DEPARTMENT OF THE INTERIOR
HUBERT WORK, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Water-Supply Paper 539

GEOLOGY AND GROUND-WATER RESOURCES

OF

TOWNSEND VALLEY, MONTANA

BY

J. T. PARDEE

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

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

CONTENTS

ILLUSTRATIONS

GEOLOGY AND GROUND-WATER RESOURCES OF TOWNSEND VALLEY, MONTANA

By J. T. Pardee

INTRODUCTION

The area described herein as Townsend Valley is in west central Montana southeast of Helena (fig. 1). It includes the widened part of the valley of Missouri River between Canyon Ferry and Toston and a broad lowland west of Toston drained by Crow Creek and its tributary Warm Spring Creek. This part of Missouri Valley trends from north to northwest, is about 45 miles long, is 16 miles wide in its southern part, and tapers to a point at the northwest. Near its south end it is joined on the west by the lowland that lies west of Toston, an area about 15 miles long and 10 miles in average width, whose longer axis trends north.

Townsend Valley, as described above, is about 60 miles long and 600 square miles in extent. Most of it is agricultural land, and farming and stock raising are the principal industries. Townsend, near the center, is the county seat of Broadwater County and the principal trading point. Toston, Winston, and Radersburg are small towns near the southeastern, northwestern, and southwestern limits of the valley respectively. On Missouri River at Canyon Ferry, near the north end of the valley, are a dam and power plant of the Montana Power Co., which form one of the units in a system that supplies a large part of the State with hydroelectric power and light. The dam impounds a body of water several miles long, known as Lake Sewell, which has a picturesque setting east of the Spokane Hills. Between Winston and Toston the valley is traversed by the Northern Pacific Railway, and between Winston and its extreme southwest limit by the automobile highway known as the Geysers to Glaciers Trail. Both routes pass through Townsend.

FIELD WORK

Within the period July 10 to August 28, 1921, an examination of Townsend Valley was made by the writer to obtain information about the geology and ground water and in particular to determine whether flowing wells could be obtained on the unirrigated "bench lands."

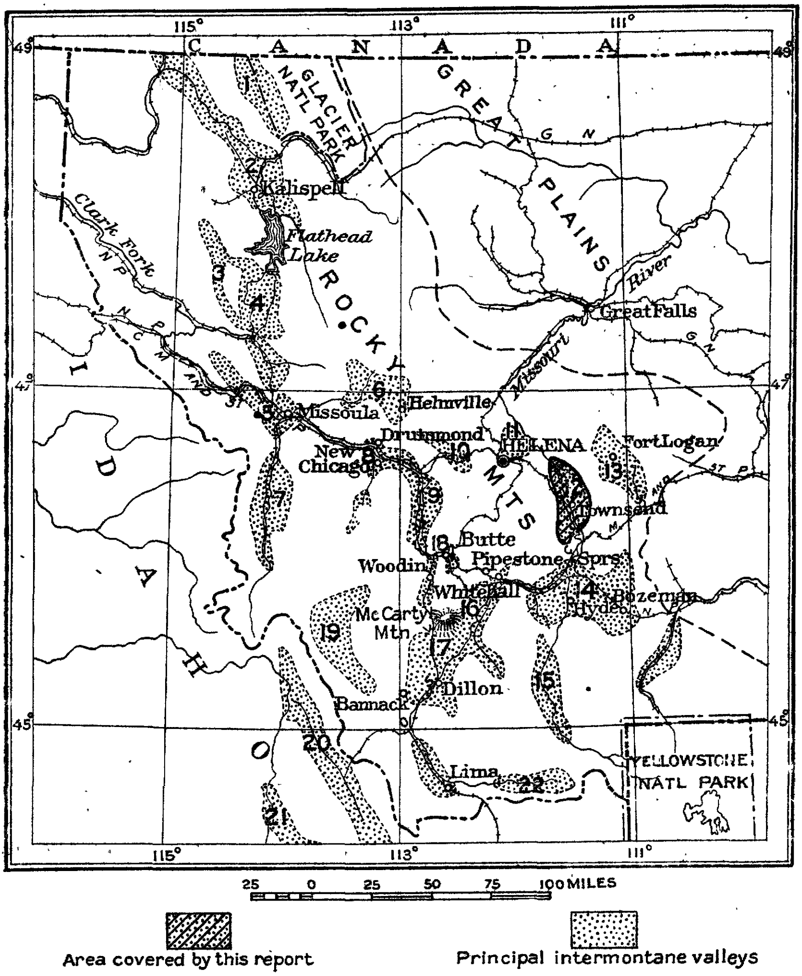


FIGURE 1.—Index map showing location of Townsend Valley. 1, Flathead Valley; 2, Kalispell Valley; 3, Little Bitterroot Valley; 4, Mission Valley; 5, Missoula Valley; 6, Blackfoot Valley; 7, Bitterroot Valley; 8 Flint Creek valley; 9, Deer Lodge Valley; 10, Avon Valley; 11, Prickly Pear Valley; 12, Townsend Valley; 13, Smith River valley; 14, Gallatin Valley; 15, Madison Valley; 16, Jefferson Valley; 17, Beaverhead Valley; 18, Silver Bow Valley; 19, Big Hole Valley; 20, Lemhi Valley; 21 Pahsimeroi Valley; 22, Centennial Valley.

SUMMARY

Townsend Valley is one of several broad basin-like depressions that diversify the mountainous part of southwestern Montana. It includes broad lowlands that adjoin the main streams and moderately elevated "benches" that project from the mountains toward the interior of the valley. The rocks consist of two groups separated by a major unconformity. The older group includes a great thickness of quartzite, shale, and limestone that range in age from pre-Cambrian to Cretaceous and have been severely deformed and deeply eroded. Associated with these beds are intrusive and extrusive igneous rocks, chiefly of Cretaceous or early Tertiary age. These rocks compose the mountains and in the valley form the bedrock upon which the younger rocks lie.

The younger group, which occupies most of the valley, includes beds of Oligocene, Miocene, Pleistocene, and Recent age. The Oligocene beds consist chiefly of light-colored and moderately hardened clay, composed of fine volcanic ash. The Miocene beds are made up chiefly of incoherent sand and gravel. The beds of these two series are moderately deformed, are separated by an unconformity, and yield vertebrate fossils that include the remains of extinct species of horses, camels, and other animals. The Pleistocene deposits consist chiefly of gravel that overspreads the benches and underlies the valley bottoms. In addition the valley contains a small amount of Recent alluvium.

Ground water that is hard but potable and suitable for most ordinary uses is found near the surface in the lowlands and at depths ranging from 100 to 300 feet in the bench lands. In most places the ground water is abundant; its chief source is seepage from the mountain streams, and it is extensively used for domestic and public supplies.

In the valley generally conditions are unfavorable to the occurrence of ground water under sufficient pressure to produce flowing wells.

