the Eagle sandstone. The samples known to come from the Fort Union and Lance formations are of the type having only carbonate hardness. The available information indicates that soft water and water with only moderate carbonate hardness are abundant if not predominant in the Lance and Fort Union formations and are also found to some extent in the Eagle sandstone.

The Quaternary alluvium and lake deposits and the Miocene (?) terrace gravels generally yield hard but potable water, although the clayey phases of alluvium and lake deposits may yield bad water.

RELATION OF QUALITY TO DEPTH.

The analyses in the table on page 41 indicate that in general the mineralization of the ground water in this area increases with the depth from which the water comes, but that the formation from which the water comes is more significant than the depth of the well. Thus, in the six sandstone wells that are about 100 feet deep the total dissolved solids range from less than 300 parts per million to more than 4,000 parts, and in the four shale wells that are 25 feet or less in depth the total dissolved solids range from less than 1,500 parts to nearly 7,000 parts. However, in many places in the parts of the area not underlain by the Fort Union or Lance formations the best water is found near the surface—in terrace gravels, alluvium, or the loose surficial part of a shale formation.

RELATION OF QUALITY TO USE.

Drinking by man.—In regard to the relation of the dissolved mineral matter in water to its potability, the following statements were made by Dole,[17] largely on the basis of highly mineralized waters from San Joaquin Valley, Calif., and the Carson Sink, Nev.:

The lower waters are in mineral content the more acceptable they are as sources of supply, yet the amount of dissolved substances that can be tolerated in drinking water is much greater than that allowable in city supplies, for which hardness, corrosion, pipe clogging, and general utility have to be considered. Though there are certain limits above which the common ingredients are intolerable, these limits are not only difficult to ascertain but are also likely to shift. A normal water is not a pure solution of one salt, whose physiologic effect can be measured, but an indeterminate mixture of solutions of several salts whose effects are not easily differentiated. Further, though all animals select for drinking waters that are lowest in solids and avoid those that are highest, the same animals, when transported to districts of poor water, accustom themselves to supplies of far greater mineral content than those which before they would not touch. Consequently any general limits that may be assigned to the various mineral ingredients must be regarded as extremely flexible.

The immediate consequence of drinking waters too high in mineral content is usually diarrhea. Many persons at first afflicted with this trouble become accustomed to the new supply and acquire what may be termed immunity. Whether other disorders result from the continued drinking of such waters is not known; and it is equally uncertain whether cattle and horses that so commonly are reported to have been killed by drinking strong mineral water were killed by the purging produced by the mineral matter in the water or by excessive consumption of water itself. It would appear from the data at hand that alkaline carbonates are most injurious and alkaline sulphates least injurious and that alkaline chlorides occupy an intermediate position. This arrangement corresponds to the order of the same substances in reference to their toxic effect on plants. The most striking feature is that the amounts of mineral matter in most of these waters is much greater than that ordinarily considered permissible in drinking water. Waters exceeding 300 parts per million of carbonate, 1,500 parts of chloride, or 2,000 parts of sulphate are apparently intolerable to most people. These limits fortunately are far beyond the points where the substances in solution are clearly perceptible to the ordinary taste. In conclusion it can not be too emphatically stated that the information on this subject is fragmentary and uncertain and that any limits of mineral tolerance are modified by individual idiosyncrasy.

The following statements were made by Meinzer and Hare on the basis of analyses of waters from Tularosa Basin, N. Mex.:[18]

Any classification based on total solids alone is unsatisfactory because the different constituents do not have the same effects, and hence much depends on the proportions of these constituents. The calcium salts are less objectionable in water used for drink-

[17] Mendenhall, W. C., Dole, R. B., and Stabler, Herman, Ground water in San Joaquin Valley, Calif.: U. S. Geol. Survey Water-Supply Paper 398, pp. 76–79, 1916.

[18] Meinzer, O. E., and Hare, R. F., Geology and water resources of Tularosa Basin, N. Mex.: U. S. Geol. Survey Water-Supply Paper 343, pp. 134–135, 1915.

ing than the same amounts of the sodium salts, and the different sodium salts are not equally objectionable. The older authorities on drinking waters for England and the eastern part of the United States fixed 570 parts per million as the extreme limit of mineral content.[19] MacDougal, judging from experience in desert regions, states that waters containing 2,500 parts per million of dissolved salts may be used for many days without serious discomfort; that those containing as much as 3,300 parts can be used only by hardened travelers; and that those containing 5,000 parts or more are inimical to health and comfort but might suffice for a few hours to save the life of a person who had been wholly without water.[20]

In Tularosa Basin, where many of the waters are practically saturated with calcium sulphate, the limits are possibly even higher than those given by MacDougal. Waters ranging up to 2,000 parts of total solids are generally considered satisfactory for drinking, and where the proportion of calcium is especially high and that of chlorine especially low, waters containing 2,500 parts, or even more, may be considered satisfactory. The more gypseous waters ranging between 2,500 and 4,000 parts of total solids are considered potable, although of inferior quality, but other waters that fall between these limits but are richer in sodium chloride are avoided for drinking. A few waters ranging between 4,000 and 5,000 parts are used for drinking, but waters containing more than 5,000 parts are almost never used by human beings except in need. The water from the Point of Sands well is commonly used by travelers for drinking. It contains 4,804 parts of total solids but is practically saturated with gypsum and contains only 188 parts of chlorine.

The conditions in Musselshell and Golden Valley counties, as shown in Figure 10, agree fairly well with those found in California, Nevada, and New Mexico. Water having more than 4,000 parts per million of total dissolved solids is used for drinking and for other domestic purposes; water having as much as 2,000 parts is regarded as good; and water having between 2,000 and 3,000 parts is regarded as fairly satisfactory. Water that contains as much as 2,500 parts per million of the sulphate radicle is used for drinking and for other domestic purposes; and water that contains as much as 500 parts of this constituent is regarded as good. The reports concerning samples 8 and 24 were not verified in the field and are so discordant with all other available data as to potability that they have not been used in the generalizations.

It will be noted that most of the samples from the dominantly sandstone formations (Eagle, Judith River, Lance, and Fort Union) are used for domestic supplies, but that most of those from the dominantly shale formations (Colorado, Claggett, and Bearpaw) are not used or are used only for stock.

It should be distinctly understood that the limits of potability here given are merely those established by the residents of the area for themselves. It is not known whether the more highly mineralized waters that are being used are harmless or injurious to the human body. In the absence of satisfactory data on this important subject

[19] Hare, R. F., and Mitchell, S. R., Composition of some New Mexico waters: New Mexico Agr. Exper. Sta. Bull. 83, p. 8, 1912.

[20] MacDougal, D. T., Botanical features of North American deserts: Carnegie Inst. Washington Pub. 99, p. 109, 1908.

it is doubtless wise to regard with some suspicion the waters that are highly enough mineralized to be unpleasant to the taste.

Drinking by stock.—The data obtained in the Tularosa Basin, N. Mex., indicate that stock will habitually drink water which is fully twice as high in mineral matter as the most highly mineralized water drunk by man. One supply used in that region for stock contained 8,967 parts per million of total dissolved solids and 4,834 parts of the sulphate radicle. This condition may, of course, be due in part to the fact that the tastes of the animals are not consulted, but it apparently shows that their tolerance is much greater than that of man. The data in the present report show that in Musselshell and Golden Valley counties water is used for stock that contains as much as 8,710 parts per million of total dissolved solids and 5,642 parts of the sulphate radicle. It should not, however, be assumed that stock can be forced to drink water of extremely high mineralization without injurious results. Even where highly mineralized water does not cause acute disorders in animals it may affect their general health or stunt their growth. An investigation of the effect of highly mineralized water on the health of cattle, horses, sheep, and hogs would doubtless be valuable to the stock raisers of Montana. Some work along this line has already been done.[21]

According to Dole, man can endure larger amounts in parts per million of dissolved sulphates than of dissolved chlorides. The same is evidently true of other animals, for the observed upper limit for the chloride radicle in water used for stock in the Tularosa Basin is about 3,000 parts per million, or a little more, whereas the observed upper limit for the sulphate radicle is 4,834 parts in the Tularosa Basin and 5,642 parts in Musselshell and Golden Valley counties.

Washing.—Most of the water of this area is high in calcium and magnesium and is therefore very hard and unsatisfactory for toilet and laundry uses. Most of the water can not be softened by heating but only by adding an alkali, such as washing soda. Exceptions are found in certain supplies that contain only small amounts of calcium and magnesium. At least some of these supplies (represented by analyses 5 and 6, p. 41) are truly soft, although they contain rather large amounts of the sodium salts. Considerable water, especially that from the Lance and Fort Union formations, is of intermediate quality for washing in that it contains relatively moderate amounts of calcium and magnesium, which can be largely removed by heating without the addition of washing soda. Much of the water is also of inferior quality for washing because of the iron which it contains, even 1 or 2 parts per million being objectionable.

[21] Taylor, W. J., Alkali water and domestic animals: Montana Agr. Exper. Sta. Circ. 7, 1911.

Boiler use.—The waters of this area are nearly all of poor quality for use in steam boilers, and many of them are quite unfit for boiler use, as is shown by the analyses in the tables on pages 41–42. Most of them contain so much calcium and magnesium that they form large amounts of hard scale in boilers. The sodium salts do not form scale, but where present in the large quantities found in many of these waters they cause trouble by foaming and priming. The principal user of water for making steam in this area is the Chicago, Milwaukee & St. Paul Railway Co., which has had much difficulty in getting locomotive supplies.

Irrigation.—Ground water is not known to occur in this area in sufficient quantities for extensive irrigation, but in some places adequate yields may be obtained from wells to irrigate gardens or other small tracts. The principal injurious effects of mineral matter in water on vegetation are usually produced by the more abundant sodium salts. Among these salts, sodium carbonate is the most injurious and sodium sulphate the least injurious. In most of the waters analyzed only the sulphate is present in sufficient amount to do much harm if the waters are used for irrigation. As shown by the tables on pages 41–42, the waters that have been analyzed range in quality for irrigation from good to bad; many of them are poor, because of their large contents of sodium and the sulphate radicle, but still may be successfully used under favorable conditions. Thus, water that will be injurious on the clay soil of the lowland flats may not be injurious if applied to the more porous soil on the better-drained uplands. Moreover, water that would be injurious if used frequently may do no harm if used only occasionally to supplement the rain.

QUALITY OF SURFACE WATER.

The table on page 43 shows that the water of Musselshell River is at times highly mineralized and that its mineral content fluctuates greatly with the stage of the river, being much higher when the river is low and carries little except ground-water run-off than when the river is high and carries chiefly water that has not been beneath the surface.

The analyses show only the dissolved mineral matter and not the suspended matter. In times of high water, when the quantity of dissolved material is low, the river carries a large amount of suspended matter, which makes the water much less desirable for nearly every use than is indicated by the quantities of dissolved constituents which are reported.

Records of wells and springs in or near Musselshell and Golden Valley counties, for which analyses are given.

[For records of other wells see pp. 49-90.]

No.[a]	Location.			Owner or name.	Type of well or spring.	Depth of well.	Diameter of well.	Water-bearing formation.		Use of water.	Quality as reported by those who use the water.
	Quarter section.	Township (north).	Range (east).					Character of material.	Geologic horizon.		
						Feet.	*Inches.*				
1	NE. 34	10	19	Arthur Kalaijin	Drilled	105		Sandstone	Judith River (?)	Domestic and stock	
2	SW. 9	9	21	Thomas Cantrell	do	275		Shale	Bearpaw		
3	SW. 24	9	21	Peter B. Madsen	do	166	6	do	do		Hard and salty.
4	NW. 27	9	21		Dug	12		do	do	Stock	
5	SE. 2	6	22	L. C. Lehfeldt	Drilled	550		Sandstone	Eagle	Domestic and stock	
6	NE. 11	6	22	Paul Brothers	do	250		do	do		Good.
7	SW. 24	7	22	L. H. Box	Spring					Domestic and stock	Medium hard.
8	NW. 25	7	22	L. H. Box	Drilled	128	6	Shale	Bearpaw	Domestic and stock(?)	Very soft; sulphur.
9	SW. 2	10	22	H. J. Griffin	do	72	6	Sandstone	Eagle	Domestic and stock	Good.
10	SE. 33	11	22	M. D. Benedict	Dug	25	48	Shale	Colorado	Stock	Bad.
11	SE. 30	8	23	J. E. Roach	Drilled	108	6	Sandstone	Lance	Domestic and stock	Soft, with a soda taste.
12	SW. 32	8	23	J. H. Beckner	do	172		do	do	do	
13	NE. 10	10	23	Oscar C. Olson	do	113	6	do	Bearpaw or Judith River.	do	Bad.
14	SW. 32	10	23	Martin W. Smith	do	102	6	do	Judith River	New well	
15	SW. 8	6	24	R. F. Haggerty	Dug	13	96	Rock	Lance	Domestic and stock	Hard.
16	SW. 2	8	24	J. N. Bricker	Drilled	155	6	Sandstone	do	do	Good.
17	SW. 4	10	24	Neal Hoffman	do	100	6	do	Lance or Fort Union	do	Do.
18	SE. 23	10	24	Frank Liess	do	169	6	do	do	do	Somewhat alkaline.
19	SE. 32	10	24	C. Labart	do	93	6	Sandy shale	(?)	do	Usable.
20	SW. 4	11	24	W. H. Kaercher	do	96	6	Sandstone	Kootenai	do	Good.
21	NW. 8	11	24		Spring				Eagle (?)	Stock	
22	SE. 13	8	25	City of Roundup	Dug	30	96 by 144	Gravel	Alluvium	Public supply	Hard.
23	NE. 19	9	25	Swanson & Reid	Drilled	200	5	Shale	(?)	Stock	Bad.
24	NW. 21	9	25	A. D. Hamilton	do	182	6	do	(?)		Hard; not salty; acts as a cathartic.
25	SW. 14	11	25	Fred Harvey	do	167	6	Sandstone	Eagle	Domestic and stock	Fair; hard.
26	SE. 34	11	25	Donald Perrin	Dug	15	48	Shale	Colorado	Stock	Bad; alkaline.
27	SW. 2	3	26	George D. Chimbouris	Spring				Lance		
28	NW. 14	3	26		Dug	25			Bearpaw or Lance		
29	SE. 35	4	26	Frank Stipeck	Spring				Lance		
30	NW. 16	10	26	W. D. Stanton	Drilled	120	6		Eagle	Stock	Bad; unfit for domestic use.
31	SW. 32	9	27	Theodore Coble	do	75	6	Sandstone	Fort Union	Domestic and stock	Hard and a little flat.
32	NW. 30	10	27	W. A. McGinley	Bored	10	7	Shale		Stock (?)	Hard and salty.
33	NE. 29	9	29	Fred W. Handel	Drilled	235	4	Sandstone	Fort Union	Domestic	Good; soft.
34		11	30		Spring				Judith River	Domestic and stock	

[a] For analyses see corresponding numbers in table, p. 41.

Analyses and classification of water from wells and springs in or near [illegible] and [illegible] counties.

[Analyzed under supervision of W. M. Cobleigh, Montana State College. Parts per million except as otherwise designated.]