The valley contains beds of diatomaceous earth, and on the bordering slopes are outcrops of marble that are undeveloped but doubtless are of future value. In one place a small bed of rather poor coal is exposed.

HISTORY OF SETTLEMENT

In 1805 the historic expedition of Lewis and Clark, on its way to the Pacific coast, passed through Townsend Valley. On July 20 of that year Captain Clark, who with a small party was scouting on foot ahead of the expedition, entered the valley near Winston over practically the same route as that now followed by the railroad and the automobile highway. That night Clark and his companions, who were the first white men to enter or see this valley, camped on the river above the mouth of Beaver Creek.[1] The next day, July 21,

[1] Original journals of the Lewis and Clark expedition, 1804–1806, edited by Reuben Gold Thwaites, vol. 2, pp. 254–270, Dodd, Mead & Co., 1904.

Captain Lewis with the main party, coming up the river in boats, reached a point near Canyon Ferry. In his journal of that date Lewis recorded that before him stretched a beautiful and extensive plain lying between high mountains whose summits still showed patches of snow. It took the members of the expedition four days to work their passage upstream as far as the gorge above Toston, During this time they made overnight camps on islands in the river below Confederate and Indian creeks and on the west bank nearly opposite the mouth of Dry Creek. The explorers referred to Beaver Creek as White Earth Creek and named the streams now known as Confederate Creek and Crow Creek, respectively, Whitehouse Creek and Gass Creek, after members of the expedition. In July of the next year, on their return, Sergeant Ordway and 10 men of the expedition again passed through the valley, descending the river in canoes, Lewis and Clark with the remaining members having separated, each taking a new route through this part of the country.

After the departure of Lewis and Clark nothing of importance occurred in Townsend Valley or its neighborhood, so far as known, until 1864, when gold was discovered in gravel on Confederate Creek. Other discoveries followed, including the placers on White Creek and Cave Creek and at Radersburg and many other places, and for several years the region contained a large but fluctuating population engaged chiefly in placer mining.

The gravel along Confederate Creek proved to be the richest ever found in Montana. Some of it yielded as much as $1,000 to the pan,[2] and one season's "clean-up" from the placers on the terrace known as Montana Bar is said to have been 2¼ tons of gold, worth about $900,000.

During the mining period several towns or villages came into existence, of which Diamond City, on Confederate Creek, quickly became the metropolis of the general region and one of the most celebrated boom mining camps in the West. The less prominent settlements included Cavetown, Radersburg, and two small camps on the bench north of Indian Creek that had the suggestive titles Hog'em and Cheat'em. Among the stirring events of that time was a bloody battle near Cavetown in which an organized gang of claim jumpers was badly worsted by the miners.

A decade after their discovery the placers of Confederate Creek had been largely worked out and abandoned, and a few years later placer mining in the neighborhood of Townsend Valley had declined to relatively small proportions. Of the several mining camps Radersburg is the only survivor, and its persistence is due to the dis-

[2] The amount called by the miners "a pan" was usually two ordinary shovelfuls.

covery of metal-bearing lodes in the hills near by. Diamond City has dwindled to a few deserted cabins, and the other camps appear to have vanished completely.

Since the early days of mining the development of agriculture has proceeded steadily in Townsend Valley, and already its products far exceed in aggregate value the tons of gold produced during the earlier and more spectacular period. At first farming consisted chiefly in cutting wild hay from the natural meadows or subirrigated lowlands. Later, with the aid of irrigation, a large part of the valley became cultivated and a wider variety of crops, including grains, were grown. There remained a considerable area, chiefly "bench lands," for which no water was easily available. Until a few years ago hardly any attempt was made to cultivate these lands; they were used chiefly as pastures and runways for stock. However, with the development in recent years of dry-farming methods a large part of these unirrigated lands have been occupied by settlers, whose attempts to cultivate them have met with varying success. A dry period that began in 1917 was so severe in parts of Townsend Valley that several of the dry farmers became literally starved out.

TOPOGRAPHY

PRINCIPAL FEATURES

Townsend Valley is a broad depression about 60 miles long that lies between two moderately high and rugged mountain ranges. The main axis is a curve concave to the west, and therefore the trend of the valley ranges from a little east of north in the southern part to northwest in the northern part. Along most of its eastern or convex side the valley is bordered by the Belt Mountains, which form an unbroken barrier from 2,000 to 4,000 feet above the valley. Two summits of this range, Mount Baldy and Mount Edith, attain an altitude of 9,600 feet above sea level. On the west the middle stretch of the valley is bordered by the similarly elevated Elkhorn Range. Elsewhere the rim is comparatively low. At the northwest, between the Elkhorn Range and the Belt Mountains, it is formed by the Spokane Hills, an uneven divide about 1,000 feet high. Around the southern third of the basin the rim is a wide, low ridge that projects from the Belt Mountains between Sixmile and Sixteenmile creeks west as far as Toston and thence southward and curves around the lowland west of Toston to the south end of the Elkhorn Range.

South of Toston this ridge is cut by a gorge through which Missouri River enters the basin; at the north, between the Spokane Hills and the Belt Mountains, is another gorge through which the river

104142—25——2

escapes. Between the Spokane Hills and the north end of the Elkhorn Range is a low, wide gap occupied by the Northern Pacific Railway and the Geysers to Glaciers Trail. Around the south end of the valley southwest of Toston the rim, though unbroken, is low for a considerable distance. At the extreme south it is crossed by the Geysers to Glaciers Trail.

Townsend Valley is one of several basin-like depressions that occur within the mountain region of western Montana. Its nearest neighbors are on the northwest Prickly Pear Valley, in which the city of Helena is situated, and on the south the large basin known as the Madison-Gallatin or Three Forks Valley. A short distance to the east, across the Belt Mountains, is the valley of Smith River (sometimes called Deep River), and just across the low rim at the southwest is a smaller basin drained by Boulder River. The more distant basins include Jefferson, Beaverhead, and Big Hole valleys, on the upper waters of the Missouri, and Deer Lodge, Avon, Flint Creek, Bitterroot, and Missoula valleys, in the Clark Fork drainage area.

The general altitude of Townsend Valley is between 4,000 and 4,500 feet above the sea. Along Missouri River the altitude ranges from 3,650 to 3,900 feet. From both sides of the river the surface rises gradually toward the mountains, at the foot of which it is from 500 to 1,200 feet higher than at the river.

The most noteworthy surface features of Townsend Valley are gently sloping plains at different levels. Together they occupy more than half of the valley, and most of them are included in four principal sets or groups that occur one above another. The lowest set includes the valley bottoms or lowlands that border the streams. The other three sets are made up of the more or less higher features known as "benches" that occur in the interstream areas and extend for greater or less distances out from the mountains. Commonly the "benches," together with the slopes or escarpments that separate them from one another or from the lowlands, are spoken of collectively as the "bench lands." The lowlands and the bench lands together cover nearly three-fourths of the valley. The remainder of its surface may be classified chiefly as uneven or hilly lands.