No.[a]	Date of collection.	Analysis: Silica (SiO_2).	Iron and aluminum oxides ($Fe_2O_3+Al_2O_3$).	Calcium (Ca).	Magnesium (Mg).	Sodium and Potassium (Na+K).[b]	Carbonate radicle (CO_3).	Bicarbonate radicle (HCO_3).	Sulphate radicle (SO_4).	Chloride radicle (Cl).	Nitrate radicle (NO_3).	Total dissolved solids at 180° C.	Computed quantities: Total hardness as $CaCO_3$.	Scale-forming constituents.	Foaming constituents.	Alkali coefficient.[c]	Classification: Chemical character.	Quality for irrigation use.	Mineral content.
1	Jan. 26, 1918	20	Trace.	49	32	[d]8.4	0.0	265	19	8.0	1.0	288	254	220	23	230	Ca-CO3	Good	Moderate.
2	Jan. 26, 1918	20	Trace.	156	93	3,043	.0	363	5,429	1,014	Trace.	10,117	771	630	8,200	1.2	Na-SO4	Bad	Very high.
3	June 20, 1916	10	.0	294	218	4,945	.0	702	10,487	622	....	17,092	1,630	1,200	13,000	1.0	Na-SO4	do	Do.
4	Jan. 26, 1918	47	5.0	80	44	335	.0	608	557	21	.72	1,478	380	360	900	7.4	Na-SO4	Fair	High.
5	Jan. 26, 1918	29	7.0	6.8	2.5	725	65	587	919	39	.12	2,083	27	53	2,000	2.1	Na-SO4	Poor	Very high.
6	Jan. 26, 1918	25	Trace.	7.5	2.2	635	88	954	349	81	Trace.	1,675	28	51	1,700	1.4	Na-CO3	do	High.
7	July 31, 1917	74	1.4	111	46	854	.0	525	1,759	42	....	3,138	466	480	2,300	6.9	Na-SO4	Fair	Very high.
8	May 23, 1916	25	4.4	53	30	3,152	.0	1,358	5,696	41	....	9,550	256	230	8,500	1.0	Na-SO4	Bad	Do.
9	Jan. 18, 1918	25	Trace.	117	86	64	.0	359	444	19	.06	976	645	510	170	60	Ca-SO4	Good	High.
10	Jan. 18, 1918	22	Trace.	410	254	1,026	.0	497	3,625	74	12	6,024	2,070	1,700	2,800	5.4	Na-SO4	Poor	Very high.
11	Jan. —, 1914	.....	....	32	8.0	1,483	.0	1,025	2,364	23	....	4,396	113	[e]140	4,000	1.4	Na-SO4	do	Do.
12	June 21, 1916	9.2	....	34	15	853	.0	692	1,355	15	....	2,620	146	130	2,300	2.5	Na-SO4	do	Do.
13	Jan. 11, 1918	46	....	398	352	213	.0	475	2,328	64	.16	4,069	2,440	1,800	580	17	Ca-SO4	Fair	Do.
14	Jan. 8, 1918	24	3.8	90	54	942	.0	851	1,654	52	.04	3,267	446	380	2,500	3.1	Na-SO4	Poor	Do.
15		.....	....	121	108	230	.0	627	671	22	....	1,548	745	[e]570	620	23	Ca-SO4	Good	High.
16	Jan. 18, 1918	26	Trace.	57	37	168	.0	342	335	21	.62	834	294	260	450	30	Na-SO4	do	Do.
17	Jan. 11, 1918	50	....	19	16	324	30	455	323	41	.57	1,069	113	130	870	3.8	Na-CO3	Poor	Do.
18	Jan. 8, 1918	24	6.2	24	15	993	.0	234	1,886	87	1.2	3,208	122	120	2,700	4.3	Na-SO4	do	Very high.
19	Jan. 8, 1918	30	9.2	65	22	1,289	.0	147	2,497	235	.30	4,292	253	260	3,500	3.5	Na-SO4	do	Do.
20	Jan. 26, 1918	19	4.4	56	52	86	.0	523	91	12	.28	617	353	270	230	15	Ca-CO3	Fair	High.
21	Jan. 18, 1918	17	Trace.	71	34	33	.0	388	39	21	.26	447	317	280	89	70	Ca-CO3	Good	Moderate.
22	Jan. 11, 1918	16	Trace.	116	50	64	.0	180	443	18	.20	830	495	440	170	60	Ca-SO4	do	High.
23	Jan. 26, 1918	22	Trace.	405	318	1,802	.0	311	5,642	73	1.8	8,710	2,320	1,700	4,900	3.3	Na-SO4	Poor	Very high.
24	Sept. 15, 1916	83	....	307	367	2,236	.0	695	5,925	278	....	9,970	2,270	1,600	6,000	2.2	Na-SO4	do	Do.
25	Jan. 18, 1918	27	Trace.	180	147	375	.0	580	1,294	31	.84	2,654	1,050	800	1,000	15	Ca-SO4	Fair	Do.
26	Jan. 18, 1918	36	8.0	521	356	694	.0	320	3,805	34	.13	6,339	2,760	2,200	1,900	8.5	Ca-SO4	do	Do.
27	Jan. 8, 1918	19	3.6	22	15	229	.0	504	172	14	1.0	744	116	110	620	4.4	Na-CO3	Poor	High.
28	Jan. 11, 1918	31	....	116	55	265	.0	275	808	17	.20	1,555	516	460	720	21	Na-SO4	Good	Do.
29	Jan. 8, 1918	19	Trace.	42	26	96	.0	388	82	11	1.7	474	212	190	260	12	Ca-CO3	Fair	Moderate.
30	Jan. 18, 1918	30	5.2	387	269	464	.0	375	2,592	52	.04	4,398	2,070	1,600	1,300	11	Ca-SO4	do	Very high.
31	Mar. 30, 1914	.....	....	56	29	705	.0	765	1,044	53	....	2,208	259	[e]240	1,900	2.8	Na-SO4	Poor	Do.
32	Dec. 7, 1914	.....	....	536	360	778	.0	436	3,961	19	....	6,794	2,820	[e]2,200	2,100	8.0	Ca-SO4	Fair	Do.
33	Dec. 5, 1910	10	4.0	13	4.7	[f]390	....	[b]357	549	17	.00	1,172	52	56	1,100	4.5	Na-SO4	Poor	High.
34	Jan. 18, 1918	22	Trace.	26	11	60	.0	229	41	6.1	.70	294	110	120	160	16	Na-CO3	Fair	Moderate.

[a] For locations and other data see corresponding numbers in table, p. 40.

[b] Calculated.

[c] Depth in inches of water which on evaporation would yield sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.

[d] Determined.

[e] Includes 30 parts per million for silica and iron and aluminum oxides based on average of determined values.

[f] Determined; sodium (Na), 378; potassium (K), 12 parts per million.

Analyses and classification of water from wells in or near Musselshell and Golden Valley counties.

[Furnished by the Chicago, Milwaukee & St. Paul Railway Co. Parts per million except as otherwise designated. Recalculated from hypothetical combinations in grains per U. S. gallon.]

Station.	Description of well.	Date of collection.	Analysis.							Computed quantities.				Classification.		
			Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).[a]	Carbonate and bicarbonate as carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).	Total dissolved solids.[b]	Total hardness as $CaCO_3$.	Scale-forming constituents.[b]	Foaming constituents.	Alkali coefficient.[c]	Chemical character.	Quality for irrigation use.	Mineral content.
Waldheim	Well in bed of Musselshell River	June 12, 1909	47	18	47	90	126	7.9	366	191	200	130	100	Ca-CO_3	Good	Moderate.
Do	Section house well, 13½ by 3 feet	July 8, 1908	141	53	156	206	516	20	1,122	570	530	420	30	Ca-SO_4	do	High.
Roundup	Coal mine well	June 20, 1908	23	11	291	179	396	16	946	103	120	790	5.7	Na-SO_4	Poor	Do.
Do	Well No. 1	Oct. 10, 1908	65	39	475	236	779	106	1,730	322	290	1,300	6.2	Na-SO_4	Fair	Do.
Do	Well No. 2	Oct. 10, 1908	59	27	410	177	762	46	1,511	258	250	1,100	9.8	Na-SO_4	do	Do.
Do	Mine No. 2, Republic Coal Co., shaft 350 by 14 by 16 feet.	Jan. 22, 1910	37	36	221	204	339	16	883	240	200	600	9.4	Na-SO_4	do	Do.
Do	Well, 40 by 10 feet	May 17, 1910	82	33	79	151	234	11	620	340	330	210	60	Ca-CO_3	Good	Do.
Do	Well of Roundup Water Co	July 8, 1910	73	32	85	143	234	12	609	314	300	230	60	Ca-SO_4	do	Do.
Do	Roundup Coal Mine Co., dug well 30 by 8 feet.	Aug. 1, 1910	79	18	197	215	319	6.1	864	271	290	530	11	Na-CO_3	Fair	Do.
Do	Old No. 1 mine shaft	Dec. 16, 1913	99	41	115	164	359	15	823	416	390	310	45	Ca-SO_4	Good	Do.
Musselshell crossing.	Drill hole, 250 feet deep, 2 inches in diameter.	Mar. 6, 1907	20	32	373	158	660	28	1,301	181	140	1,000	8.3	Na-SO_4	Fair	Do.
Musselshell	Well 130 feet deep, 3 inches in diameter.	Dec. 23, 1909	10	4.3	320	181	393	19	957	43	67	860	4.6	Na-SO_4	Poor	Do.
Japan	Well 400 feet deep, 2 inches in diameter.	Dec. 23, 1909	7.2	1.9	488	454	209	79	1,269	26	54	1,300	1.8	Na-CO_3	do	Do.
Melstone	K. E. Parker's well, 100 feet deep, 8 inches in diameter.	Dec. 23, 1909	389	116	922	427	2,380	182	4,446	1,450	1,400	2,500	4.7	Na-SO_4	do	Very high.
Vananda (Rosebud County).	Drilled well, 215 feet deep	Nov. 13, 1913	20	9.1	1,720	333	3,095	32	5,239	87	100	4,600	1.7	Na-SO_4	do	Do.
Do	Drilled well, 3,275 feet deep, 4¾ inches in diameter.	Aug. 28, 1914	6.0	1.6	1,034	242	1,190	442	2,946	22	50	2,800	1.7	Na-SO_4	do	Do.
Do	Drilled well, 3,200 feet deep	Oct. 18, 1914	21	11	1,812	368	3,228	39	5,509	98	110	4,900	1.6	Na-SO_4	do	Do.

[a] Calculated.
[b] Includes 30 parts per million for silica and iron and aluminum oxides based on average of determined values in table on page 41.
[c] Depth in inches of water which on evaporation would yield sufficient alkali to render a 4-foot depth of soil injurious to the most sensitive crops.

Analyses of water from Musselshell River in Musselshell and Golden Valley counties.

[Furnished by Chicago, Milwaukee & St. Paul Railway Co. Samples filtered before analysis. Results in parts per million except as otherwise designated. Recalculated from hypothetical combinations in grains per U. S. gallon.]

Station.	Date of collection.	Calcium (Ca).	Magnesium (Mg).	Sodium and potassium (Na+K).[a]	Carbonate and bicarbonate as carbonate (CO_3).	Sulphate (SO_4).	Chloride (Cl).	Sum of constituents.	Discharge (second feet).[b]
Melstone	Jan. 15, 1909	206	53	400	381	878	37	1,955	(c)
Do	Aug. 14, 1908	91	53	295	135	798	20	1,392	1.7
Roundup	Aug. 12, 1908	86	42	219	147	566	20	1,080	.6
Do	Sept. 19, 1908	31	18	285	180	425	20	959	15
Do	May 8, 1909	73	32	77	132	235	11	560	182
Burgoyne	May 7, 1909	74	19	91	132	213	13	542	226
Roundup	June 20, 1908	53	19	88	158	124	5.9	448	690
Do	June 12, 1909	45	17	55	90	134	7.9	349	957
Burgoyne	June 12, 1909	44	19	42	108	84	7.9	305	957
Melstone	June 12, 1909	39	13	30	75	78	6.9	242	957

[a] Calculated.
[b] At U. S. Geol. Survey gaging station, Harlowton. (See p. 3.)
[c] River frozen.

UTILIZATION OF RAIN AND SURFACE WATERS FOR DOMESTIC AND STOCK SUPPLIES.

STORAGE OF RAIN WATER IN CISTERNS.

By Kirk Bryan.

In rather large areas, in Musselshell and Golden Valley counties, chiefly those underlain by the Bearpaw shale, wells have small yields, have highly mineralized water, or are expensive because of depth. In these localities storage of rain water is likely to prove economical and profitable.

In many parts of the world rain water is collected on roofs and stored in cisterns. In humid regions this system of water supply seems adequate, but the efficacy of the same system in regions of small rainfall seems questionable. However, the value of water increases with aridity, and by economical use small supplies of water can be made to last for a long time. In southern Arizona, for example, cisterns are in use in areas that have less than 10 inches of rainfall. The rainwater is reserved for drinking and cooking, and water for other purposes is obtained from wells and mine shafts.

In Bermuda, India, and other British colonies natural rock surfaces or artificial surfaces constructed for the purpose are used for collecting rain water. These surfaces, known as water catches, are usually on hillsides, and the water is led to cisterns. In Musselshell and Golden Valley counties there are few natural rock surfaces suitable for water catches, and the surface would generally need to be artificially prepared. A smooth hillside should be found which would require little grading and this site covered with a concrete surface leading to a cistern placed at the foot of the slope. The construction of such a surface is simple, and care need be taken only in providing expansion joints, similar to those of concrete highways, and to preventing failure due to weak foundation or heaving by frost. As the surface would bear no weight, the concrete would need to be only 2 to 3 inches thick. A stout fence of woven wire should be built to prevent contamination of the surface by stock and small animals.

A water catch of this type would serve no other purpose than the collection of water. Probably, however, a roof of equal area would be no more expensive to construct, and the inclosures under the roof could be used for storage of wagons and machinery. Most ranches lack adequate space of this sort, and the roof would thus serve a double purpose.

Calculation of the area of a water catch is a complex problem. The size required depends on the total amount of rainfall, its periodicity, and the requirements of the user. In Sandoval County, N. Mex., a shed with a galvanized-iron roof 14 by 20 feet equipped with a gutter and a 500-gallon tank supplied water for 2 men and a saddle horse.

A preliminary calculation based on data from the rainfall station at Billings, Mont., has been made for the year 1921. The mean annual rainfall is 14.17 inches, and as only 11.13 fell in 1921 this was a relatively dry year, though drier years have occurred. In this calculation it was assumed that at least 0.05 inch of rain would be required to wet the roof and cause run-off to the cistern, or the moisture would be lost by evaporation and leakage. The amount of 0.05 inch was subtracted from the rainfall of each day and the remainder was assumed to go into the tank. Another assumption that was made was that the precipitation from November 1 to January 31 fell as snow and did not always melt rapidly enough to cause run-off. This assumption is probably too conservative. A summary of this calculation is presented below. The drainage area covers 100 square feet, and the daily use is 1 gallon. The cistern had 500 gallons of water at the beginning of the season.

Calculation of water available at the end of each month in the year 1921.

Date.	Water shed from 100 square feet of surface.	Water used at the rate of 1 gallon daily.	Water remaining in cistern at each date, assuming 500 gallons at the start.	Remarks.
	Gallons.	*Gallons.*	*Gallons.*	
January 1			500	
January 31	1.9	31	470.9	Precipitation on 1 day; assumed to be used.
February 28	None.	28	442.9	
March 31	14.2	31	426.1	The amounts shown are half the total, of which part fell as snow.
April 30	31.7	30	427.8	
May 31	170.6	31	567.4	
June 30	130.0	30	667.4	
July 31	30.5	31	666.9	
August 31	17.4	31	653.3	
September 30	22.4	30	645.7	
October 31	None.	31	614.7	
November 30	63.5	30	584.7	All snow.
December 31	17.4	31	553.7	Do.

Favorable balance, 53.7 gallons.

The calculation shows that in 1921 a roof of 100 square feet would have supplied 1 gallon daily with a balance of 53.7 gallons at the end of the year. The greatest deficiency at the end of any month would have been 73.9 gallons, but at certain other dates the deficiency would have been slightly larger. There were in the year two periods of drought of 59 days each, and similar longer periods must be expected in drier years. It seems probable, therefore, that storage of 200 gallons for each gallon required daily is necessary. An ordinary ranch requires about the following amounts of water daily:

Daily water requirements of an ordinary ranch.

	Gallons.
Each person	10
Each horse	10
Each cow	12
Each hog or sheep	1

A ranch with 2 persons, 4 horses, 1 cow, and 5 hogs or sheep would require 77 gallons daily. But the absolute necessity is much smaller than this figure, and in periods of shortage about 2 gallons daily is sufficient for each person. The water requirements of stock can not, however, be reduced. Continuous use of 80 gallons would require 8,000 square feet of roof area. A house 30 by 40 feet and a barn 30 by 50 feet will provide 2,700 square feet, and there must be constructed for the special purpose of shedding water a roof 53 by 100 feet, or 5,300 square feet in area. Such a roof is excessive in size, and it will doubtless be cheaper to provide larger storage for a smaller roof.

The foregoing preliminary calculation of the required area is only of value as illustrating the method, and each rancher should make his own estimate, based as far as possible on local experience.