BENCHES

A large part of Townsend Valley consists of nearly flat areas that stand at moderate heights above the lowlands adjoining the streams. These are clearly the remnants of ancient river plains, alluvial fans, and possibly other nearly flat surfaces. The higher ones surmount the divides between the principal streams and commonly take the form of flat-topped ridges and plateaus. Most of the lower ones are shelves or terraces. In accordance with the custom of this general region the term "bench" is used herein for convenience to include the features mentioned above and in addition any other remnants of the ancient plains referred to. As thus used the term is practically synonymous with "remnant of an ancient moderately elevated plain." In a belt 2 to 10 miles wide that extends along the east side of the valley from Canyon Ferry to Toston and in a smaller area west of the river that lies north and south of Beaver Creek the benches are separated from one another and from the valley bottoms by abrupt steep slopes or escarpments. Along the west side of the valley between Winston and Indian Creek and in the southern part south of Crow Creek considerable areas are covered by smoothly sloping surfaces that lie above the valley bottoms but are not themselves terraced or otherwise separated into plains at different levels. Presumably they include the different benches as well as the slopes that separate them and therefore are to be classified as bench lands.

Beginning with the highest the different benches described herein are designated No. 1, No. 2, and No. 3. All are remnants of plains approximately parallel to one another and to the valley bottoms which form the fourth and lowest plain of the series. In most places bench No. 3 is less than 50 feet higher than the valley bottoms adjacent to it. Bench No. 2 is generally from 100 to 150 feet above No. 3, and No. 1 from 50 to 100 feet above No. 2.

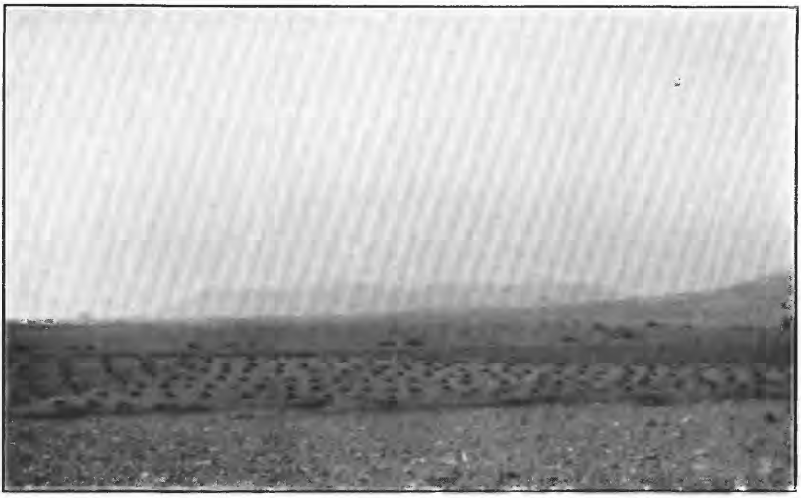
Bench No. 1 (Pl. I, *A*) occupies considerable areas on the east side of the valley south of Deep Creek, where it extends from the mountains well out into the valley. Between Deep Creek and Greyson Creek it is a smooth plain that rises toward the mountains at an average rate of about 70 feet to the mile. Along Greyson Creek it is parallel to and about 150 feet above the valley bottom. Along Deep Creek, however, the valley bottom rises less steeply than the bench and lies from 175 to 250 feet below it. Between Greyson Creek and Dry Creek bench No. 1 is a generally smooth plain rudely parallel to the valley bottoms on either side and from 150 to 200 feet higher. Near the mountains its slope is about 150 feet to the mile. South of Dry Creek the bench rises toward the southeast at the rate of 100 feet or more to the mile and attains an altitude of 500 feet above the bottoms along Sixmile Creek. From Deep Creek north to Gurnett Creek bench No. 1 does not extend far out from the mountains. Its slope ranges from 100 to 200 feet to the mile, and at its extreme upper limit, at the foot of Mount Baldy, it attains altitudes ranging from 5,400 to 5,600 feet. Between Gurnett Creek and Hellgate Creek, a distance of 18 or 20 miles, bench No. 1 is practically limited to a few small areas along Confederate Creek, some of which are well within the mountains and attain slopes ranging from 200 to 300 feet to the mile and an extreme altitude of 6,200 feet. In the north end of the valley adjacent to Cave Creek, bench No. 1 covers a small area about 250 feet above the valley bottoms and exhibits slopes ranging from 100 to 200 feet to the mile, but it is not very distinctly separated from bench No. 2. West of the river on both sides of Beaver Creek bench No. 1 rises westward at the rate of 100 feet to the mile and lies from 200 to 300 feet above the adjacent valley bottoms.

Bench No. 2 covers a considerably greater total area than bench No. 1 and next to the valley bottoms is the most extensive of the plainlike surfaces being considered. East of the river it occupies most of the bench lands between Gurnett Creek and Hellgate Creek. Here it lies from 50 to 100 feet below adjacent areas of bench No. 1 and is from 100 to 150 feet higher than the valley bottoms. South of Gurnett Creek bench No. 2 is composed of terraces that lie in front of bench No. 1 and are from 75 to 100 feet lower. Along Cave Creek this bench occurs at a level about 50 feet below bench No. 1 and consists of narrow terraces or "bars" that have been mined for gold. The famous Montana Bar and other gold-bearing terraces along Confederate Creek are probably parts of bench No. 2. West of the river this bench was not identified unless it is represented by a narrow terrace north of Beaver Creek at a level 200 feet below bench No. 1.

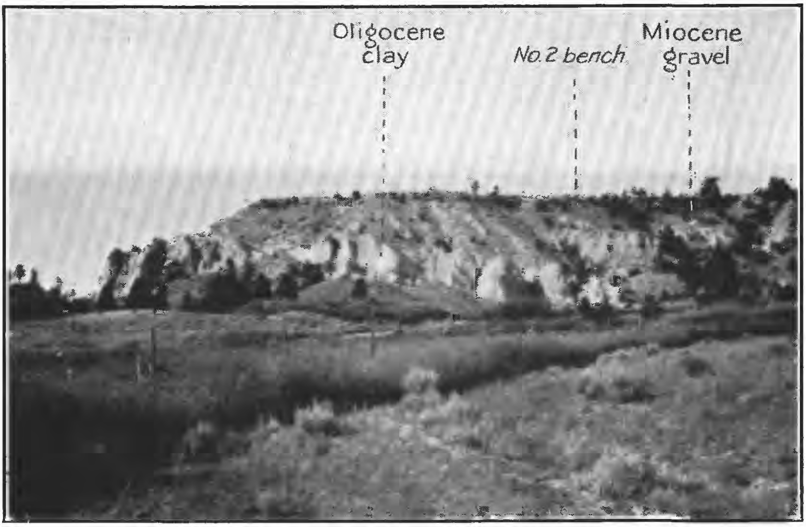
Bench No. 3 occupies comparatively small areas on the east side of the valley between Gurnett Creek and Toston and on the west side of the valley below Beaver Creek. It consists of shelves or terraces a few rods to 3 miles wide that lie in front of bench No. 2 and are from 50 to 100 feet lower than that bench and 30 or 40 feet higher than the valley bottoms.