Cisterns may be of various types, and for temporary residences galvanized-iron tanks set on the porch or on a platform outside the kitchen door will be found useful. Concrete cisterns built below ground and fitted with a pump or above ground and fitted with an outlet pipe are the most permanent and satisfactory. Elaborate designs for such cisterns have been prepared by Murdock.[22] A simple cistern is shown in Figure 11. It is designed to receive water directly from a catch. If fed by the gutters of a roof it should be slightly modified at the top. It is 13 feet square and 10 feet high

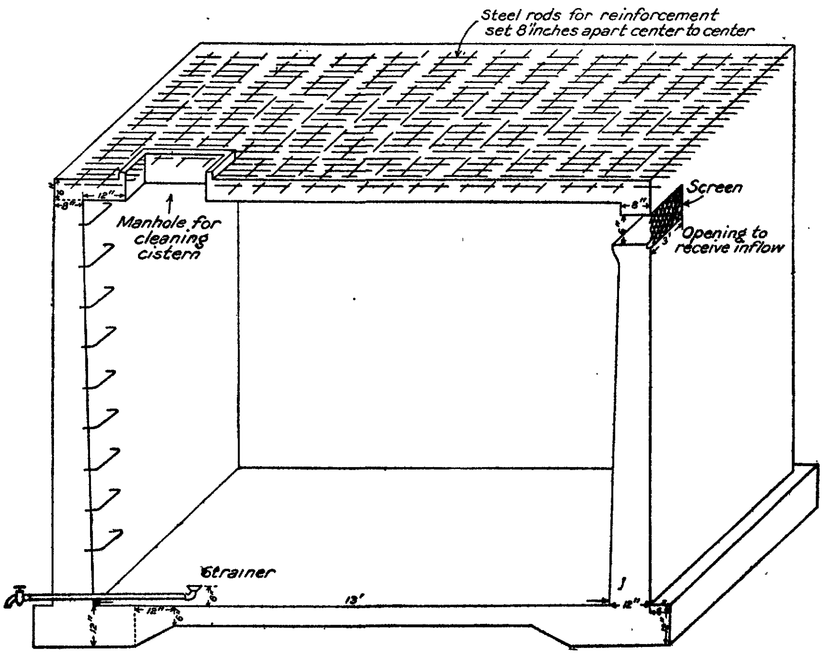

FIGURE 11.—Reinforced-concrete cistern. Designed by A. J. Ellis.

(inside measurements) and has a capacity of about 12,000 gallons. It requires for construction 30.8 cubic yards of concrete, which if made with a mixture of 1 part of cement to 2 of sand and 3 of gravel and if the cistern is plastered inside will require 56 barrels of Portland cement. If the reinforcing rods are spaced 8 inches apart 690 feet of ½-inch rods will be required.

TANKS FOR STORING STOCK WATER.

By G. M. HALL.

Settlers in regions where successful wells are difficult to obtain and springs are very rare, as in the areas where the Colorado and Bearpaw shales lie at the surface, frequently construct "tanks" by damming

[22] Murdock, H. E., The domestic water supply on the farm: Montana Univ. Agr. Exper. Sta. Circ. 66, pp. 89–92, 1917.

small washes. These tanks hold enough water to supply herds of moderate size. Even in hot, dry summers they hold water for a considerable period in spite of the high rate of evaporation.

The rancher selects a small wash or coulee with relatively low sides, and at a point where it narrows a little he constructs a dam. Great care must be used in selecting the proper wash and the best location in it for the dam. If the drainage area is too large, or the fall of the stream at the point too great the dam will not hold and will be swept away by the first heavy rain, the rancher losing not only the dam but also the water. The best way is to watch the washes during storms and note the relative volumes of water and the rate of flow. The wash carrying a fairly large volume should be selected, and the dam should be located at the point where the velocity is small and the surroundings suited for the least amount of embankment.

These tanks have earth dams or embankments made by plowing up the soil and shale above the dam and putting it in place with scoops. The tramping of the animals' hoofs and the dragging of the scoops pack the earth. Great care must be taken to keep trash rocks, roots, sage brush, and greasewood from getting into the dam because, if this precaution is not taken, the water will percolate along these objects, move the fine particles and finally wash out the dam. Generally a spillway should be provided to care for the excess water. This spillway should be riprapped with stones or constructed of concrete. If stone is available it is, of course, much cheaper but not as satisfactory as concrete.

A tank having an area of 10,000 square feet (100 feet square) and averaging 4 feet in depth will hold 300,000 gallons of water. If the bottom is shale it is nearly impervious, and almost the only loss is by evaporation. If two-thirds of the water were lost by evaporation, a liberal estimate, there would be left 100,000 gallons, which would be sufficient to supply 50 head of cattle for 100 days allowing 20 gallons a day per animal, which is also a liberal estimate.

The cost of constructing such a tank is difficult to estimate, as the average rancher would have no expenses except for labor in plowing and scooping the dirt and possibly hauling stone for riprapping. If a concrete spillway is constructed the cost will be higher and will vary with the price of cement at the railroad and the distance it must be hauled.

STORAGE OF ICE.

By G. M. Hall.

In many parts of Montana, where streams or lakes are at hand, the ranchers cut ice and store it in ice houses. The ice is used both as a cooling agent in summer and as a source of water for domestic purposes. The water obtained from ice generally contains less mineral matter than the water from which it froze. In some regions, 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.

PURIFICATION OF SURFACE WATER BY CHLORINATION.

By W. M. Cobleigh.

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 ten 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.

GROUND WATER DESCRIBED BY TOWNSHIPS.

T. 5 N., R. 19 E.

In the southeastern part of T. 5 N., R. 19 E., the Colorado shale lies at the surface except along the Big Coulee, where it is overlain by a mantle of alluvium. (See Pl. I, in pocket.) As shown by the deep well drilled by the Seventy-nine Oil Co., described on page 22, the Colorado shale is here nearly 2,000 feet thick and is very unpromising as a source of water. The Seventy-nine Oil Co. well, in sec. 36 (?), was drilled 2,018 feet and was dry. In sec. 35 the well of G. S. Hill, 2,000 feet deep, yields hard water. A satisfactory water supply might possibly be found in some formation below the Colorado shale, but this is uncertain, and, moreover, drilling to such great depths for water would be impracticable under ordinary conditions. Along the Big Coulee small water supplies can probably be developed by digging shallow wells.

In the rest of the township the Colorado shale is overlain by the Eagle sandstone, which in most places will yield adequate supplies for domestic and farm uses to dug or drilled wells of moderate depths. Along the west margin of the township the Eagle sandstone is overlain by the Claggett shale. Here potable supplies can probably be obtained by drilling through the shale and into the Eagle sandstone.

T. 6 N., R. 19 E.

The part of T. 6 N., R. 19 E., which lies south of Fish Creek is underlain at no great depth by the Eagle sandstone (see Pl. I, in pocket), which generally yields adequate supplies of water for domestic and general farm use to dug or drilled wells of moderate depth. In some places in this part of the township it is overlain by shale of the Claggett formation, which must be drilled through before the sandstone is reached. The well of Henry Thien, in the SE. ¼ sec. 24, drilled to the depth of 90 feet, yields an adequate supply of water that is used for domestic purposes. This supply is probably obtained from the Eagle sandstone.

North of Fish Creek the Claggett formation increases in thickness until, in the second tier of sections from the north, it probably has a thickness of 400 or 500 feet. The Claggett formation is generally unfavorable as a source of water.

In the northern part of the township the Claggett formation is overlain by the Judith River formation, which will probably yield small supplies of water where it is not too thin or too much exposed to drainage.

Musselshell River crosses the northern part of the township in a valley which is here nearly a mile wide. In the valley some water can be obtained from shallow wells ending in the alluvium.

T. 7 N., R. 19 E.

The oldest formation exposed in T. 7 N., R. 19 E., is the Colorado shale, which lies at the surface in several places from sec. 2 to sec. 19. This formation is about 2,000 feet thick and is very unfavorable as a source of water supply. The Eagle sandstone, which lies above the Colorado shale, is at or near the surface throughout most of the northwestern half of the township. (See Pl. I, in pocket.) In most places it yields small supplies of potable water. Two successful wells in sec. 8, one on the property of W. W. Hubbell, the other on the property of James T. Williamson, end in this sandstone at depths of 75 and 90 feet. Both wells are reported to yield hard water. The water from the Hubbell well is used only for stock; that from the Williamson well is used for domestic supply.

In most of the southeastern half of the township the Bearpaw shale is at the surface. This shale does not generally yield potable water, except in some localities to very shallow wells. It is underlain by the Judith River formation, which includes water-bearing sandstones. As indicated on the geologic map (Pl. I), the Judith River formation lies at the surface along the south margin of the township and in a narrow belt extending almost from the northeast to the southwest corner. In parts of the area occupied by the Bearpaw shale the Judith River formation can be reached by drilled wells of moderate depth and may yield potable supplies to such wells.

T. 8 N., R. 19 E.

In most of T. 8 N., R. 19 E., the rock formations dip gently toward the north. In the southern part of the township the Claggett formation is at the surface. This formation is generally unfavorable as a source of water, but it is underlain by the Eagle sandstone, which in many places in the county yields water of satisfactory quality. Near the south line of the township wells of moderate depth will reach the Eagle sandstone, but northward the depth to this sandstone gradually increases until, in the second tier of sections from the south, it is probably about 500 feet. Above the Claggett formation is the Judith River formation, which, as shown in the geologic map (Pl. I), is at the surface in much of the second, third, and fourth tiers of sections from the south. In most of this belt underlain by the Judith River formation it should be possible to obtain water for domestic or stock use, either from dug wells or from drilled wells of moderate depth. Farther north the Bearpaw shale appears above the Judith River formation. This shale, which is unfavorable as a source of water, lies at the surface throughout most of the northern half of the township. Near the margins of the Bearpaw shale area it may be practicable to drill through the shale into the underlying sandstone, but in much of the area the shale is probably a few hundred feet thick. In some places it may be possible to get small supplies of water from very shallow wells in the Bearpaw shale area. In other places it may be necessary to store rain water or surface run-off.

T. 9 N., R. 19 E.

In a large part of T. 9 N., R. 19 E., the Bearpaw shale is at or near the surface (Pl. I), producing unfavorable ground-water conditions. Farther east the Judith River formation, which lies below the Bearpaw shale, comes to the surface and presumably affords better prospects for getting water supplies from wells. In the northwestern part of the township the Lance formation occurs above the Bearpaw shale. It generally includes water-bearing beds. Upland gravelly deposits occur extensively in this township and in some places yield water of fairly satisfactory quality. The dug well of Charles Mahon, in the NE. ¼ sec. 12, is 32 feet deep and yields an adequate supply for farm use, but the water is reported as "hard."

T. 10 N., R. 19 E.

Most of T. 10 N., R. 19 E., is underlain by the Lance formation (Pl. I), which generally yields water. In the southeastern corner the Lance gives way to the underlying Bearpaw shale and in the two northern tiers of sections it gives way to the Bearpaw and older formations. The rock formations are extensively mantled by gravel, which will probably yield water in some places. In section 4 a drilled well, 78 feet deep, on the property of Emma Brewington, yields water reported as "soft" and used by the public school. In the NE. ¼ sec. 22 the dug well of L. O. Helmey is 20 feet deep and yields a supply of water used for farm purposes. In the NE. ¼ sec. 34 the drilled well of Arthur Kalaijin is 105 feet deep and yields good water from a sandstone in the Judith River formation. For an analysis of the water, see page 41.

T. 11 N., R. 19 E.

T. 11 N., R. 19 E., lies in the Big Snowy Mountains (Pl. I) and is largely underlain by Madison limestone and other old rocks. Water can be obtained in some places from the surface gravels.

T. 5 N., R. 20 E.

As shown on the geologic map (Pl. I) most of T. 5 N., R. 20 E., has Colorado shale immediately below the surface. This formation is about 2,000 feet thick and yields only meager supplies of water of very poor quality. Many of the holes drilled into this formation in this section of the State are reported to be entirely dry. The well of Harry D. Barr, in the SW. ¼ sec. 32, ends in the Colorado shale at a depth of 87 feet and yields water of poor quality that is used only for watering stock. Along the Big Coulee small supplies of potable water can probably be obtained from shallow wells ending in alluvium. In parts of the township, especially in the northwest corner and along the east side, Eagle sandstone lies above the Colorado shale. Where this sandstone is sufficiently thick, it will probably yield potable supplies to wells of moderate depths.

T. 6 N., R. 20 E.

In the southern two tiers of sections in T. 6 N., R. 20 E., the Eagle sandstone is at or near the surface (Pl. I) and will probably yield supplies of potable water adequate in quantity for domestic and stock uses. The drilled well of J. H. Fraher in the SW. ¼ sec. 28, which is 103 feet deep, and the drilled well of Charles A. Engel, in the SW. ¼ sec. 32, which is 150 feet deep, both end in this sandstone and yield water for domestic use. The Engel well is reported to yield only 2 gallons a minute, but the yield of the Fraher well is apparently larger. Farther north in the township, as shown in Plate I, younger formations appear above the Eagle sandstone. The Claggett formation, which lies next above the Eagle sandstone, is generally unsatisfactory as a source of water. The well of J. A. Morrow, in the SW. ¼ sec. 8, which is 150 feet deep, evidently ends in this formation. It yields 2 gallons a minute of water which is reported to be soft but salty and which is used for all purposes except drinking. Throughout several sections in the east-central and northern parts of the township the Judith River formation appears above the Claggett formation and presumably introduced more favorable ground-water conditions. Musselshell River crosses the northern part of the township in a valley ranging from about half a mile to somewhat over a mile in width. In the valley there is some water-bearing alluvium.

T. 7 N., R. 20 E.

Most of T. 7 N., R. 20 E., is underlain by the Bearpaw shale (Pl. I), which does not generally yield good water. In the southern part of the township and in the northwest corner the Judith River formation, which generally includes beds of water-bearing sandstone, appears at the surface or near enough to the surface to be reached in drilling. In the northeastern part of the township the Lance formation lies above the Bearpaw shale and is the surface formation throughout about four sections. This formation generally yields water where it is sufficiently thick.

T. 8 N., R. 20 E.

The northeastern part of T. 8 N., R. 20 E., lies in the Woman's Pocket, which is a shale lowland underlain by the Colorado shale and encircled by an escarpment of the Eagle sandstone, which is the formation next above the Colorado shale (Pl. I). This feature has resulted from the upwarping of the formations along a line extending southeastward from the southern part of T. 9 N., R. 20 E., to a point near the south margin of T. 7 N., R. 22 E., and the subsequent erosion of the formation that had been domed up. The Colorado shale, which underlies the Woman's Pocket, is about 2,000 feet thick and in that entire depth it contains little or no water that is fit for use. The Tri-City Oil Co. drilled a well 1,917 feet deep in the NE. ¼ sec. 15. This well started in the Colorado shale and passed into the Kootenai formation at 1,550 feet. No water is reported in the log. The Foster well No. 1, also in the Woman's Pocket, is 1,360 feet deep. It also started in the Colorado shale and ended in the Kootenai formation. A small flow was obtained between the depths of 468 and 475 feet.

In the southwestern part of the township the ground-water conditions are somewhat variable. Along the west side supplies can probably be obtained from the Judith River formation, and in an area of a few square miles in the southeastern part supplies can perhaps be obtained from the Lance formation. Between the Judith River area and the Lance area there is, however, an intervening area of Bearpaw shale which is about as unfavorable as the Colorado shale. In the SW. ¼ sec. 28 Guy Esti drilled into the Bearpaw shale to a depth of 600 feet without success. At a depth of about 100 feet water of bad quality was encountered. This was cased out, and the rest of the hole is reported to have been dry.

T. 9 N., R. 20 E.

The extreme southern part of T. 9 N., R. 20 E., lies in the Woman's Pocket, which is underlain by the Colorado shale (Pl. I). The formations in most of this township dip away from this area of Colorado shale in a general northerly, northwesterly, or northeasterly direction, and successively younger formations appear in these directions.

The north rim of the Woman's Pocket is formed by the Eagle sandstone, which generally yields water where it extends down to the water table. A drilled well, 163 feet deep, on the farm of Resner Thompson, in the SE. ¼ sec. 30, yields a supply of potable water from sandstone, which is probably the Eagle sandstone.

Next comes the Claggett formation, which overlies the Eagle sandstone and occurs at the surface throughout a broad belt in the southern half of the township. The Claggett is generally unfavorable as a source of water, but in the southern part of the area occupied by the Claggett the water-bearing Eagle sandstone can be reached by drilling through the Claggett.

Much of the northern part of the township is underlain by the Judith River formation, which lies above the Claggett formation. In many places in this part of the State it yields small supplies of water that are used for domestic purposes. The drilled well of Charles Kosbob, in sec. 24, is 30 feet deep and apparently ends in the Judith River formation. It yields water which the owner reports to be satisfactory. The well of William Corners, in the NW. ¼ sec. 14, is 116 feet deep and also ends in the Judith River formation. Its water is, however, reported as "bad."

In the northeastern corner of the township Bearpaw shale rests on the Judith River formation. This thick shale is unfavorable as a source of water.

Gravelly deposits are extensively spread over the eroded surfaces of the older formations, especially on the uplands. Where they have considerable thickness and are not too much exposed to drainage, they constitute a promising source of water for dug or even drilled wells. The dug well of F. C. Metzger, in the NE. ¼ sec. 7, is only 9 feet deep and yields an adequate domestic supply. The water comes from the gravel and is reported as "hard."

T. 10 N., R. 20 E.

Not much information was received in regard to the ground-water conditions in T. 10 N., R. 20 E. The Bearpaw shale, which is unfavorable for yielding water, occurs at or near the surface in the southeastern half of the township, but is overlain by the more promising Lance formation farther northwest (Pl. I). Over large parts of this township the older formations are mantled by gravelly deposits, which in places are water-bearing. The well of B. A. Emerton, in the NE. ¼ sec. 14, T. 10 N., R. 20 E., ends in blue clay at a depth of only 12 feet and yields a supply for live stock and household uses. The water-bearing material of this well is probably either the loose surficial part of the Bearpaw shale or alluvium largely derived from shale

T. 11 N., R. 20 E.

T. 11 N., R. 20 E., lies in the Big Snowy Mountains and has conditions similar to those in T. 11 N., R. 19 E. (p. 52).

T. 5 N., R. 21 E.

In most of T. 5 N., R. 21 E., the Eagle sandstone is at the surface or near enough to the surface to be easily reached in drilling (Pl. I). As this sandstone is generally water-bearing there should be comparatively little difficulty in this township in obtaining water supplies for domestic and general farm uses. In the north-central and northeastern parts of the township there is probably a considerable thickness of Claggett shale above the Eagle sandstone. On the farm of Gilbert Stein, in the NW. ¼ sec. 20, a drilled well, 212 feet deep, yields a small supply of potable water.

T. 6 N., R. 21 E.

The valley of Musselshell River extends across the northern part of T. 6 N., R. 20 E., with an average width of about half a mile, and the Big Coulee passes through the southwestern and central parts of the township. Both contain some water-bearing alluvium. The well of H. L. Francis, situated in the Big Coulee, in the NW. ¼ sec. 24, is 25 feet deep and is reported to end in gravelly material that is probably alluvium. It yields water for domestic supply.

In other parts of the township the Eagle sandstone, the Claggett formation, or the Judith River formation is at the surface (Pl. I). The Eagle sandstone is at the surface in certain localities in the southeastern and southwestern parts of the township and can probably be reached in drilling throughout a considerable part of the southern half of the township. It generally yields water that is good enough to be used for domestic and general farm supplies. Throughout much of the township, however, the Claggett formation lies above the Eagle sandstone and has a thickness of a few hundred feet. The Claggett formation does not generally yield satisfactory water supplies. In much of the northern half of the township, on both sides of the river, the Claggett formation is overlain by the Judith River formation, which is more promising as a source of water. The drilled well of A. E. Dale, in the SE. ¼ sec. 6, is 55 feet deep and apparently ends in the Judith River formation. It is reported to yield 4 gallons a minute of hard water which is used for household and stock supplies.

T. 7 N., R. 21 E.

The northeast corner of T. 7 N., R. 21 E., lies in the Woman's Pocket, which is underlain to a depth of about 2,000 feet by Colorado shale, a formation that yields little or no potable water (Pl. I).

Southwest of the Woman's Pocket the formations dip steeply toward the southwest, and hence successively younger formations appear in this direction. In a distance of about a mile one can pass from the Colorado shale over the outcropping edges of the Eagle sandstone, the Claggett formation, the Judith River formation, and the Bearpaw shale, and reach the overlying Lance formation.

In the northwestern part of the township an area of several square miles is underlain by the Lance formation, which contains beds of water-bearing sandstone wherever it is sufficiently thick. This formation apparently supplies the well of A. D. Fitch, in the SW. ¼ sec. 4 (136 feet deep), the well of Mary Sager, in the NE. ¼ sec. 6 (187 feet deep), the well of Charles Smith, in the NE. ¼ sec. 4 (78 feet deep), the well of Erwin Hindle, in the SW. ¼ sec. 10 (79 feet deep), and the well of John Alom, in the W. ½ sec. 4 (138 feet deep). All of these wells furnish adequate supplies for domestic and stock uses. There are also springs of satisfactory water in this vicinity, which apparently issue from the Lance formation.

South of the Lance area is an area underlain by Bearpaw shale. It forms an east-west belt from 2 to 3 miles wide, extending through the middle of the township (Pl. I). As the Bearpaw shale has a thickness of about 1,000 feet, this is obviously a belt in which it is difficult to find water. In the northern part of the belt a well would have to be sunk about a thousand feet to reach the underlying Judith River formation, which generally yields small supplies of potable water. Near the south margin of this belt, however, the Judith River formation can be reached at more moderate depths, and in the southern part of the township it comes to the surface. In parts of the Bearpaw shale area it may be necessary to develop water supplies from very shallow wells or by storing rain water and run-off.

T. 8 N., R. 21 E.

Woman's Pocket extends through T. 8 N., R. 21 E., in a southeasterly direction (Pl. I). It has a width in this township of more than 3 miles. This feature consists of a lowland underlain by the Colorado shale, which in a thickness of about 2,000 feet contains little or no potable water. Below the Colorado shale there may be beds that would furnish water of better quality, but they are at too great depth to be reached by ordinary drilling. On the southwest the Woman's Pocket is bordered by a series of sandstone ledges that range from the Eagle sandstone to the Lance formation. In the extreme southwest corner of the township water supplies can probably be obtained from the Lance formation. On the northeast side of the Woman's Pocket the formations dip more gently and consequently outcrop in wider belts. In going from the Woman's Pocket to the northeast corner of the township one passes successively over the Eagle sandstone, which is generally water-bearing, the Claggett formation, which in most places does not yield satisfactory water supplies, the Judith River formation, which is generally water-bearing, and the Bearpaw shale, which contains little or no potable water. Evidently, therefore, the ground-water conditions change greatly from place to place. In many places, however, where the water-bearing formations are not at the surface they can be reached by drilling to moderate depths. In some localities, especially in the northern part of the township, the rock formations are mantled by a deposit of gravelly material that may yield water to shallow wells. In the Woman's Pocket water supplies must probably be obtained from such gravels, from the loose surficial part of the shale, from alluvial deposits along Currant Creek or Pocket Creek, or by storing the rain water and run-off.

The well of Joseph Bradish, in the NW. ¼ sec. 4, which is 62 feet deep, ends in sandstone that evidently belongs to the Judith River formation. It is pumped by a windmill and is reported to yield an adequate supply of water that is used for domestic and ordinary farm purposes. The well of William Roach, in the SE. ¼ sec. 4, which is 120 feet deep, and the well of J. A. Machino, in the SE. ¼ sec. 12, which is 225 feet deep, both end in shale and yield water that is practically unfit for use. The dug well of J. W. Roach, in sec. 10, which is only 16 feet deep, ends in alluvial deposits and yields water that is used for a general farm supply. In a well drilled by the Tri-City Oil Co., in the SW. ¼ sec. 21, to a depth of 2,145 feet, artesian flows were reported from a sandy limestone between 550 and 570 feet; from a gray sandstone between 1,450 and 1,500 feet; from a hard limestone between 1,605 and 1,608 feet (sulphur water); and from white sand between 1,787 and 1,790 feet (gas with the water).

T. 9 N., R. 21 E.

The rocks underlying T. 9 N., R. 21 E., are warped down, forming a structural trough or syncline, the axis of which passes diagonally across the township from a point near the northwest corner to a point near the southeast corner (Pl. I). The Bearpaw shale lies at or near the surface in most of the township. It forms a belt about 5 miles wide, extending diagonally through the township along the axis of the syncline. On both sides of the belt of Bearpaw shale the underlying Judith River formation comes to the surface, and beyond the Judith River belts the Claggett formation makes its appearance. The southwestern belt of outcropping Claggett passes through the southwest corner of the township; the northeastern belt, however, lies entirely beyond the limits of this township. The only one of these formations that is promising as a source of water is the Judith River formation. Along the margins of the Bearpaw shale area there is a fair prospect of obtaining a supply of potable water from sandstone beds in the underlying Judith River formation by drilling through the shale. Along the axis of the syncline, however, the Bearpaw shale is probably several hundred feet thick, and here drilling to the Judith River would be more expensive and the result more problematical.

Throughout much of the township gravelly deposits rest on the eroded surfaces of the older formations. These deposits will doubtless yield water to shallow wells in some places. Near Twin Coulee the upland gravelly deposits are generally absent, but small supplies may possibly be developed from alluvium in the coulee or from the loose upper part of the shale in low places where the water table is near the surface.

Records were obtained of wells dug or drilled into the Bearpaw shale in secs. 9, 19, 20, 24, 27, 28, and 29. They range from 12 to 160 feet in depth and all yield bad water. A dug well, only 12 feet deep, in the NW. ¼ sec. 27, ends in shale and yields water that is used for live stock. An analysis of this water is given on page 41. Most of the wells in the Bearpaw shale, however, are drilled wells somewhat more than 100 feet deep. As indicated by the geologic map (Pl. I), some of these wells are near the margin of the Bearpaw shale area, and there is a reasonable prospect that they would have obtained potable water if they had been drilled deeper.

The well of Thomas Cantrell, in sec. 9, is 275 feet deep and ends in shale. An analysis of its water is given as No. 2 in the table on page 41. This well is near the axis of the syncline, where the Bearpaw shale may have considerable thickness, and it therefore probably ends in Bearpaw shale. The well of Peter B. Madsen, in the SW. ¼ sec. 24, ends in Bearpaw shale at a depth of 166 feet and yields very bad water. It passes through 10 to 15 feet of gravel and then enters a brownish clay, which gradually changes to blue unweathered shale at about 50 feet.

The well of Roy Tuffley, in sec. 34, which is 36 feet deep, and the well of Edward Seger, in the NW. ¼ sec. 32, which is 98 feet deep, both end in sandstone, evidently belonging to the Judith River formation, and yield water that is used for domestic and general farm supplies.

The well of C. L. Tuffley, in the SW. ¼ sec. 34, which is 76 feet deep, and the well of Mike McMone, in the SE. ¼ sec. 33, which is 168 feet deep, both end in shale of the Claggett formation and both yield water of bad quality.

The well of Walter Valenweider, in the NW. ¼ sec. 20, which is 100 feet deep, ends in shale and yields water of bad quality that is used for livestock. The shale from which this well derives its supply probably belongs to the Judith River formation, although it may be Claggett. As the Judith River formation has a maximum thickness of about 400 feet and as most of its thickness is represented in this locality, it is not unlikely that sandstone may be reached by drilling to a somewhat greater depth.

The well of B. F. Johns, in the NE. ¼ sec. 12, was dug to a depth of 18 feet. It passes through 15 feet of sandy loam and ends in 3 feet of sand and gravel. It yields water that is reported to be satisfactory in quantities adequate for domestic and general farm supplies.

T. 10 N., R. 21 E.

In most of T. 10 N., R. 21 E., the rock formations dip in a general southwestward direction (Pl. I). The Devils Pocket extends into the northeastern part of the township and is underlain by Colorado shale. Southwestward from this area of Colorado shale successively younger formations appear at the surface, consisting of the Eagle sandstone (which generally contains water-bearing beds), the Claggett formation (which as a rule is unpromising as a source of water), the Judith River formation (which in most places contains some water-bearing sandstone), and the Bearpaw shale (which contains little or no potable water). The Judith River formation extends in a broad belt along Cameron Creek. The Bearpaw shale is at or near the surface in most of the western two tiers of sections.

In large parts of the township the older formations are covered by a mantle of gravelly material, which will probably supply water in some places. Water can also in some places be obtained in alluvium of the present valleys. The well of E. E. Moats on the upland in the SE. ¼ sec. 8, is dug to a depth of 42 feet and is reported to pass through "clay, limestone, and coarse gravel." It yields a small supply of water that is regarded as satisfactory for domestic use. In sec. 7 good water is reported to be obtained at a depth of only 15 feet. The well of W. J. Barrett, in the valley in the NE. ¼ sec. 14, is dug to a depth of 22 feet. It is reported to have passed through 6 feet of gravel, 4 feet of sandstone, and 12 feet of hard gray clay. Water was found in the clay, at a depth of 20 feet, which is used for domestic and general farm supplies.

T. 11 N., R. 21 E.

T. 11 N., R. 21 E., lies in or near the Big Snowy Mountains, and only the eastern part of the township was examined. The southeastern part is underlain by Colorado shale, which is about 2,000 feet thick in the southeast corner but gradually thins out toward the west and north, until, in a distance of 2 or 3 miles, it disappears and the underlying Kootenai formation comes to the surface. Most of the township is underlain by rocks that are older than the Kootenai. The Colorado shale contains little or no potable water, except possibly near its base, but the Kootenai formation includes beds of sandstone that are probably water-bearing.

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T. 5 N., R. 22 E.

In the western part of T. 5 N., R. 22 E., the Eagle sandstone is at or near the surface and is likely to yield supplies of water for domestic and general farm uses. In some places shale of the Claggett or Eagle must be drilled through in order to reach water-bearing sandstone. In the eastern part of the township the rock formations dip toward the east, and in going from the center to the eastern border one passes successively over the outcrops of the Claggett formation, the Judith River formation, the Bearpaw shale, and the Lance formation. Much of the eastern part of the township is underlain by the thick Bearpaw shale, which is unpromising as a source of water.

T. 6 N., R. 22 E.

The northern part of T. 6 N., R. 22 E., is crossed by Musselshell River, which occupies a rather wide valley underlain by alluvium that will yield some water (Pl. I). In much of the southwestern and south-central parts of the township the Eagle sandstone, which is relatively favorable as a source of water, lies at the surface or near enough to the surface to be reached in ordinary drilling. In the northwestern and north-central parts of the township the Claggett formation is present above the Eagle sandstone, and in the northwest corner the entire thickness of the Claggett, 400 to 500 feet, overlies the Eagle. The Claggett formation is unpromising as a source of water. Near the east margin of the township the formations dip eastward at a considerable angle, so that, within a distance of only a mile or two, one may pass over the outcropping edges of the entire Judith River formation and Bearpaw shale. The Bearpaw shale is very unfavorable as a source of water, but the prospects of getting a satisfactory supply from the Judith River formation are somewhat better. Along the east margin of the township the Lance formation is at the surface. This formation yields supplies in most places where it is not too thin.

In the SE. ¼ sec. 2, on the property of L. C. Lehfeldt, there is a flowing well 550 feet deep, and in the NE. ¼ sec. 11 there are two flowing wells 250 feet and 500 feet deep, respectively. All three wells probably tap the Eagle sandstone. The water is used for domestic supplies. The analyses (Nos. 5 and 6, on p. 41) show that it is truly soft but rich in sodium sulphate and sodium bicarbonate and also contains some sodium carbonate. Northeast of Lavina a drilled well on the property of William Hendershot, 300 feet deep, yields bad water. A hole southwest of the same town, 300 feet deep, did not strike water. The well of Mrs. O. E. Olcott, in the SE. ¼ sec. 2, was dug in alluvium to a depth of 20 feet and yields an ample supply for domestic purposes.

T. 7 N., R. 22 E.

The Woman's Pocket extends into T. 7 N., R. 22 E., from the northwest corner to a point within about 2 miles of the southern and eastern boundaries (Pl. I). The Woman's Pocket is underlain by Colorado shale, which is here nearly 2,000 feet thick and yields little or no potable water. The portion of the Woman's Pocket that lies in this township has no outlet for its surface water but drains to an intermittent lake near its southeast end. The shale lowland is bordered by an escarpment of Eagle sandstone, beyond which, in going toward the southwest, south, east, or northeast, one passes over the outcropping edges of successively younger formations that dip away from the Woman's Pocket in all these directions. Thus, within the township not only the Colorado shale and Eagle sandstone are exposed but also the Claggett formation, the Judith River formation, and the Bearpaw shale. Both the Claggett formation and the Bearpaw shale are unfavorable as sources of water. An analysis of one sample from the Bearpaw shale (well of L. H. Box, No. 8, on p. 41) indicated a very bad water, unfit for domestic use. Hence, the ground-water conditions in this township are generally unfavorable, except perhaps in small areas underlain by the Judith River formation or the Eagle sandstone. L. H. Box has a small spring in the NW. ¼ sec. 25.

T. 8 N., R. 22 E.

Formations ranging from the Colorado shale, which is the oldest, to the Lance formation, which is the youngest (Pl. I), underlie the area contained in T. 8 N., R. 22 E. The Colorado shale is at the surface over an area of about 2 square miles in the southwestern part of the township, into which the Woman's Pocket extends. The Lance formation is at the surface in a small triangular area in the northeast corner of the township. The formations in general dip toward the northeast, and hence successively younger formations are encountered in that direction. In general the areas underlain by the Colorado shale, the Claggett formation, and the Bearpaw shale have unfavorable ground-water conditions, but the areas underlain by the Eagle sandstone, the Judith River formation, and the Lance formation have somewhat better prospects. A few localities contain surface gravel that may be water-bearing.