VALLEY BOTTOMS

Nearly one-third of the area of Townsend Valley consists of low lands that border the streams. Along Missouri River, Crow Creek, and Warm Spring Creek these lands range from 1 to 5 miles in width. Along the other streams they are much narrower. Their slope varies in agreement with the gradients of the streams they border. Those along Missouri River descend northward at an average rate of 5 or 6 feet to the mile. Those along the tributary streams descend eastward or westward, as the case may be, at rates ranging from 40 or 50 to 100 feet or more to the mile. In addition they rise

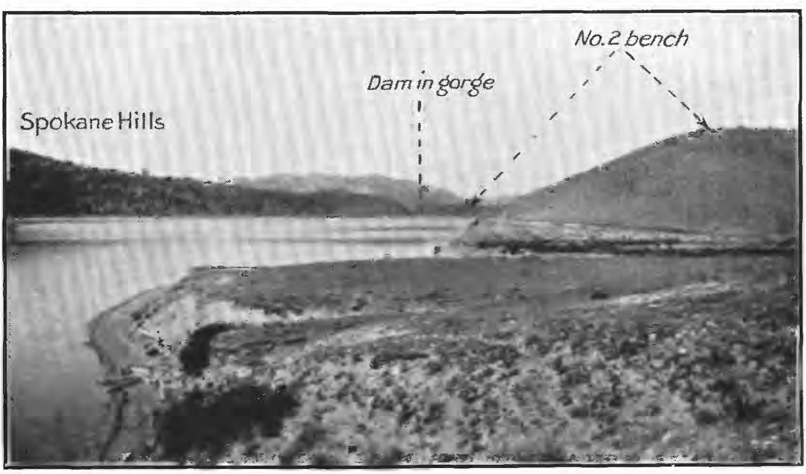


A. BENCH NO. 1



B. OLIGOCENE BEDS TRUNCATED BY BENCH NO. 2

A. MARBLE (CAMBRIAN LIMESTONE) SOUTHWEST OF TOWNSEND



B. LAKE SEWELL AND SPOKANE HILLS

gradually away from the streams. Small parts are subject to overflow, but most of them are above the reach of floods and are therefore hardly to be regarded as flood plains. For convenience the term "valley bottoms," which is in common use in this region, is applied to them herein. Together the valley bottoms compose a continuous plain, the larger part of which forms a belt that extends from one end of the valley to the other and lies considerably to the west of the valley's axis. The remainder of the plain is made up of the narrow branches that extend from the main part up along the side streams to the points at which they issue from the mountains.

HILLY LANDS

On the sides of the valley near the mountains are some areas of rough or hilly lands, the largest of which is a chain of hills that extends from Gurnett Creek to Confederate Creek and rises slightly above bench No. 1. A low rounded hill east of Winston, a rather high and prominent butte south of Radersburg, known as Lone Mountain, and a small but rugged knob southeast of Warm Spring Creek stand well out in the valley. A small but noteworthy feature is the canyon or gorge of Missouri River at Canyon Ferry. Here the river leaves the open valley for a short distance and passes through a narrow trench that is cut from 100 to 200 feet deep across a short spur of the Spokane Hills. If the trench were filled the river would be forced to flow through the open valley and around the end of the spur. The river cut this trench at a time when the valley, as explained on page 43, was obstructed by sediment that since then has been eroded away.

DRAINAGE

Missouri River enters Townsend Valley through a gorge at the southeast above Toston and leaves it through another at the northwest below Canyon Ferry. Between these points its course lies near the west side of the valley, and it receives several tributaries whose sources are in the neighboring mountains. At Toston the altitude of the river is approximately 3,900 feet. Between that point and Canyon Ferry, a distance of 48 miles measured along its somewhat winding course, the stream descends 250 feet, or a little more than 5 feet to the mile.[3] Measurements at Toston during the years 1911 and 1913 to 1915 show the mean annual flow of the river to range from 5,060 to 6,990 cubic feet per second, the average being about 5,800 cubic feet per second. The maximum and minimum flows were 29,800 and 1,100 cubic feet per second.[4]

[3] U. S. Geol. Survey Water-Supply Paper 367, pl. 1, 1914.
[4] U. S. Geol. Survey Water-Supply Papers 306, 356, 386, and 406.

Nine or ten perennial streams issue from the Belt Mountains on the east side of the valley, and two from the Elkhorn Mountains on the west. All of them have steep gradients. Deep Creek, for example, in its course of 12 miles between the mountains and the river, falls 600 feet, as determined by aneroid barometer, or at an average rate of 50 feet to the mile. Similar determinations show the gradient of Crow Creek to be 50 feet to the mile, Greyson Creek 68 feet, Beaver Creek 100 feet or more, and the remaining streams from 50 to 100 feet. Detailed surveys would show that the profiles of these streams are slightly concave upward; their gradients generally become somewhat steeper upstream as the mountains are approached. So far as known these streams have not been systematically measured, but their average aggregate summer flow is estimated[5] to range from 65 to 100 cubic feet per second. About two-thirds of this amount is discharged by the streams on the east side. Deep Creek on the east and Crow Creek on the west are about equal in size and together discharge about half of the total estimated volume. Between the mountains and the river all the streams lose more or less water by seepage into the gravel beneath their beds, and during the dry season they are reduced a little by evaporation but most of them maintain a perennial surface flow to the river.

VEGETATION

The mountains are partly covered with a forest of pine and fir. The valley is practically bare of timber, except for cottonwoods and willows that line the streams and scattering cedars or junipers on some of the steep and sunny slopes. In most places the predominant vegetation is of the bunch-grass type or was until destroyed by overgrazing or plowing. Sagebrush and similar shrubs are plentiful in some areas, and two or more species of cactus or prickly pears are rather widely distributed. Where the land has been overgrazed or abandoned after cultivation the place of the native bunch grass is taken by weeds of comparatively small forage value.

CLIMATE

The Townsend Valley possesses a dry temperate climate characterized by abundant sunshine, bracing atmosphere, cool summer nights, and other attractive features. Records of the United States Weather Bureau at Helena and Three Forks, Mont., which are near the Townsend Valley and have similar climate, show the following averages and extremes:

[5] Holloway, T. L., Townsend, Mont., personal communication.

Climatic data at Helena and Three Forks, Mont.