In secs. 6 and 8 there are five wells which apparently end in sandstone of the Judith River formation and, with one exception, yield supplies that are regarded as satisfactory. In the SE. ¼ sec. 2, on the property of George Foster, a drilled well, 112 feet deep, ends in shale (probably Bearpaw shale) and yields salty water that is used only for livestock. In the NW. ¼ sec. 18, on the property of William A. Rainford, there is a well 150 feet deep, which ends in shale of the Claggett formation and yields water that is too highly mineralized for use.

T. 9 N., R. 22 E.

The rocks that lie at the surface in T. 9 N., R. 22 E., range in age from the Eagle sandstone to the Lance formation (Pl. I). Consequently the ground-water conditions are variable. The Eagle sandstone is exposed in an anticline that extends southeastward near the northeast corner of the township, and the Lance formation is exposed in a syncline that extends northwestward through the southern part of the township. In most of the township the formations therefore dip toward the southwest. There are fairly good prospects of getting satisfactory wells for domestic use and for stock in the southeastern part of the township, where the Lance formation is at or near the surface, in a belt that runs through the middle of the township and widens out in the northwestern part, where the Judith River formation is at or near the surface, and in an area in the northeastern part of the township, where the Eagle sandstone is at or near the surface. The extensive areas underlain by the Claggett formation and the Bearpaw shale are unfavorable for water supplies, except when it may be practicable to drill through them into an underlying sandstone or where they are overlain by alluvium or terrace gravels. Considerable terrace gravel occurs in a belt extending from the middle of the west side of the township to the middle of the south side.

The E. C. Lewis Oil & Development Co. drilled a hole 445 feet deep in sec. 2 but did not report any water. This drill hole started in the Eagle sandstone and passed into the Colorado shale at 255 feet.

The well of Fred Cram in the NE. ¼ sec. 18, is dug 33 feet deep and apparently ends in sandstone of the Judith River formation. It yields about half a gallon a minute of water that is reported to be hard but is used for domestic and other purposes. In the SW. ¼ sec. 8 there is a drilled well, 200 feet deep, which yields a small amount of water that is reported by the owner to be of fairly satisfactory quality. This water doubtless comes from the Judith River formation. The well of James F. Lynch, in the SE. ¼ sec. 18, was drilled to a depth of 240 feet, the first 60 feet being in yellow clay and the rest in dark shale, evidently belonging to the Bearpaw shale. The only water found in this hole was too salty for use. The well of Peter Madson, in sec. 19, ends at a depth of 166 feet in Bearpaw shale and yields bad water.

T. 10 N., R. 22 E.

Most of the northern part of T. 10 N., R. 22 E., is occupied by the Devils Pocket, a flat lowland underlain by Colorado shale (Pl. I) and nearly surrounded by an escarpment of Eagle sandstone, which dips away from it in all directions. Farther away younger formations overlie the Eagle sandstone. In the Devils Pocket the ground-water conditions are unfavorable because of the great thickness of Colorado shale. Where the Eagle sandstone and Judith River formations are exposed the prospects of obtaining satisfactory wells are much better. In much of the southern part of the township and in a small area in the northeastern part the Claggett formation lies at or near the surface and produces conditions unfavorable for water. Where it lies at the surface a satisfactory supply may perhaps be found by drilling through it into the underlying Eagle sandstone. Surface gravels occur in parts of the township and will probably yield water in some places.

The well of Mrs. M. D. Benedict, in the NW. ¼ sec. 2, which is 72 feet deep; the well of H. J. Griffin, in the SW. ¼ sec. 2, which is 72 feet deep; the well of F. R. Kessen, in the NE. ¼ sec. 2, which is 43 feet deep; and the well of Pearl C. Estep, in the SW. ¼ sec. 28, which is 85 feet deep—all apparently end in the Eagle sandstone and yield adequate supplies of water that is used for domestic purposes. The well of Carl Robison, in the NE. ¼ sec. 20, which is 200 feet deep, ends in sandy shale of the Colorado shale and yields a small supply of water which the owner regards as of fair quality. The well of H. B. Samuels, in the SE. ¼ sec. 2, which is 45 feet deep, ends in terrace gravels and yields a supply of satisfactory water.

T. 11 N., R. 22 E.

In most of T. 11 N., R. 22 E., the formations dip gently toward the south (Pl. I). Thus, the Kootenai formation is at or near the surface in a belt that runs through the northern part of the township. North of this belt older rocks appear. Farther south the Colorado shale is at or near the surface, except near the south boundary, where it is overlain by the Eagle sandstone. The Kootenai formation contains beds of sandstone which will probably yield potable water, but the Colorado shale is unfavorable for water supplies. In the northern part of the area occupied by the Colorado shale it may be practicable to drill through the shale into a sandstone of the Kootenai formation, but in the southern part the shale is about 2,000 feet thick. In a strip of land along the south margin water can probably be obtained from the Eagle sandstone. The uplands of much of the township are covered with terrace gravels, which in some places may yield water to shallow wells.

The well of Herbert Young, in the SW. ¼ sec. 34, which is 76 feet deep, and the well of Charles Dawson, in the SE. ¼ sec. 31 (?), which is 108 feet deep, end in the Eagle sandstone and yield water that is regarded by those who use it as fairly good. The dug well of L. R. Phillips, in the NE. ¼ sec. 28, which is 12 feet deep; a well in the NW. ¼ sec. 22, which is 78 feet deep; the drilled well of C. M. Hellyer, in the NE. ¼ sec. 23, which is 68 feet deep; and the dug well of M. D. Benedict, in the SE. ¼ sec. 33, which is 25 feet deep—all end in Colorado shale and yield bad water. (See analysis No. 10, p. 41.)

T. 5 N., R. 23 E.

The area contained in T. 5 N., R. 23 E., is occupied almost entirely by the Lance formation (Pl. I), which, as a rule, furnishes moderate supplies of fairly satisfactory water. Records were obtained of 7 drilled wells that end in sandstone of the Lance formation. They are situated in secs. 8, 20, 28, and 32, range in depth from 75 to 116 feet, and all yield adequate supplies of water that is used for domestic purposes. However, the well of Carl Martin, in the SW. ¼ sec. 20, which is believed to be in the Lance formation, was drilled to a reported depth of 250 feet without finding more than a very meager supply of water. The dug well of Thomas Smith, in the SW. ¼ sec. 30, is 22 feet deep and yields a satisfactory supply, probably from the Lance. Near the southwest corner of the township the Lance formation is absent, and the underlying Bearpaw shale, which yields very little potable water, lies at the surface.

T. 6 N., R. 23 E.

The northern part of T. 6 N., R. 23 E., is crossed by Musselshell River, which occupies a valley that is underlain by alluvium that yields some water to shallow wells (Pl. I). The rest of the township is underlain by the Lance formation, which in most places yields adequate supplies of potable water to wells of moderate depths.

The well of Guy McCreary, on the upland in the SE. ¼ sec. 14, ends in sandstone of the Lance formation at a depth of 102 feet and is reported to yield water at the rate of 10 gallons a minute. The water is used for domestic and general farm supplies. This well is probably fairly representative of what may be expected in most parts of this township, although the conditions differ from place to place and here and there dry wells or wells yielding bad water are to be expected.

T. 7 N., R. 23 E.

The area contained in T. 7 N., R. 23 E., is underlain by the Lance formation except near the west margin, where the Lance pinches out and the underlying Bearpaw shale is exposed (Pl. I). The Lance formation generally yields potable water to wells of moderate depths, but the Bearpaw shale is unfavorable for water supplies. The dug well of M. Sobstic, in sec. 6, is 100 feet deep and yields an adequate supply of water that is reported to be good. The drilled well of William Hendershot, in sec. 8, is more than 300 feet deep and yields bad water. The drilled well of Rudolph Lehfeldt, in the SW. ¼ sec. 21, is 75 feet deep, and yields water that is reported to be good.

T. 8 N., R. 23 E.

The area included in T. 8 N., R. 23 E., is underlain by the Lance formation except a small part in the southwest corner, where the Lance pinches out and the underlying Bearpaw shale is exposed (Pl. I). In a few square miles in the eastern part of the township the Lance formation is overlain by the Lebo member of the Fort Union formation. Water supplies can probably be obtained in most parts of the township by sinking wells to moderate depths. In the southwest corner, however, where the Bearpaw shale is at the surface, the conditions are unfavorable.

Records were obtained of 8 drilled wells, situated in secs. 5, 10, 24, 28, 30, 32, and 34, which range in depth from 62 feet to 184 feet. Most of these wells yield water that is reported to be soft but otherwise unsatisfactory. Some of the water is used for domestic purposes and some only for stock. The analyses of two samples from this township (Nos. 11 and 12), given on page 41, show rather highly mineralized waters, which, however, are not very hard.

T. 9 N., R. 23 E.

The formations that are present in T. 9 N., R. 23 E., form an anticline, or arch, which extends from a point near the southeast corner of the township to a point near the northwest corner and pitches toward the southeast. Hence the oldest rocks are at the surface in the northwestern part of the township (Pl. I). The formations that are exposed in the township are the Claggett formation, the Judith River formation, the Bearpaw shale, and the Lance formation. The Lance and Judith River formations will yield water supplies that are good enough for use, at least in some places. The Lance is at or near the surface in the southwestern and south-central parts of the township, and the Judith River formation is also exposed over a considerable area (Pl. I). The Bearpaw shale and the Claggett formation are generally unfavorable. In parts of the township it may be feasible to drill through them into an underlying sandstone that may yield satisfactory supplies.

T. 10 N., R. 23 E.

The formations that lie at or near the surface in T. 10 N., R. 23 E., as shown in Plate I, are the Eagle sandstone, which crops out in the northwest corner and near the middle of the west margin; the Claggett formation, which rests upon the Eagle sandstone and is exposed in an irregular belt in the western and northwestern parts of the township; the Judith River formation, which rests on the Claggett formation and crops out in an irregular belt in the western part of the township, just east of the outcrop of the Claggett formation; the

Bearpaw shale, which rests on the Judith River formation and extends through the northeastern, central, and south central parts of the township in a belt having an average width of about 3 miles; and the Lance formation which rests on the Bearpaw shale and crops out in the eastern tier of sections. Usable water can probably be obtained by digging or drilling to moderate depths in most places where the Eagle sandstone, the Judith River formation, or the Lance formation lies at the surface. In the belt in which the Claggett formation lies at the surface it is difficult to get satisfactory wells unless drilling is continued into the underlying Eagle sandstone. In the broad belt in which the Bearpaw shale is exposed the prospects of obtaining satisfactory wells are not good. Near the west margin of this belt it may be practicable to drill through the Bearpaw shale into sandstone of the underlying Judith River formation, but near the east edge of this belt the Bearpaw shale is about a thousand feet thick and the results of deep drilling are more uncertain. It may be possible to obtain water supplies from surface gravels in some localities.

The well of Martin W. Smith in the SW. ¼ sec. 32 is drilled to a depth of 102 feet and ends in sandstone of the Judith River formation. As shown by the analysis (No. 14, p. 41), it yields water which is highly mineralized but which can be used for stock. Mr. Smith's well in the SE. ¼ sec. 32 is 87 feet deep and also ends in sandstone of the Judith River formation. It yields an ample supply of water that is used for domestic and stock purposes. The well of Oscar C. Olson, in the NE. ¼ sec. 10, was drilled to a depth of 113 feet. It passed through 10 feet of gravel, 40 feet of clay, and the rest of the distance through sandstone that probably belongs to the Judith River formation. As shown by analysis No. 13 on page 41, it yields very highly mineralized water. A dug well in the NW. ¼ sec. 10, 30 feet deep, yields an ample supply of potable water from the Judith River formation. The drilled well of Mrs. M. A. McLeod, in the SE. ¼ sec. 12, is 60 feet deep and yields an adequate supply of potable water, probably from the Lance formation.

T. 11 N., R. 23 E.

The formations that are exposed in T. 11 N., R. 23 E., range in age from rocks older than the Kootenai formation to the Bearpaw shale (Pl. I). The Kootenai formation crops out near the northwest corner of the township. The formations dip in general toward the southeast, and hence successively younger formations appear in that direction. In most of the township the Colorado shale lies at or near the surface. It is about 2,000 feet thick along the southeast margin of its outcrop, where it passes beneath the Eagle sandstone. Toward the northwest it decreases in thickness, until it wedges out where the underlying, Kootenai formation appears. The Colorado shale contains only meager supplies of highly mineralized water except possibly near its base. In the northwestern part of the township it may be possible to get more satisfactory water supplies by drilling to the base of the Colorado or into the Kootenai formation, but farther southeast the Colorado shale is so thick that very deep wells would be required to reach the Kootenai, and, moreover, the water in such deep wells might not be good enough for use. The Eagle sandstone, Claggett formation, and Judith River formation crop out in narrow belts, the sandstones of the Eagle and Judith River forming ridges. A few sections in the southeastern part of the township are occupied by the Bearpaw shale, which is unfavorable for water supplies. In most of this area the Bearpaw is a few hundred feet thick, so that rather deep wells would be required to reach the sandstones of the underlying Judith River formation.

T. 5 N., R. 24 E.

The surface formations in T. 5 N., R. 24 E., are the Lance and Fort Union formations except near the southern margin, where in small areas these rocks are covered by Quaternary alluvium or lake beds (Pl. I). On the whole, the ground-water prospects are favorable in this township, although inadequate yields or water of poor quality may be found in the lake beds or in certain strata of the older formations.

The well of William Cramer, in the NW. ¼ sec. 28, was dug to a depth of 50 feet and ends in sandstone which yields a small supply of hard water that is used for domestic purposes. A number of drilled wells in the same neighborhood are reported to be only slightly deeper than Mr. Cramer's well and to yield satisfactory supplies. The well of Otto Sandbock, in the SW. ¼ sec. 28, is dug to a depth of 14 feet and ends in shaly material which yields a small supply. The well of Soren Nelson, in the SW. ¼ sec. 27, is dug to a depth of 24 feet and is reported to yield an ample supply. The water from both wells is used for domestic purposes and is regarded as satisfactory by the users. In other places in the township satisfactory supplies may be developed from seepage springs or by digging shallow wells in low places, the water being supplied either from alluvium or from the upper part of the bedrock.

T. 6 N., R. 24 E.

In the western half of T. 6 N., R. 24 E., the Lance formation is at or near the surface; in the eastern half the Lance is overlain by the Fort Union formation (Pl. I). Throughout the township these formations have a general eastward dip. In some places in the valleys water supplies can probably be developed by digging out seepage springs or by digging shallow wells, and throughout the township the prospects are favorable for getting domestic and stock supplies by drilling to moderate depths. The character of the mineral content of the water of the 13-foot dug well of R. F. Haggerty in the SW. ¼ sec. 8, is shown by analysis No. 15 in the table on page 41. The well is in a coulee, and the water comes from between layers of rock. The water is highly mineralized but is used for domestic supply. The dug well of W. E. Davies, on the upland in the SE. ¼ sec. 18, ends in sandstone at the depth of 40 feet and yields a satisfactory supply for farm use.

T. 7 N., R. 24 E.

The rock formations exposed in T. 7 N., R. 24 E., are the Lance and Fort Union (Pl. I). Both these formations generally yield small supplies of potable water, either in seepage springs or shallow dug wells in valleys or in somewhat deeper drilled wells on higher ground. On the whole, the best wells will probably be obtained in areas underlain by the Lance formation, which contains considerable sandstone, and poorer success is likely to attend drilling in the Lebo shale member of the Fort Union formation, which comprises the lower part of that formation and occurs at the surface over a large part of this township. Even where there is considerable thickness of shale, however, it should be possible to find water by drilling into underlying sandstone. The southeastern part of the township is crossed by Musselshell River, the valley of which contains water-bearing alluvium.

The drilled well of G. B. Sjostrom, in the SE. ¼ sec. 30, which is 76 feet deep, and that of L. V. Toulouse, in the SE. ¼ sec. 6, which is 165 feet deep, both end in sandstone and yield adequate supplies for household use and stock. These wells are probably typical of what will be found in most places in the township.

T. 8 N., R. 24 E.

The formations exposed in T. 8 N., R. 24 E., are the Bearpaw shale, the Lance formation, and the Fort Union formation (Pl. I). In the northern part of the township the formations dip steeply toward the south, in the western and southwestern parts they dip much more gently east and northeast, and in the central and eastern parts they lie nearly level. The Bearpaw shale, which is unfavorable for water supplies, occurs at the surface in only a small area in the northern tier of sections. In the rest of the township the wells will penetrate the Lance or the Fort Union and will commonly find water-bearing sandstones before reaching the underlying Bearpaw shale. The Lance formation consists of alternating beds of sandstone and shale. The Lebo shale member of the Fort Union formation, which rests on the Lance, consists chiefly of dark shale but includes a few thin beds of sandstone. The upper part of the Fort Union formation exposed in this township consists chiefly of sandstone but includes beds of shale.