	Length of record (years)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Normal monthly temperature (°F.):														
Helena	26	20	22	31	42	52	61	67	66	56	44	33	25	43
Three Forks	19	20	24	32	43	53	62	67	65	55	43	30	22	43
Highest temperature on record (°F.):														
Helena	32	63	65	72	86	95	102	103	98	92	84	71	64	103
Three Forks	5	64	67	79	75	95	100	101	97	91	83	68	59	101
Lowest temperature on record (°F.):														
Helena	32	−42	−41	−20	6	22	31	36	29	20	−1	−22	−40	−42
Three Forks	5	−30	−29	−19	10	22	29	32	28	23	−9	−21	−43	−43
Normal rainfall (inches):														
Helena	41	0.93	0.66	0.76	1.06	2.15	3.10	0.84	0.69	1.25	0.90	0.71	0.76	13.81
Three Forks	9	.31	.34	.40	.88	1.62	2.46	1.39	.66	1.44	1.02	.61	.49	11.53
Normal snowfall (inches):														
Helena	29	11.5	8.0	9.6	5.8	1.4	Trace	0	0	0.6	3.1	6.6	8.1	54.7
Three Forks	5	4.0	4.7	2.9	2.7	1.9	0	0	0	.2	2.3	4.9	4.4	28.0
Average number of days with measurable amount of precipitation:														
Helena	28	9	7	8	8	12	12	8	5	7	6	7	8	97
Three Forks	5	4	4	4	5	8	6	4	6	6	6	4	17	74

Average date of last killing frost in spring:
- Helena .... May 7
- Three Forks .... May 29

Average date of first killing frost in autumn:
- Helena .... September 28
- Three Forks .... September 11

As a rule the extremes of heat and cold are easily endurable because of the prevailingly dry atmosphere. In the summer refreshing local showers or thunderstorms of short duration are moderately frequent. Generally these storms cross the valley from west to east, and occasionally they cause washouts or damage by hail. In any one season they may be more frequent in one part of the valley than another, but in the course of time they appear to cover all parts about equally. In the area considered and in the surrounding region as well it is evident without the aid of detailed records that the mountains receive a much greater precipitation than the valleys. A large part of the excess falls as snow during the winter, but in summer also it rains more frequently and copiously on the mountains than in the valley. Within the valley itself the precipitation appears to be greater near the foot of the mountains than elsewhere. This inference is supported by the records, which show that Helena, situated at the foot of a mountain range, receives about 2 inches more precipitation annually than Three Forks, which is near the middle of a wide valley.

So far as dry-farming methods have been developed in Townsend Valley it appears that, other conditions being favorable, the average annual rainfall here is barely sufficient for the growing of profitable crops. Therefore, the cyclic variations in precipitation described below have to a great extent controlled the growth of dry farming in this region. The time covered by the records at Helena may be divided into alternating wet and dry periods, each of which is about nine years long. (See fig. 2, a.) Two successive periods form a cycle that includes the changes through dry to wet and back to dry again. The record begins in 1881 at the beginning of a dry period, comprehends two complete cycles, and ends (1922) in the middle of a dry period that apparently is to form the first half of a new cycle.

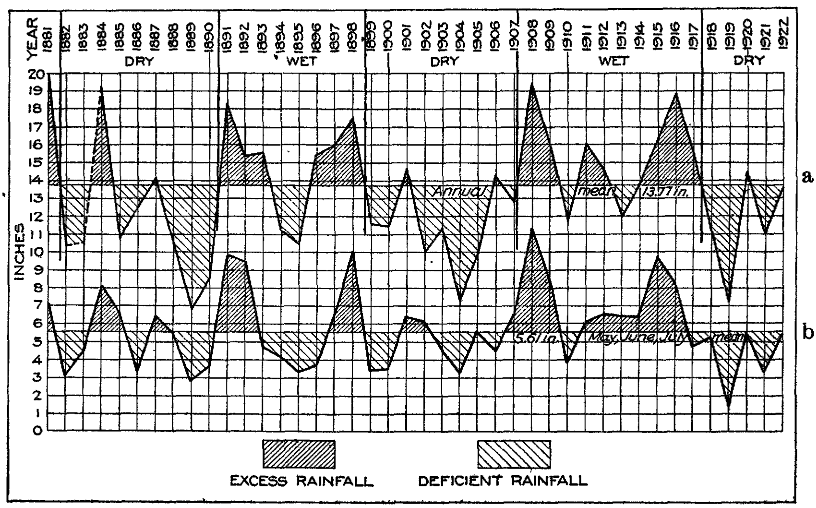


FIGURE 2.—Variations in precipitation at Helena

Within each period there are minor fluctuations that tend to modify but do not alter its dominant character. Among other variations in distribution, the most noticeable is a yearly wet season that may extend through parts or all of May, June, and July but generally reaches its height early in June. (See fig. 2, b.) The recorded rainfall for this season ranges from more than 10 inches to less than 2 inches and averages nearly 6 inches or about two-fifths of the mean yearly total. The seasons that show more than average rainfall and those that show less can be grouped to correspond with the periods of wet and dry years (fig. 2, b.) Exceptions are shown in 1917, when the spring rainfall was less than the average, though the rainfall for the year was more; and in 1913 and some earlier years, when the reverse was true.

Before the latest wet period began dry farming had not been undertaken extensively in Townsend Valley. The results obtained since then indicate that generally fair to good crops may be expected during the wet periods and rather poor crops or none at all during the dry period. The fact that the wet season comes in the spring is favorable, and occasionally the rainfall at that time is enough to overcome the effect of a dry year. Whether the cyclic variations described will continue can not be predicted, owing to the uncertain character of weather changes generally.

GEOLOGY

PRE-TERTIARY ROCKS

STRATIGRAPHY

Rocks ranging in age from pre-Cambrian to late Cretaceous or possibly early Tertiary form the mountains and probably constitute a bedrock floor that extends across Townsend Valley beneath the Tertiary and later deposits. (See fig. 3.) Shale and sandstone belonging to the pre-Cambrian Belt series crop out in the Spokane Hills, in the canyons of Greyson Creek and Deep Creek, and at many other places around the edge of the valley. At the mouth of Deep Creek canyon is an exposure of dark-colored shaly rocks and quartzite that belong to the Greyson shale, a formation named by Walcott[6] from Greyson Creek and of particular interest because it contains pre-Cambrian (Algonkian) fossils. On the ridge between Deep Creek and Greyson Creek this formation has a measured thickness of 3,000 feet. The Spokane shale, so named by Walcott[7] because of its occurrence in the Spokane Hills, near the northwest end of Townsend Valley, lies stratigraphically next above the Greyson shale. In the canyon of White Creek east of the Spokane Hills this formation attains an estimated thickness of 1,500 feet. It consists chiefly of deep-red shale with some layers of green shale and ripple-marked sandstone and varieties of these rocks that may be termed argillite and quartzite.

Rocks of Paleozoic age appear on the lower slopes of the Belt Mountains, on the spur southwest of Townsend, and at other places around the edge of the valley. On the spur southwest of Townsend, west of the area of red Spokane shale, are several conspicuous outcrops of Paleozoic limestone, with which some layers of quartzite and shale are interbedded. The exposures include beds of Cambrian, Devonian, and Carboniferous age that aggregate 4,000 feet or more

[6] Geol. Soc. America Bull., vol. 10, p. 206, 1899.

[7] Idem, p. 207.

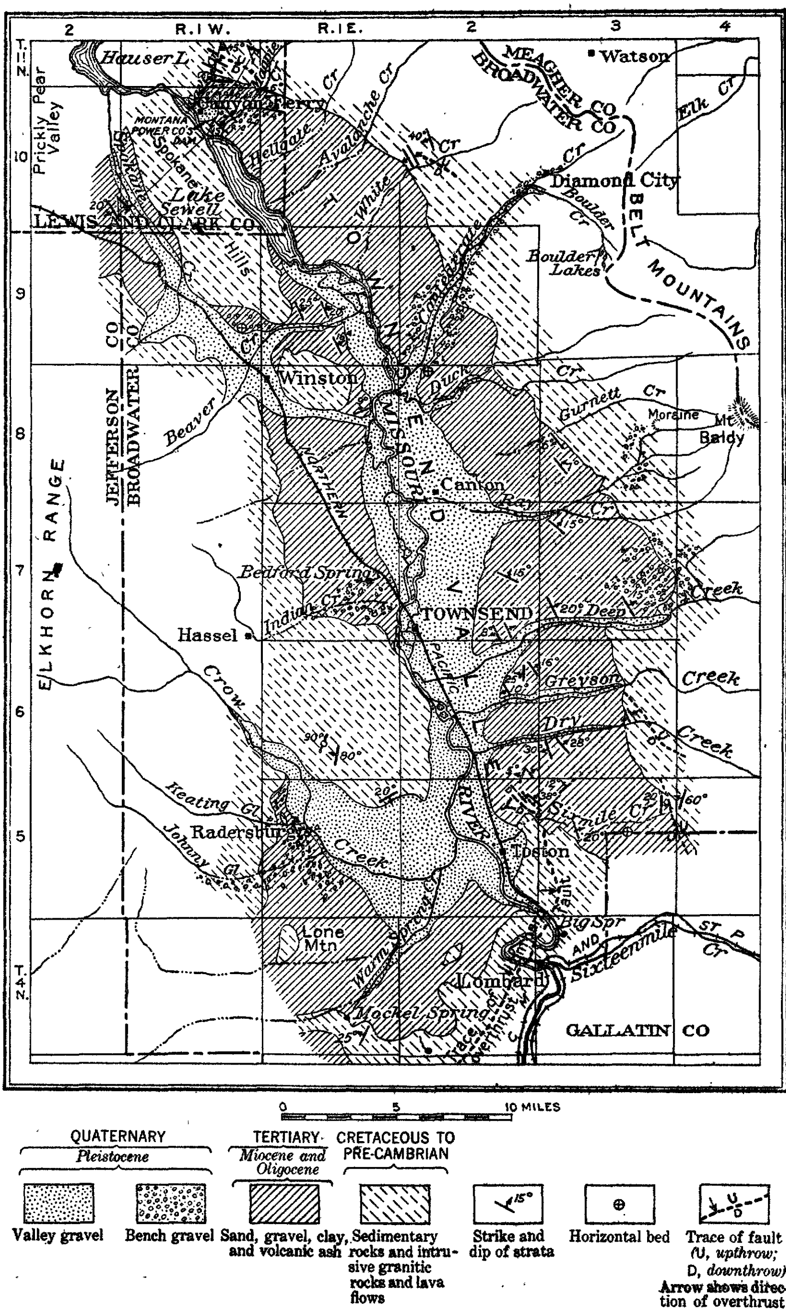


FIGURE 3.—Geologic map of Townsend Valley. *A–A′*, Line of section in Figure 5

in thickness. Altogether five different beds of limestone appear that range from black to light gray or white in color and in many places possess the texture of fine-grained marble (Pl. II, *A*). On the slope facing Townsend Valley north and south of Hellgate Creek the Madison limestone appears in rough and conspicuous outcrops and forms the imposing walls and crags at the mouth of Avalanche Creek canyon.

Rocks of Mesozoic age are rather poorly exposed along the southwest margin of Townsend Valley, in the western part of T. 3 N., R. 1 E. Here they consist chiefly of gray to red sandstone and sandy shale that probably belong to the Ellis (Jurassic) and Kootenai (Cretaceous) formations. In the hill south of Sixmile Creek, about 3 miles east of Toston, variegated shale and sandstone that probably belong to the Kootenai are exposed.

Rocks of igneous origin are associated with the pre-Tertiary sediments at several places around the margin of the valley. The butte south of Radersburg, known as Lone Mountain, and the mountain slopes west of Radersburg and Winston are formed of an andesitic lava of probable Cretaceous age that came to place as flows, tuffs, and breccias. Generally this rock is heavy and dark colored, and commonly it shows small porphyritic crystals of light feldspars or dark hornblende or pyroxene. At several places, including the neighborhoods of Radersburg and Winston, the andesite contains ore deposits that are valuable for gold, silver, and other metals.

Granitic rocks intrusive into the pre-Tertiary sediments occupy a considerable area at the eastern margin of the valley north of Ray Creek. At Canyon Ferry a granitic rock (monzonite or granodiorite) of rather coarse texture and medium-gray color forms a natural foundation and supplies the material for the Montana Power Co.'s dam and power house. A light-gray fine-grained granite or related rock projects as a small ragged knob above the bench lands southeast of Warm Spring Creek. At the mouth of the canyon of Sixmile Creek, east of Toston, is a large dike or sill of a dark greenish-gray crystalline rock (diorite or diabase) that has shared in the deformation of the inclosing sediments and therefore is probably older than the other igneous rocks mentioned.

STRUCTURE

The limestone, shale, and other bedded rocks mentioned in the foregoing paragraphs are everywhere severely deformed. As a result of extensive earth movements the beds, which originally were horizontal, have been bent into arches and troughs, broken and dislocated by faults, and in general made to incline at angles nearer the vertical than the horizontal. (See figs. 4 and 5.) On the mountain spur southwest of Townsend the Spokane shale is bent into an arch whose east side dips moderately toward the valley. The west side is steep and involves a great thickness of beds in addition to the Spokane, including the Cambrian marbles, most of which stand practically on edge. In the Spokane Hills, the type locality of the Spokane shale, the beds are bent into an open trough or syncline. On the east side of the valley beds of Paleozoic limestone exposed at the mouth of Cave Creek canyon are bent into a sharp arch that trends northwest (fig. 5). White Creek cuts through a similar arch, and at many places from that point south to Sixmile Creek steeply tilted beds are exposed. Along the southern edge of the valley southwest of Toston the dips are westward at moderate angles.