Many small springs occur in the valleys, principally in the valley of Horsethief Creek, which flows eastward through the middle of the township. The well of J. N. Bricker, in the SW. ¼ sec. 2, is drilled 155 feet deep and yields an adequate supply of water reported as "good." (For analysis see No. 16, p. 41.) The well of G. Hoadley, in the SE. ¼ sec. 4, is drilled 108 feet deep and yields an adequate supply which is used on the farm and is reported as "good." The well of James F. Riley, in the SW. ¼ of the same section, is drilled 80 feet deep and yields a small supply of water which is used for the household but is reported as "hard and soda." Water can probably be obtained by digging shallow wells in the valleys or by drilling to moderate depths in most places that are underlain by the Lance or Fort Union formations.

T. 9 N., R. 24 E.

The ground-water conditions in most of T. 9 N., R. 24 E., seem to be rather unfavorable. There is some uncertainty as to the actual geologic conditions. Several sections in the southwestern part of the township are underlain by the Bearpaw shale, which is unfavorable for water supplies (Pl. I). Farther northeast the Bearpaw shale is overlain by the Lance formation, which generally yields water that can be used for domestic supplies. Much of the northern, eastern, and central parts of the township, however, lie in a basin that is only imperfectly drained by Willow Creek, which flows through it. This basin contains Mason Lake, a permanent body of water, at its south end, and two smaller intermittent lakes or alkali flats along its southwest margin. The strata have here been warped downward, and this downwarp has probably produced the basin and its poorly drained condition. The basin is underlain by stream and lake deposits consisting largely of clay, and the Lebo shale member of the Fort Union formation may underlie the stream and lake deposits. In this basin attempts to develop water supplies by sinking wells have not been very successful.

The well of Mary Berrigan, near the center of sec. 10, was drilled to a depth of 300 feet and ends in shale that yields water which is too salty for use. The well of J. B. Brant, in the NW. ¼ sec. 2, was drilled to a depth of 160 feet and ends in sandstone, which yields 2 gallons a minute of water that is used for stock. The well of William Schnell, in the SW. ¼ sec. 4, was sunk to a depth of 32 feet and ends in gravelly alluvium. It yields an ample supply of water for domestic use and for stock.

T. 10 N., R. 24 E.

Most of T. 10 N., R. 24 E., is underlain by the Lance formation, which here has a general southward dip (Pl. I). It includes considerable sandstone, which in most places yields small supplies of fairly satisfactory water. Older formations come to the surface in the northeast and northwest corners of the township. The southern part of the township lies in the Mason Lake basin and is apparently mantled by alluvium.

The well of Albert Lipke, in the SW. ¼ sec. 8, which was dug to a depth of 41 feet and ends in sandstone, is reported to yield soft water that is used for domestic supply and for stock. The well of Arthur Smirl, in the NW. ¼ sec. 18, which was drilled to a depth of 90 feet and ends in sandstone, is reported to yield a large supply. The well of Neal Hoffman, in the SW. ¼ sec. 4, which was drilled to a depth of 100 feet and ends in sandstone, yields relatively soft water, as shown by analysis No. 17 (p. 41). The well of Frank Liess, in the SE. ¼ sec. 29, which was drilled to a depth of 169 feet and ends in sandstone, also yields relatively soft water which is, however, somewhat mineralized, as shown by analysis No. 18 (p. 41). The well of C. Labart, in the SE. ¼ sec. 32, was drilled to a depth of 93 feet and ends in sandy shale of somewhat uncertain correlation. It yields water that is not excessively hard but very rich in sodium sulphate. (See analysis No. 19, p. 41). The water from all these wells is used for domestic supplies.

T. 11 N., R. 24 E.

The formations that are exposed in T. 11 N., R. 24 E., range in age from the Kootenai to the Lance (Pl. I). They are warped up in the northeastern part of the township and warped down in the southwestern or south-central part. The Kootenai formation comes to the surface in the upwarped part, and the Lance is found in the downwarped part. On account of the variety in rock formations in the township the ground-water conditions are variable. Wells sunk into the Kootenai formation will probably find supplies of potable water. The Colorado shale, which rests on the Kootenai formation and underlies considerable areas in the eastern and northern parts of the township, is a thick formation that is very unfavorable for water supplies. Near the outcrops of the Kootenai formation, however, the Colorado thins out, and wells might be drilled through the shale into a sandstone at the base of the Colorado or in the Kootenai. In an area of several square miles in the south-central and southwestern parts of the township, in which the Lance formation occurs, wells can probably be obtained at moderate depths. Between the area underlain by the Colorado shale and the area underlain by the Lance formation the beds have steep dips; consequently they are exposed in only narrow belts, and the ground-water conditions change radically within very short distances. In some localities water may be found in surface gravels.

The well of W. H. Kaercher, in the SW. ¼ sec. 4, was drilled to a depth of 96 feet and ends in sandstone, which apparently belongs to the Kootenai formation. It yields an ample supply of satisfactory water that is used for the household and for stock. The analysis of this water (No. 20 in the table on p. 41) shows that, although it is moderately hard, it is exceptionally low in sodium sulphate, as compared with the other waters of this area. The well of C. B. Graves, in the SW. ¼ sec. 28, which was drilled to a depth of 97 feet and ends in sandstone of the Lance formation, yields a very small supply of water that is reported to be soft and otherwise satisfactory. The table on page 41 includes the analysis (No. 21) of water from a spring in the NW. ¼ sec. 8. This water resembles that from the Kaercher well in being moderately hard but exceptionally low in sodium sulphate and in total dissolved solids, as compared with the other waters from this area that were analyzed.

Several deep wells that were drilled in the Devils Basin in this township in search for oil give information in regard to the deep-seated water horizons. (See p. 28.)

T. 5 N., R. 25 E.

In T. 5 N., R. 25 E., the Lance and Fort Union formations lie at the surface, except in small areas where they are overlain by alluvium (Pl. I). The Lance formation lies at the surface in most of the southern third of the township. It consists chiefly of sandstone, which will doubtless yield water. Farther north the Lance formation is overlain by the Lebo shale member of the Fort Union formation, which consists largely of olive-green to drab shale that is less promising for water supplies. In the northern half of the township beds of the Fort Union formation, consisting of sandstone, shale, and coal, are exposed above the Lebo shale member. The sandstone beds predominate and form prominent cliffs or rim rocks. In most places they will probably supply fairly satisfactory water to wells of moderate depths. The formations in this township dip gently toward the northeast.

T. 6 N., R. 25 E.

The rocks that crop out in T. 6 N., R. 25 E., belong wholly to the upper part of the Fort Union formation (Pl. I) and consist of beds of sandstone, shale, and coal, which dip gently toward the northeast. The sandstones generally yield small supplies of potable water to shallow wells dug in the valleys or to somewhat deeper drilled wells in other parts of the township.

T. 7 N., R. 25 E.

The Fort Union formation lies at the surface throughout T. 7 N., R. 25 E., except in a small area at the mouth of Goulding Creek, where the underlying Lance formation is exposed, and in the valley of Musselshell River, where the rocks are covered by alluvium. The Fort Union formation consists of beds of sandstone, shale, and coal, the sandstone predominating, except in the basal part of the formation, which is known as the Lebo shale member and which crops out in the western part of the township on both sides of the Musselshell valley. Even the Lebo shale member, however, contains considerable sandstone. Water supplies for domestic and stock use can probably be obtained by sinking shallow wells in the valleys or by drilling to sandstone beds in other parts of the township.

The well of H. B. Hersey, in the NW. ¼ sec. 18, was drilled to a depth of 355 feet and ends in a gravelly bed, which furnishes an ample supply of water that is used for the household and is reported to be soft but somewhat "alkaline." A spring occurs in Hay Coulee, in sec. 26, and seepage springs also occur along Halfbreed and Goulding creeks.

T. 8 N., R. 25 E.

The formation that lies at the surface in the northern part of T. 8 N., R. 25 E., is believed to be the Lance (Pl. I). Farther south the Fort Union formation lies at the surface. Both formations consist mainly of beds of sandstone and shale, but the Fort Union also contains beds of coal. The strata are warped downward to form a trough, or syncline, the axis of which crosses the township from northwest to southeast in the southern part of the township. Throughout the township water supplies for domestic use and for stock can probably be obtained by drilling wells to beds of sandstone.

The drilled well of Jack Davies, in the SE. ¼ sec. 28, which is 50 feet deep; the drilled well of Corliss Fairchild, in the NE. ¼ sec. 32, which is 103 feet deep; and the drilled well of the Roundup Coal Mining Co., in the SW. ¼ sec. 14, which is 250 feet deep, are probably typical of what may be expected from drilled wells in this township. All these wells end in sandstone of the Fort Union formation and yield ample supplies. The Davies well is reported to have been tested at 25 gallons a minute and the Roundup Coal Mining Co. well at 40 gallons a minute. The water from the last-named well is used in steam boilers and is regarded as satisfactory for that purpose. The water from the Fairchild well is reported to be soft and that from the Davies well to be medium hard. The drilled well of James White, in the SW. ¼ sec. 6, which is 190 feet deep, is reported to yield an adequate supply of satisfactory water. It doubtless ends in the Lance formation.

The southeastern part of the township is crossed by Musselshell River, the valley of which is underlain by water-bearing alluvium. In 1923 the public supply for the city of Roundup was obtained from a well 8 by 16 feet in cross section and about 35 feet deep, which is supplied by gravelly alluvium in the valley of Musselshell

River, two 7-inch drilled wells, 150 and 200 feet deep, that pass through sandstone of the Fort Union formation, and two infiltration tunnels, 450 and 500 feet long, that consist of 12-inch and 15-inch tile laid in the alluvial gravel. (See pp. 14, 17.) The water is lifted by an electrically driven two-stage horizontal centrifugal pump that has a capacity of 600 to 800 gallons a minute and is installed about 17 feet below the surface. This pump delivers the water to two reservoirs on high ground—one constructed of concrete and having a capacity of 1,000,000 gallons, the other constructed of masonry and having a capacity of 110,000 gallons. An old steam-driven duplex pump is held in reserve for emergencies. The water table fluctuates somewhat but is commonly about 15 feet below the surface. The consumption of water ranges from 500,000 to 800,000 gallons a day. In September, 1923, the drawdown was reported to be only about 2 feet, but in dry years the entire system will barely yield 800,000 gallons a day.

T. 9 N., R. 25 E.

In most of T. 9 N., R. 25 E., the Lance or Fort Union formation is at the surface (Pl. I). These formations consist of alternating beds of sandstone and shale. Water can generally be obtained by digging shallow wells in the low valleys or by drilling to beds of sandstone at moderate depths in other parts of the township. A little of the northwestern and west-central parts of the township lies in the Mason Lake basin, where the older formations are concealed beneath the more recent stream or lake deposits. Under this basin there appears to be a considerable thickness of shale, which is likely to yield poor water. The Lance formation also seems to contain more poor water in this township than is usual. (See analysis on p. 41.) As a rule, the shallow wells seem to yield better water than the deeper wells.

The well of Chris Jensvold, in the SW. ¼ sec. 6, is 93 feet deep and ends in sandstone. It yields an adequate supply of water that is used for domestic purposes and is regarded satisfactory. The well of W. C. Abstem, in the SW. ¼ sec. 22, which is 107 feet deep, and the well of R. J. Shelden, in the SW. ¼ sec. 28, which is 150 feet deep, yield salty water that is used only for stock. The well of Swanson & Reid, in the NE. ¼ sec. 19, which is in the lowland flat of the Mason Lake basin, is 200 feet deep and ends in shale. The well of A. D. Hamilton, in the NW. ¼ sec. 21, is 182 feet deep and also ends in shale. The water in both wells is very highly mineralized, as shown by the analyses on page 41, but the Swanson & Reid well is used for watering stock.

T. 10 N., R. 25 E.

The northern part of T. 10 N., R. 25 E., lies in the so-called Devils Basin and is a flat lowland underlain by Colorado shale (Pl. I), which is unfavorable for water supplies and which probably ranges in thickness in this township from a few hundred feet to fully 2,000 feet along the edge of the lowland where it passes beneath the Eagle sandstone. In going southwestward from the Devils Basin one passes in succession over the outcropping edges of the Eagle sandstone, the Claggett formation, the Judith River formation, the Bearpaw shale, the Lance formation, and possibly the Fort Union formation. The Eagle sandstone, the sandstone of the Judith River formation, and the rim rock of the Lance formation form a series of three parallel escarpments. The southwestern part of the township is underlain by the Lance or the Fort Union formation, which may yield supplies of potable water. Between the lowland of the Devils Basin and the upland underlain by the Lance formation is a belt, only about a mile wide, across which the geology and hence the ground-water conditions change greatly within short distances. Much of the upland is mantled with gravel, which may yield water in some places.

Three dry holes drilled into the Colorado shale were found in this township—one in the NE. ¼ sec. 10 on the property of John H. Sheldon, which is 69 feet deep, and two in the SW. ¼ sec. 23, on the property of Bert Anderson, which are respectively 152 and 156 feet deep. The well of Mrs. Sadie West, in the NW. ¼ sec. 26, which is 160 feet deep, and the well of J. C. West, in the NE. ¼ sec. 26, which is 112 feet deep, both end in Eagle sandstone and yield adequate supplies that are used for the households and for stock.

T. 11 N., R. 25 E.

Nearly all of T. 11 N., R. 25 E., lies in the Devils Basin, a flat lowland which is for the most part underlain by Colorado shale (Pl. I). The strata have a general eastward dip. At one place along the west side of the township the Kootenai formation, which underlies the Colorado shale, comes to the surface, and in the eastern part the Colorado shale is overlain by the Eagle sandstone, which in turn is overlain by the Claggett formation. The Colorado shale is unfavorable as a source of water supply. Where it passes beneath the Eagle sandstone in the eastern part of the township it is about 2,000 feet thick, but it becomes thinner toward the west and pinches out in the area where the underlying Kootenai formation comes to the surface. Water-bearing sandstones occur near the base of the Colorado shale and in the Kootenai formation, and near the outcrop of the Kootenai these may be reached by drilling through the Colorado shale. The water near the base of the Colorado shale is highly mineralized. In most of the township the water-bearing sandstones lie too deep to be reached except by very expensive drilling. Supplies can perhaps be obtained in some localities from very shallow sources, such as alluvial deposits or the loose upper part of the shale, but in some parts of the township it may be necessary to store rain water in cisterns for domestic use and to impound storm waters in earth reservoirs for stock. In the east-central and southeastern parts of the township, where the Eagle sandstone is present above the Colorado shale, adequate supplies for households and for stock can probably be obtained from wells that end in this formation.

Data were obtained in regard to five holes that were drilled and one that was dug into the Colorado shale in this township. A hole in the SW. ¼ sec. 9, on the property of Fred Sadler, and one in the NW. ¼ sec. 10, on the property of B. L. Wood, were drilled to a depth of 300 feet and ended in shale without finding any water. The well of Clarence Wood, in the NE. ¼ sec. 20, which was drilled to a depth of 60 feet, ends in shale and furnishes a small supply of bad water that is used only for stock. The well of Lidel Bros., in the SW. ¼ sec. 2, was drilled to a depth of 131 feet and yields water which is used for a domestic supply as well as for stock. The well of Donald Perrin, in the SE. ¼ sec. 34, was dug to a depth of 15 feet in the Colorado shale and yields water that is too highly mineralized for domestic use but is given to stock. (For an analysis of this water see No. 26 in the table on p. 41.) The Spokane-Roundup Oil Co. drilled a well, 1,510 feet deep, in the NE. ¼ sec. 9, and obtained a flow of highly mineralized water from the "First Cat Creek sand" at 1,500 to 1,510 feet.

Data were also obtained in regard to five wells in this township that are supplied from the Eagle sandstone. The well of August Meyer, in the NE. ¼ sec. 13, which is 70 feet deep; a well in the SE. ¼ sec. 12. which is 90 feet deep; and the well of Kirk Stanton, in the SE. ¼ sec. 23, which is 212 feet deep—all end in Eagle sandstone and yield water that is reported to be satisfactory and is used for domestic supplies as well as for stock. Two wells have also been drilled into the Eagle sandstone by Fred Harvey, in sec. 14, one of which is 140 feet deep and the other 167 feet deep. The analysis of the water from the 167-foot well (No. 25 in the table on p. 41) shows that this water is very hard and otherwise mineralized, although not as highly mineralized as some of the water that is used in this area for drinking and other domestic purposes.