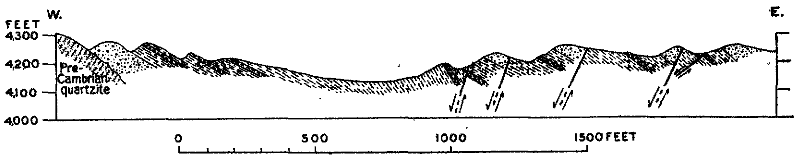


FIGURE 4.—Geologic section north of Sixmile Creek, showing faults in Tertiary sand, clay, and conglomerate

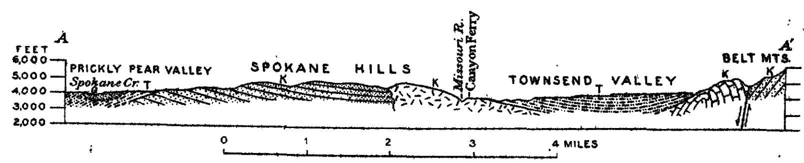


FIGURE 5.—Geologic section near Canyon Ferry, along line *A–A′*, Figure 3. Q. Quaternary; T, Tertiary; K, Cretaceous to pre-Cambrian

A large overthrust fault described by Haynes[3] extends through the hills south of Toston and is well exposed in the gorge of Missouri River at the double horseshoe bend below Lombard. It trends northward, dips moderately to the west, and has been traced for a distance of 13 miles. West of this break the rocks have been thrust upward and over the rocks east of it so far that in one place Belt rocks overlie beds of Cretaceous age. The extensive displacement thus indicated is thought to have occurred at the end of Cretaceous time or the beginning of the Tertiary.

Faults that appear to be normal, or in other words faults whose hanging walls appear to have fallen relative to their footwalls, were observed near the margin of the valley at Cave Creek, White Creek, and Sixmile Creek. Those at Cave Creek and White Creek trend northwest and cause Belt rocks on the east to abut against Paleozoic rocks on the west—that is, the blocks on the valleyward sides of the faults are downthrown (fig. 5). The fault on upper Sixmile Creek

[3] Haynes, W. P., The Lombard overthrust: Jour. Geology, vol. 24, pp. 269–290, 1916.

also shows a downward displacement on the valley side and is otherwise of interest because it cuts both Paleozoic and Tertiary rocks. Presumably these normal faults are all of the same age, and the one last mentioned is evidently Tertiary or later.

TERTIARY ROCKS

LITERATURE

Previous descriptions of the Tertiary rocks of Townsend Valley are limited to reports by Douglass (see Nos. 11, 13, 16, and 18 below), which deal chiefly with the vertebrate fossils, and a report by Jennings (No. 23), which gives a small list of fossil plants and discusses their relations. The Tertiary beds of Townsend Valley, however, are similar to those of the neighboring valleys in the mountainous region of western Montana, and as a guide in studying them the principal reports describing the Tertiary of all these valleys are listed below in the order of their publication:

1. Hayden, F. V., U. S. Geol. and Geog. Survey Terr. Fifth Ann. Rept., p. 33, 1871. Mentions the occurrence of light-colored marl and sandy clay in the valley of Red Rock Creek, southwestern Montana. The beds attain a thickness of several hundred feet and dip 5° W. They were found to contain fossil remains of a small three-toed horse (*Anchitherium*) and a snail (*Helix*).

2. Leidy, Joseph, U. S. Geol. Survey Terr. Rept., vol. 1, pp. 251, 252, 323, 1873. Describes the fossil horse (*Anchitherium agreste*) found by Hayden in the valley of Red Rock Creek. (See No. 1.)

3. Grinnell, G. B., and Dana, E. S., On a new Tertiary lake basin: Am. Jour. Sci., 3d ser., vol. 11, pp. 126–128, 1876. Describes Tertiary beds found in the valley of "Deep Creek" [not the Deep Creek of Townsend Valley but Smith River, sometimes called Deep River] in the neighborhood of Camp Baker [Fort Logan, just east of the area shown on fig. 3]. The beds are horizontal, consist chiefly of homogeneous cream-colored clay, and closely resemble the Miocene beds at Scotts Bluff, near North Platte River in Nebraska. In bluffs about 3 miles southeast of Camp Baker a lower and an upper series of beds are exposed. The lower beds [later named Fort Logan beds] attain a thickness of 200 feet, the upper beds 50 feet, and the two are separated by 6 feet of hard sand with layers of small pebbles. In the lower beds were found a species of rhinoceros, several species of *Oreodon* and *Eporeodon*, a canine tooth, and remains of turtles. In the upper beds the principal fossils found were a species apparently of *Merychyus*, a small horse, and turtles. The authors refer to the lower beds as Miocene and to the upper as Pliocene.

4. Cope, E. D., Descriptions of new Vertebrata from the upper Tertiary formations of the West: Am. Philos. Soc. Proc., vol. 17, 1878. Describes (pp. 219–223) several mammalian species from the upper beds in the Smith River valley which he correlates with the "Loup Fork" of Nebraska. ("Loup Fork" is no longer used as a formation name because in the early reports it was applied to several distinct units.)

5. Cope, E. D., The relations of the horizons of extinct Vertebrata of Europe and North America: U. S. Geol. and Geog. Survey Terr. Bull., vol. 5, pp. 50–52, 1879. The author divides the "Loup Fork" into lower and upper parts which he calls, respectively, "*Ticholeptus* beds" and "*Procamelus* beds"; the former is the upper part of the Tertiary beds on Smith River called Pliocene by Grinnell and Dana. (See No. 3.)

6. Cope, E. D., On two new species of three-toed horses from the upper Miocene, with notes on the fauna of the *Ticholeptus* beds: Am. Philos. Soc. Proc., vol. p. 539, 1886. Gives a list of mammalian species from the "Deep River" [Smith River] "*Ticholeptus* beds," including a deer, a horse, a camel, a mastodon, and several oreodonts.

7. Scott, W. B., Mammalia of the Deep River beds: Am. Philos. Soc. Trans., new ser., vol. 18, pp. 56–185, 6 pls., 1895. Describes the results of the Princeton geologic expedition of 1891 to the valley of "Deep River" [Smith River]. The two formations mentioned by Grinnell and Dana (see No. 3), to which the Deep River beds belong, differ widely in lithologic character, the upper being chiefly incoherent sand and the lower very hard clay. The two are separated by an erosional unconformity that probably represents a considerable lapse of time. In the lower beds (the Miocene of Grinnell and Dana) were found 10 species of extinct mammals which were regarded as indicating a correlation with the John Day formation of Oregon. From the upper beds (the Pliocene of Grinnell and Dana and the "*Ticholeptus* beds" of Cope) several new forms were obtained which, together with those previously reported by Cope, make a total of more than 20 species. The author concludes that these beds form a well-marked unit at the base of the "Loup Fork."