T. 5 N., R. 26 E.

T. 5 N., R. 26 E., is drained southward by Razor Creek and its tributaries (Pl. I). The gray sandstone and shale of the Lance formation crop out in the southern tier of sections and some distance up Razor and West Razor creeks. North of these beds and overlying them the olive-green and drab shale and coarse yellowish sandstone of the Lebo shale member of the Fort Union formation crop out in an irregular belt from less than one-fourth of a mile to nearly 1½ miles wide. Above this shale and sandstone lies the upper part of the Fort Union, extending over more than half of the township. It consists of beds of sandstone, shale, and coal, of which the sandstone is the most prominent. The strata dip gently toward the north in all parts of the township. The township contains few springs, but wells for domestic use and for stock can probably be obtained in most relatively low places by drilling to moderate depths.

T. 6 N., R. 26 E.

T. 6 N., R. 26 E., lies west of the Bull Mountains proper and comprises a portion of a partly dissected plateau of nearly horizontal sandstones and shales of the Fort Union formation (Pl. I). The Yellowstone-Musselshell divide swings across the township from the southwest corner to the middle of the eastern boundary. Water supplies for domestic use and for stock can be obtained in some of the coulees by digging shallow wells and doubtless in other parts of the township by drilling to moderate depths into sandstone beds.

T. 7 N., R. 26 E.

All the rocks in T. 7 N., R. 26 E., belong to the upper part of the Fort Union formation (Pl. I), of which about 1,000 feet of strata is exposed. The formation consists of beds of sandstone, clay, shale, and coal, in which the buff to yellowish-gray sandstone is predominant. The structure is simple. A synclinal trough that has gently dipping sides extends northwest and southeast across the township, its axis coinciding with the main ridge between Halfbreed and Parrott creeks. The maximum dips in the township are not over 2°.

The only running water in the township is found north of sec. 33, in Halfbreed Creek, whose principal source is the "Big Spring," in sec. 21. A smaller spring was noted in sec. 25. Water can be obtained at comparatively shallow depths almost anywhere in the valleys by drilling into the underlying beds of sandstone.

T. 8 N., R. 26 E.

Beds of the Lance formation, of the Lebo shale member, and of the upper part of the Fort Union formation crop out in T. 8 N., R. 26 E. (Pl. I). The gray sandstone and clay shale of the Lance formation crop out over parts of secs. 4, 5, and 6 and are overlain by the somber shale and coarse yellow sandstone of the Lebo shale member, which is 200 to 300 feet thick. This member crops out over most of the area north of Musselshell River and extends in a narrow strip south of the river across part of sec. 10 and secs. 11 and 12. The upper or coal-bearing part of the Fort Union underlies nearly all the southern two-thirds of the township and consists of beds of sandstone, clay, shale, and coal, of which the buff to yellowish-gray sandstone is predominant, though in beds which are extremely variable in thickness and which locally give way to sandy shale or clay. The total thickness of the strata exposed is about 1,800 feet. The main synclinal axis of the Bull Mountains crosses the township in a southeast direction from sec. 30 to sec. 33. North of this axis the dips are low and somewhat irregular. There are a few springs in the southern part of the township. Water for domestic use and for stock can doubtless be obtained in low places by sinking wells to moderate depths. Supplies can also be obtained from the alluvium in the Musselshell Valley. The city of Roundup, just west of this township, obtains most of its public water supply from alluvium (p. 72).

T. 9 N., R. 26 E.

In most of T. 9 N., R. 26 E., the Lebo shale member of the Fort Union formation is at the surface (Pl. I). Where this member crops out in the Musselshell Valley, just south of this township, it is 200 to 300 feet thick and consists of somber shale and coarse yellow sandstone. In many parts of this township it is doubtless much thinner or it gives way to the underlying Lance formation, which also consists of sandstone and shale.

In general in this township wells will probably find supplies for domestic use and for stock from sandstones at moderate depths. If in any locality considerable shale is encountered which does not yield water that is good enough for use, the water should be cased off and drilling should be continued in search for a satisfactory water-bearing sandstone. There are several successful dug wells in the township that are only 10 to 20 feet deep. There are also a few drilled wells. The well of C. E. Campbell, in the NE. ¼ sec. 24, is 180 feet deep and is pumped by an engine, which, however, pumps the well empty. The water from this well is used for drinking and other purposes on the farm but is not entirely satisfactory.

T. 10 N., R. 26 E.

The rock formations underlying T. 10 N., R. 26 E., are warped in such a way as to produce variable geologic and ground-water conditions (Pl. I). In the upwarped areas along the west margin and in the east-central part of the township the Colorado shale, about 2,000 feet thick, is at the surface and produces very unfavorable ground-water conditions. Bordering the two areas of Colorado shale and extending between them is a considerable tract in which the Eagle sandstone is present above the Colorado shale and the ground-water conditions are more favorable. On each side of this tract the Eagle sandstone is overlain by the Claggett formation, which consists almost entirely of unproductive shale. Here there is some prospect of getting potable supplies by drilling through the Claggett formation into the Eagle sandstone. Near the south margin of the township the beds dip rather steeply toward the south, and hence the Claggett formation passes beneath the surface and successively younger formations appear. These younger formations are the Judith River formation, which contains some water-bearing sandstone; the Bearpaw shale, which contains little or no potable water; and the Lance formation, which generally includes water-bearing sandstones.

The dug well of A. L. Chapman, near the east margin of sec. 18, ends in Eagle sandstone at a depth of 51 feet and yields a small supply of water that is used for domestic and stock purposes. The drilled well of W. D. Stanton, in the NW. ¼ sec. 16, apparently ends in the same formation but yields very hard, highly mineralized water that is fit only for stock, as is shown by analysis No. 30, on page 41. The well of the Ohio Oil Co., in sec. 24, 2,450 feet deep, was started in the Colorado shale and passed through the "First Cat Creek sand" from 1,665 to 1,690 feet. There was water in the sand, but it did not overflow.

T. 11 N., R. 26 E.

In most of T. 11 N., R. 26 E., the Claggett formation is at the surface (Pl. I). In the northwestern part of the township and also in the southwest corner the Claggett pinches out and gives way to the underlying Eagle sandstone. In the northwest corner the Eagle sandstone in turn disappears, and the underlying Colorado shale comes to the surface. As a rule the Eagle sandstone yields supplies for domestic and stock use, but in some places its water is highly mineralized, like that of the shale formations above and below it. The Claggett formation and the Colorado shale are both unpromising for water supplies. The Colorado shale in this township is probably about 2,000 feet thick. The Claggett formation, however, is nowhere more than a few hundred feet thick, and near the outcrops of the Eagle sandstone it is quite thin. Hence, in the large area in which the Claggett formation is at the surface there is some prospect of finding a supply by drilling through the shale of this formation into the Eagle sandstone.

T. 6 N., R. 27 E.

T. 6 N., R. 27 E., lies in the Bull Mountains and has a rugged topography. The rocks exposed in the township belong to the Fort Union formation (Pl. I) and consist of beds of sandstone, shale, and coal. The beds of sandstone are the most prominent, but they are very irregular in thickness and locally they disappear, giving place to shale. The total thickness of strata exposed in the township is about 1,000 feet. The strata appear to be almost horizontal. There are several good springs in the township. Water supplies for domestic use and for stock can probably be developed in low places by sinking wells into underlying beds of sandstone.

T. 7 N., R. 27 E.

In T. 7 N., R. 27 E., a series of rocks about 1,200 feet in total thickness is exposed. These rocks belong wholly to the Fort Union formation (Pl. I) and consist of beds of sandstone, shale, and coal. Buff to yellowish-gray sandstones are predominant and form steep bluffs or scarps along the valley walls and at the edges of the high mesas. In the northern and central parts of the township the beds dip gently toward the southwest, but in the high mesas in the southwestern part they are practically horizontal. There are several shallow wells in the township, and supplies for domestic use and for stock can probably be obtained in most places by sinking wells into underlying sandstones. A dug well, 32 feet deep, ending in alluvial gravel, in the NE. ¼ sec. 20, on the property of Samuel James, yields an ample quantity of water that is used for a farm supply. The water is considered good by those who use it.

T. 8 N., R. 27 E.

The northern part of T. 8 N., R. 27 E., is crossed by Musselshell River, which occupies a rather wide valley underlain by water-bearing alluvium (Pl. I). The somber shale and coarse yellow sandstone, which make up the Lebo shale member of the Fort Union formation, crop out over the area north of Musselshell River and in a narrow strip south of its flood plain. Above these rocks lie the sandstones and shales of the upper part of the Fort Union formation, which are at the surface in nearly all of the township south of the river. The outcropping beds have a total thickness of about 1,600 feet and dip very gently toward the south. Water supplies for domestic use and for stock can probably be obtained in most places by sinking wells to moderate depths. If shale is encountered that yields poor water it should be cased off, and the drilling should be continued with a view to finding a more satisfactory water-bearing sandstone. The drilled well of George D. Mills, in sec. 4, is 60 feet deep and yields an adequate quantity of water that is used for a general farm supply.

T. 9 N., R. 27 E.

The surface rocks of T. 9 N., R. 27 E., belong to the Fort Union formation (Pl. I). The Lebo shale member, which forms the lower part of this formation, is exposed in the western and southwestern parts and consists of about 200 feet of olive-drab sandy shale and shaly sandstone that contains a prominent carbonaceous zone near the middle. The portion of the Fort Union formation above the Lebo, consisting of yellowish-gray sandstone and shale, lies at the surface in the greater part of the township. Many of the sandstone beds are lenticular, in places attaining a thickness as great as 75 feet but within a short distance giving place to soft sandy shale.

Water supplies for domestic use and for stock can generally be obtained from the sandstone beds by sinking relatively shallow wells in the valleys or somewhat deeper wells on higher ground. The dug well of M. R. Powers, in the NE. ¼ sec. 2, is 14 feet deep and ends in gravelly deposits that yield water for domestic use and for stock. The well of Earl Parker, in the SW. ¼ sec. 30, is drilled in rock to a depth of 140 feet and furnishes a small supply of water for household use and for stock.

The water from the 75-foot sandstone well of Theodore Coble, in the SW. ¼ sec. 32, is also used for a domestic supply and for stock, but the analysis (No. 31, p. 41) shows that it is very rich in sodium sulphate.

T. 10 N., R. 27 E.

The Colorado shale lies at the surface in the vicinity of Willow Creek, in the west-central part of T. 10 N., R. 27 E. (Pl. I). This thick shale is unpromising as a source of water. Outside of the area of outcrop it is overlain by younger formations, which dip away from this area—gently on the north and east but steeply on the south. The Eagle sandstone lies immediately above the Colorado shale and is at the surface in a belt adjacent to the shale area. It is relatively promising as a source of water. East and north of this belt there is an extensive area, including about half the township, in which the Eagle sandstone is overlain by the Claggett—a formation which consists almost entirely of shale that yields little or no potable water. As the Claggett formation is nowhere more than a few hundred feet thick and as it thins out in the direction of the sandstone outcrop, this shale can be drilled through in the hope of finding potable water in the underlying Eagle sandstone. However, the water in the sandstone in some places where the sandstone is overlain by shale may not be good enough for use. Near the south margin of the township the formations change greatly from place to place within short distances, so that within a distance of a mile one may pass from the Claggett formation over the outcrops of the Judith River formation, the Bearpaw shale, and the Lance formation and come upon the rocks of the Fort Union formation.

The bored well of W. A. McGinley, in the NW. ¼ sec. 30, is 10 feet deep and ends in shale. It discharges into a gravity ditch and yields hard salty water that is used for watering stock. (For analysis see No. 32, p. 41.)

The Romar Oil Co. drilled a well, 1,900 feet deep, in the NE. ¼ sec. 20, which started in the Colorado shale and ended in the Kootenai formation. Some water was obtained at 842 feet, and the water from the "First Cat Creek sand," at 1,660 to 1,690 feet, filled the hole but did not overflow. No information was obtainable as to the quality of the water.

T. 11 N., R. 27 E.

In nearly all of T. 11 N., R. 27 E., the Claggett formation, which consists almost entirely of shale that yields little or no potable water, lies at the surface (Pl. I). Throughout the township it is probably a few hundred feet thick. Wells drilled through it will probably find water in the underlying Eagle sandstone, but whether the water in the sandstone is good enough for use where it is covered by the Claggett has not been determined. If potable supplies can not be found in the Eagle sandstone efforts must be made to develop shallow supplies in alluvial or other surface deposits or in the loose surficial part of the Claggett formation, and if these sources are not available, rain and storm run-off can be stored. In a few square miles in the northeastern part of the township the Judith River formation occurs above the Claggett. It generally contains beds of sandstone that yield more or less potable water.

The Northern Pacific well No. 1, which was drilled in search of oil in Howard Coulee, in sec. 13, is 2,165 feet deep, but the log makes no mention of the water conditions.

T. 6 N., R. 28 E.

Throughout T. 6 N., R. 28 E., only the northern half of which lies in Musselshell County, the surface rocks belong to the Fort Union formation (Pl. I) and consist of beds of sandstone, shale, and coal. The sandstone beds will probably yield small or moderate supplies of water for domestic use and for stock to wells that extend below the water table.

T. 7 N., R. 28 E.

The rocks which crop out in T. 7 N., R. 28 E., belong wholly to the upper part of the Fort Union formation (Pl. I). They consist of nearly horizontal beds of sandstone, shale, and coal, of which the sandstone is the most prominent, as it forms the steep scarps or rim rocks of the high mesas and of the valley walls. The total thickness of the rocks that are exposed in the township is about 1,200 feet. There are several springs and shallow wells in the valleys, and additional water supplies for domestic use and for stock can doubtless be developed by digging shallow wells at points in the valleys where the water table is near the surface or by drilling to underlying sandstones.

T. 8 N., R. 28 E.

The rocks that appear at the surface in T. 8 N., R. 28 E., belong wholly to the upper part of the Fort Union formation (Pl. I) and consist of prominent cliff-making buff sandstones, shales, and coal beds. The beds lie practically horizontal. There are several springs and shallow wells in the township. Small to moderate supplies of water can probably be obtained by digging shallow wells at points in the valleys where the water table is near the surface or by drilling somewhat deeper wells to tap underlying sandstones. The drilled well of Mrs. E. B. Wilson, SE. ¼ sec. 10, is 195 feet deep and yields a supply for domestic use and for stock. The water from this well is reported to be rather soft.

T. 9 N., R. 28 E.

The rocks exposed in T. 9 N., R. 28 E., include the upper part of the Bearpaw shale, all of the Lance formation, all of the Lebo shale member of the Fort Union formation, the lower 400 to 500 feet of the upper part of the Fort Union, and Quaternary river deposits that form the terraces and flood plain of Musselshell River (Pl. I). The Bearpaw shale extends across the northern part of the township and has a moderate south dip. It is succeeded by the sandstone and shale of the Lance formation, which occupy a belt about half a mile in width from sec. 6 to sec. 12 and dip somewhat more steeply than the Bearpaw shale. Succeeding the Lance to the south and overlying it is the Lebo shale member of the Fort Union, which also dips steeply toward the south and consequently occupies a strip only a few hundred feet in width. Near the outcrop of the Lebo shale member the succeeding sandstone and shale of the upper part of the Fort Union dip steeply south, but farther south the dip decreases until at the south border of the township the beds are nearly horizontal or dip gently north.

Water supplies for domestic use and for stock can generally be obtained from the alluvium of Musselshell Valley and from the beds of sandstone in the Fort Union and Lance formations. In the Musselshell Valley and in the lower parts of the principal tributary coulees flowing wells may probably be obtained by drilling to moderate depths. In the small area in the northeastern part of the township where the Bearpaw shale is at the surface the ground-water prospects are not good.

T. 10 N., R. 28 E.

In most of T. 10 N., R. 28 E., the surface formation consists of shales that are unpromising for water supplies. In the southern part of the township the shale is the Bearpaw shale and in the northern part it is the shale of the Claggett formation (Pl. I). Just south of Willow Creek is a belt, about 1 to 2 miles wide, in which the Judith River formation is at the surface. This formation lies below the Bearpaw shale and rests on the Claggett formation. In this township it dips gently toward the southeast. It contains considerable sandstone, which is likely to yield small to moderate supplies of water for domestic use and for stock.

The Bearpaw shale ranges in thickness from about a thousand feet along the southern margin of the township to less than a hundred feet near the outcrop of the Judith River formation. This shale is doubtless underlain by the Judith River formation everywhere in this township, but the Judith River formation may not invariably contain satisfactory water where it is deeply buried by the shale. The well of R. L. Hamilton, in the N. ½ sec. 24, in the area of Bearpaw shale, is, however, encouraging in this respect. It passes through 190 feet of shale, which is cased off, and ends in sandstone of the Judith River at a depth of 317 feet. It yields an abundant supply of water that is used for drinking and other purposes on the farm.

The Claggett formation is probably nowhere more than 500 feet thick, and in some places in the western part of the township it may be much thinner. It is underlain by the Eagle sandstone, which is water-bearing but does not everywhere contain water of satisfactory quality.

In some places in the valleys water can be obtained by digging shallow wells, as on the farm of Paulina Slater, in the SW. ¼ sec. 20, where a small supply of water for domestic use was found in sand at a depth of only 10 feet.

T. 11 N., R. 28 E.

In most of T. 11 N., R. 28 E., the Claggett formation, which consists almost entirely of shale that yields little or no potable water, is at the surface (Pl. I). It is, however, underlain, at a depth of a few hundred feet, by the Eagle sandstone—a formation that generally yields water.

In an area of a few square miles in the east-central part of the township and in a strip half a mile to 1½ miles wide along the northern margin of the township, the Claggett formation is overlain by the Judith River formation (Pl. I). The Judith River includes sandstones which in many places yield water for domestic use and for stock.

T. 6 N., R. 29 E.

T. 6 N., R. 29 E., lies east of the Bull Mountains and is crossed by the divide between Musselshell and Yellowstone rivers. Only the northern half of the township lies in Musselshell County. All the rocks that are exposed in the township belong to the upper portion of the Fort Union formation (Pl. I). They consist of beds of sandstone, shale, and coal, of which sandstone is the most prominent, forming the rugged scarps or rim rocks of the valley walls, mesas, and buttes. The beds are practically horizontal.

Water supplies can probably be developed in some places in the valleys by digging shallow wells and more generally by drilling to moderate depths into underlying beds of sandstone. A dug well, only 6½ feet deep, in the SW. ¼ sec. 2, on the property of Rex H. Leberman, yields an adequate supply for the farm. The water level in this well is only 2 feet below the surface.

T. 7 N., R. 29 E.

The rocks in T. 7 N., R. 29 E., belong to the upper part of the Fort Union formation (Pl. I). They consist of beds of sandstone, shale, and coal, of which the sandstones are the most prominent, forming the rugged scarps or rim rocks of the valley walls and mesas. The beds are practically horizontal. Hawk Creek contains running water throughout the year for short distances below the springs at the several ranches. The ground-water conditions are essentially like those in T. 6 N., R. 29 E.

T. 8 N., R. 29 E.

The rocks in T. 8 N., R. 29 E., belong to the upper part of the Fort Union formation (Pl. I). They consist of sandstone, clay, shale, and coal, among which the massive buff to yellowish-gray sandstones are predominant and form the prominent rim rocks of the valley walls. The sandstone beds, however, are very irregular in thickness and are represented locally by grayish thin-bedded sandstone, clay, and shale. The beds in the greater part of the township are practically level, but in the west-central part they are raised into a dome.

The surface of the township is characterized by nearly level uplands interrupted by numerous valleys. A fairly abundant supply of water is furnished by Hawk Creek, which is a perennial stream, and by a few springs near the heads of ravines. Water can be reached by shallow wells at most places in the valley bottoms and doubtless by drilled wells of moderate depths in other places. Artesian water flows from a well directly north of the township, in the SE. ¼ sec. 32, T. 9 N., R. 29 E. The structure indicates that flowing wells may perhaps be obtained also in low places in the northern part of this township.

T. 9 N., R. 29 E.

The rocks that crop out in T. 9 N., R. 29 E., belong to the Bearpaw, Lance, and Fort Union formations (Pl. I). The bluish-gray Bearpaw shale comes to the surface in the northern part of the township. The dip of the beds at the top of the Bearpaw is 15° to 35° S., but farther north—that is, lower in the stratigraphic succession—the dip is less. South of its outcrop the Bearpaw shale is overlain by about 700 feet of sandstone, clay, and shale which make up the Lance formation. These beds dip even more steeply than the underlying Bearpaw, especially in the eastern part of the township, where they are tilted 25° to 40°. The Lance formation is overlain by about 200 feet of dark sandy shale and thin-bedded sandstone of the Lebo shale member of the Fort Union, and this in turn is overlain by the sandstone, shale, and coal of the upper part of the Fort Union. The lower beds of the Fort Union are sharply tilted, like those of the underlying formations. On the south side of the township, however, the beds dip gently north. These facts indicate that the township is crossed by a syncline, whose axis extends nearly east and west across its middle part. The township is drained by Musselshell River and Hawk Creek, which are the only perennial streams.

In the areas underlain by Lance or Fort Union supplies of water can generally be obtained by drilling to moderate depths into beds of sandstone in these formations. In the Musselshell Valley, and in some places in tributary valleys, supplies can also be developed from shallow wells that end either in alluvium or in the surficial part of the bedrock. Records were obtained of several drilled wells, in secs. 18, 20, and 29, that range in depth from 130 to 380 feet and yield ample supplies from sandstones of the Lance or the Fort Union formation. The water from some of these wells is reported to be soft, and this report is corroborated by analysis No. 33 (p. 41), of water from the 235-foot sandstone well of Fred W. Handel, in the NE. ¼ sec. 29. A well drilled to test for coal, in the NW. ¼ sec. 29, to a depth of 265 feet, ends in 50 feet of soft sandstone from which the water rises and overflows at the surface. Another flowing well was obtained in the SE. ¼ sec. 32.

The public waterworks at Musselshell are supplied by an 8-inch well that is 310 feet deep and obtains its water from sandstone. The water level in this well is reported to be 27 feet below the surface. The water is lifted by a pump having a capacity of 3,300 gallons an hour, into a concrete reservoir with a capacity of 50,000 gallons, situated on high ground. The average daily consumption is reported to be about 15,000 gallons, and the maximum about 35,000 gallons.

In the area underlain by Bearpaw shale, in the northern part of the township, the ground-water conditions are unfavorable. The shale probably ranges from several hundred to about a thousand feet in thickness and is likely to be entirely without potable water. The Judith River formation, which generally contains water-bearing sandstone, lies below the Bearpaw shale. In some low places it may be possible to develop water supplies at very shallow depths from the surficial part of the Bearpaw shale or from some overlying gravelly deposits.

T. 10 N., R. 29 E.

In most of T. 10 N., R. 29 E., the surface formation is the Bearpaw shale, which yields little or no potable water. In an irregular belt extending from the northwestern part of the township to the middle of the east margin, the Judith River formation, on which the Bearpaw shale rests, comes to the surface (Pl. I). This formation includes considerable sandstone that is generally water-bearing. On each side of the outcrop of this formation it can be reached by drilling through the overlying shale, but in the southern and northeastern parts of the township the shale is probably several hundred feet thick. In some places in the shale areas it may be possible to develop very shallow water supplies in the surficial part of the shale or in the overlying alluvium.

In the northwest corner of the township the Judith River formation is absent or very thin. Here wells are likely to penetrate shale of the Claggett formation, which yields little or no water. The Claggett formation is a few hundred feet thick and is underlain by the Eagle sandstone, which is generally water-bearing and may contain water good enough for use.

T. 11 N., R. 29 E.

Along Howard Coulee, which crosses the northern part of T. 11 N. R. 29 E., the Claggett formation is at the surface in a belt about a mile to a mile and a half wide (Pl. I). This formation is a few hundred feet thick and consists almost entirely of shale that is unpromising for water supplies. It is underlain by the Eagle sandstone, which may yield water good enough for use.

On each side of this shale belt is a belt of about the same width in which the Judith River formation occurs above the Claggett and lies at the surface. The Judith River formation also lies at the surface in the southwestern part of the township (Pl. I). This formation includes considerable sandstone that generally yields some water.

In most of the southern part of the township the Judith River formation is overlain by the Bearpaw shale, which is unpromising for water supply. This shale is thin near the outcrop of the Judith River formation but probably reaches a thickness of a few hundred feet in the southeast corner.

In some places in the shale areas small supplies can be developed by digging shallow wells into the surficial part of the shale or into alluvium that may mantle the shale.

T. 7 N., R. 30 E.

Only the northwestern part of T. 7 N., R. 30 E., lies in Musselshell County. This is practically the part that drains into Musselshell

River. The rocks that lie at the surface in this township belong to the upper part of the Fort Union formation. They consist of beds of buff to yellowish-gray sandstone, shale, and coal. The beds are practically level, although slight irregularities were observed. There are several springs in the township. The ground-water conditions are similar to those in T. 6 N., R. 29 E., and T. 7 N., R. 29 E.

T. 8 N., R. 30 E.

The surface of T. 8 N., R. 30 E., is a broad upland plateau dissected by Hawk and Carpenter creeks and their tributaries. Hawk Creek contains running water along the greater part of its course in this township throughout the year. Numerous seepage springs flow out along its banks and in the lower course of Coulee Creek, and there is a good spring on Carpenter Creek in lot 10, sec. 1. The rocks that lie at the surface in the township belong to the upper part of the Fort Union formation (Pl. I). They consist of beds of buff to yellowish-gray sandstone, shale, and coal, among which the sandstones are most prominent. The strata dip gently but persistently toward the north throughout the greater part of the township. Additional water supplies can probably be obtained in some places in the valleys by digging shallow wells and more widely throughout the township by drilling to moderate depths into underlying sandstones. In lot 17, sec. 2, a dug well, 10 feet deep, on the property of A. T. Rykken, yields an ample supply of rather hard water which is used for the farm.

T. 9 N., R. 30 E.

In T. 9 N., R. 30 E., the Bearpaw shale, the Lance formation, and the Fort Union formation are exposed (Pl. I). The greater part of the Bearpaw shale is covered by alluvium in the Musselshell Valley and crops out only in small areas along the south side of the valley chiefly in secs. 12, 13, 14, 15, and 16. The valley here is exceptionally wide, probably because of the ease with which the river eroded the Bearpaw shale. The massive yellow sandstone and shale of the Lance formation crop out in a range of rugged hills on the south side of the river. The dark shale and thin-bedded sandstone of the Lebo shale member of the Fort Union formation crop out in a narrow strip south of these hills, and owing to their lack of resistance to weathering they form a valley between the ridges of the more resistant adjacent formations. The Fort Union formation crops out in the southern part of the township. The beds dip to the southwest. In the southern part of the township the dips are slight, but farther north they become steeper and reach the maximum at approximately the outcrop of the Lebo shale, where, in sec. 18, angles as high as 35° were observed.

In the areas underlain by the Lance or the Fort Union formation water supplies can generaly be obtained either from shallow wells in certain places in the valleys or from somewhat deeper drilled wells that reach into underlying sandstones in other places. The Lebo shale member is somewhat less favorable for water supplies than the overlying part of the Fort Union formation and also less favorable than the Lance formation.

In the Musselshell Valley water supplies should be developed so far as possible from shallow wells in the alluvium, because the underlying Bearpaw shale is several hundred feet thick and practically without potable water.

T. 10 N., R. 30 E.

In nearly all of T. 10 N., R. 30 E., the surface formation is the Bearpaw shale (Pl. I), which is very unfavorable for water supplies. Below this shale is the Judith River formation, which comes to the surface in sec. 19. The Judith River formation includes considerable sandstone, which generally yields some potable water, although where it is covered by shale its water may be of poor quality. In most of the township the Bearpaw shale is probably several hundred feet thick, but it thins out near the outcrop of the Judith River formation.

In parts of the southern tier of sections and perhaps in other places the Bearpaw shale is mantled with water-bearing alluvium that will furnish small supplies to shallow wells. In some low places it may also be possible to develop small supplies from the surficial part of the Bearpaw shale itself.

T. 11 N., R. 30 E.

In most of T. 11 N., R. 30 E., the Bearpaw shale is at the surface (Pl. I), and the ground-water conditions are unfavorable, as they are in most of T. 10 N., R. 30 E. In the northern part of the township the strata are arched up gently to form an anticline that trends nearly due east and west. Here the Bearpaw shale has been eroded away, and the underlying Judith River formation, which generally contains beds of water-bearing sandstone, is for the most part at the surface. In small areas along the axis of the anticline the Judith River formation has also been worn away and the underlying Claggett formation, which is unfavorable for water supplies, is at the surface. In the northern part of the township it may be practicable to drill through the Bearpaw shale and to find a water supply in the sandstone of the Judith River formation, but in the southern part this shale is probably several hundred feet thick and the results of deep drilling are more uncertain. The Claggett formation is probably somewhat less than 500 feet thick. It is underlain by the Eagle sandstone, which is generally water-bearing.

One of the softest and best waters in either county that have been analyzed was obtained from a spring on sec. 12 in this township (No. 34, p. 41). This water comes from the Judith River formation.

T. 8 N., R. 31 E.

The rocks that lie at the surface in T. 8 N., R. 31 E., belong to the upper part of the Fort Union formation (Pl. I). They consist of practically horizontal beds of buff to yellowish-gray sandstone, clay shale, and coal, of which the sandstone is the most prominent. There is a good spring on Carpenter Creek, in the NW. ¼ sec. 7, and a few small seepage springs along Alkali Creek and its tributaries. The sandstone beds generally yield water in quantities adequate for domestic use and for stock to shallow wells in low places in the valleys or to somewhat deeper drilled wells in other locations. Several drilled wells in the northern part of the township are between 75 and 160 feet deep and penetrate 25 to 80 feet of sandstone. The drilled well of W. C. Colburn, in the SW. ¼ sec. 22, is 95 feet deep and is reported to end in blue shale, but it yields a small supply of potable water.

T. 9 N., R. 31 E.

Only the western two-thirds of T. 9 N., R. 31 E., lies in Musselshell County (Pl. I). Musselshell River crosses the northwest corner of the township, and its flood plain is half a mile to 1½ miles in width. Several intermittent streams have completely dissected the original upland surface of the township and flow through broad valleys, which in some places are separated from the uplands by rim rocks. The rocks which appear at the surface in the township belong to the Bearpaw, Lance, and Fort Union formations (Pl. I). The Bearpaw shale crops out in a narrow strip along the south side of the flood plain of the Musselshell, by which the greater part of it is concealed. The Lance formation consists of 700 to 800 feet of grayish sandstone and shale with thin streaks of coal near the top. It lies at the surface in most of the northern and central parts of the township. Overlying the Lance formation is the Lebo shale member of the Fort Union formation, which consists of about 200 feet of yellow, brown, and dark sandy shale and thin-bedded sandstone. The upper part of the Fort Union is at the surface in the southern part of the township and consists of beds of sandstone, shale, clay, and coal. All the beds dip southward. The maximum dips range from 15° in the western part of the township to 4° in the eastern part. The line of maximum dips is roughly along the outcrop of the top of the Lance formation. The dip decreases both northward and southward from this line.

In the Musselshell Valley water supplies should, if possible, be obtained from the alluvium, because the underlying Bearpaw shale is about a thousand feet thick and contains little or no potable water. In other parts of the township water supplies can generally be obtained by sinking wells to moderate depths into sandstone beds of the Lance or the Fort Union formation. The Lebo shale member is probably less favorable for water supplies than the overlying part of the Fort Union or the underlying Lance formation because it is more shaly.

There are a few seepage springs along the lower course of Lost Horse Creek, and a good spring rises in the SW. ¼ sec. 12.

T. 10 N., R. 31 E.

The Musselshell Valley, which is here exceptionally wide, extends north-northeastward through T. 10 N., R. 31 E. (Pl. I). It is floored with a deposit of alluvium which in most places will yield water to shallow wells. (See description of the Melstone city well, p. 14.) In the part of the township that lies west of the river valley the surface formation is the Bearpaw shale. This shale is here several hundred feet thick and contains little or no potable water. Below it lies the Judith River formation, which generally contains water-bearing sandstone but does not everywhere furnish water of satisfactory quality. In some places in the area of Bearpaw shale small supplies may be found very near the surface, either in the shale itself or in overlying material.

A hole was drilled at Melstone, in the SW. ¼ sec. 30, to a depth of 517 feet. It ended in shale and obtained no supply except an insignificant seep of bad water. It was not deep enough to test the water-bearing possibilities of the sandstone beds of the underlying Judith River formation.

T. 11 N., R. 31 E.

Musselshell River flows northward through the middle of T. 11 N., R. 31 E. (Pl. I). Only the part of the township west of the river is in Musselshell County. The river valley is underlain by alluvium, which will doubtless yield water in most places to shallow wells.

The anticline in the northern part of T. 11 N., R. 31 E., extends eastward at least as far as the river, bringing to the surface the Judith River formation, which is generally water-bearing, and the underlying Claggett formation, which contains little or no potable water (Pl. I). On both sides of the anticline the Bearpaw shale covers the Judith River formation and lies at the surface. In the northern part of the township it may be practicable to drill through this shale and to find potable water in the sandstone of the Judith River formation. In the southern part of the township the shale is probably several hundred feet thick, and the quality of the water in the underlying sandstone is not known. Where the Claggett formation crops out in the northern part of the township it is probably less than 500 feet thick. It is underlain by Eagle sandstone, which may contain potable water.

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