8. Peale, A. C., U. S. Geol. Survey Geol. Atlas, Three Forks folio (No. 24), 1896. Describes the Bozeman "lake beds," which occupy an area of about 900 square miles in the Gallatin and Madison valleys and neighboring basins, and assigns them to the Neocene. The lowest beds are made up of conglomerate containing pebbles of local origin. Above these is a great thickness of rusty or discolored volcanic dust with a few layers of pure-white dust, consisting of sharp, angular fragments of pumiceous glass. The upper beds, especially near the edges of the basins, contain materials derived from the erosion of the older rocks. In the main (Madison-Gallatin) basin the beds dip a few degrees eastward or northeastward. A thickness of 800 to 1,000 feet is shown, and a total thickness of 2,000 to 2,500 feet is indicated. The beds are regarded as having been deposited in fresh-water lakes held in basins that were practically the same as the basin-like valleys of to-day. In the summit of the bluffs along lower Madison River were found immense quantities of opalized wood and fossil bones indicating the *Pliohippus* zone of Marsh.

9. Douglass, Earl, The Neocene lake beds of western Montana, Montana University, 1899. The author points out the general similarity of the Tertiary lake beds in the different valleys of western Montana and observes that the presence of layers of pure volcanic ash is an almost constant feature. In several of the valleys fosils of White River and "Loup Fork" age have been found. In the lower Madison Valley the "Loup Fork beds," to the extent that they are exposed, include rather soft cream-colored clay and fine sand that form an upper part, and clay, sand, and gravel with layers of volcanic ash that form a lower part—the whole about 500 feet thick. The lower part contains fossil wood and the remains of turtles, birds, clams, and fossil mammals, of which several new species are described. In a neighboring area are exposed beds that underlie the "Loup Fork." These aggregate 600 feet in thickness; the upper 400 feet consists of soft light-colored marl, volcanic dust, and fine sand; the remainder (200 feet) is made up principally of rather hard gray and yellow clay, fine sand, volcanic ash, and conglomerate. Fossil snails are found in the upper part, and mammals and turtles in the lower. Both parts are regarded as of White River age.

10. Douglass, Earl, A new species of *Merycochoerus* in Montana: Am. Jour. Sci., 4th ser., vol. 10, pp. 428–438, 1900. Describes the skull of *Merycochoerus laticeps* found in clay bluffs near New Chicago, Mont. A similar form was found in the "Loup Fork beds" of the lower Madison Valley.

11. Douglass, Earl, Fossil Mammalia of the White River beds of Montana: Am. Philos. Soc. Trans., new ser., vol. 20, pp. 238–279, pl. 9, 1902. Describes 18 new species of mammals regarded as Oligocene, the fossils of which, together with the remains of turtles, were found in light-colored clays of the "Pipestone beds" near Whitehall, the "Thompson Creek beds" northwest of Three Forks, the "Blacktail Deer Creek beds" southeast of Dillon, and the "Toston beds" (pp. 242, 243), which are exposed in Townsend Valley a short distance northeast of Toston. Eight species from the "Toston beds" are listed—namely, *Hyaenodon montanus, Oreodon robustum, Eucrotaphus helenae, Colodon cingulatus, Colodon* sp., *Mesohippus, Titanotherium*, and *Caenopus?* The author concludes that the "Thompson Creek beds" apparently belong to the lower White River or *Titanotherium* zone, and that part at least of the "Toston beds" correspond more nearly to the younger *Oreodon* zone. In addition north of Avon in Avon Valley were found bone fragments regarded as Oligocene, and near Drummond in Flint Creek valley fresh-water snails and plant remains in beds resembling the Oligocene and the remains of "Loup Fork" mammals in the overlying beds. The report contains a map (p. 241) showing approximately the areas occupied by the Tertiary beds in southwestern Montana.

12. Matthew, W. D., The fauna of the *Titanotherium* beds at Pipestone Springs, Mont.: Am. Mus. Nat. Hist. Bull., vol. 19, pp. 197–226, 1903. Describes more than 20 species of mammals the remains of which were found in soft reddish-brown to greenish-white clay with cross-bedded sandy layers. Associated with the mammalian fossils are the remains of lizards and tortoises. At this locality the beds mentioned are steeply tilted and lie upon ancient crystalline rocks. Above them stratigraphically are the "*Oreodon* beds," consisting of somewhat harder, less sandy, and more calcareous buff clays in which only a few determinable fossils were found. A lithologic distinction between the lower or "*Titanotherium* beds" and the upper or "*Oreodon* beds" was observed at other places in the neighboring region. The author concludes that the "Pipestone (*Titanotherium*) beds" are at the base of the Oligocene but above the Eocene and are probably of about the same age as the White River beds of Swift Current Creek, Canada.

13. Douglass, Earl, New vertebrates from the Montana Tertiary: Carnegie Mus. Annals, vol. 2, pp. 145–200, pl. 2, 1903. Describes fossil remains representing more than 30 species of mammals, two reptiles, and a fish. Most of the mammalian remains were found in the "Madison Valley beds" south of Three Forks and the "Flint Creek beds" near New Chicago, both of which are regarded as Miocene. Two species from a locality northwest of Three Forks are described as White River Oligocene, four species from beds exposed east of Drummond are regarded doubtfully as upper Oligocene, and his Sage Creek beds near Lima are regarded doubtfully as Eocene. The remains of one of the reptiles came from the White River beds on Pipestone Creek near Whitehall, the other came from "Loup Fork" Miocene in the lower Madison Valley, and the fish was found in the Miocene "Flint Creek beds" near New Chicago. The author introduces the name Fort Logan beds for the lower part of what had previously been called the Deep River beds (Miocene of Grinnell and Dana) and correlated by Scott with the John Day (Oligocene and Miocene) of Oregon. At several places fossil plants were found in the White River beds, and the tracks of birds and ripple marks were observed at that same horizon in the lower Madison Valley. Beds exposed in Townsend Valley east of Winston and regarded as of White River age are estimated to be about 5,000 feet thick (p. 148). Near Big Round Top, in the lower Madison Valley, about 9 miles north (south?) of Logan, is an exposure, illustrated by Douglass's

Plate 2, showing an erosional unconformity between the "Loop Fork" and the White River. The author observes that the White River beds in Montana are made up of lake, marsh, and river deposits; that commonly the finer materials are distinctly stratified; that the fauna includes fresh-water diatoms, mollusks, and fish; and that the mammalian remains are usually fragmentary and occur near hills of the older rocks, which formed the shores of lakes or marshes. He also conceives the idea that the drainage obstructions that caused the deposition of the Tertiary beds may have been lava flows or mountain-building movements.

14. Douglass, Earl, The Tertiary of Montana: Carnegie Mus. Mem., vol. 2, pp. 203–233, pl. 22, 1905. Describes several mammals, chiefly moles, from the lower White River or "*Titanotherium* beds" at McCarty's Mountain, north of Dillon.

15. Douglass, Earl, *Merycochoerus* and a new genus of merycoidodonts: Carnegie Mus. Annals, vol. 4, pp. 84–98, 1907. Gives a history of the generic term *Merycochoerus* and discusses the sequence of the later Tertiary formations. Proposes the name *Pronomotherium* for a new genus, the type of which is the skull from clay beds near New Chicago that he had previously described as *Merycochoerus laticeps*. The "Flint Creek beds" and the "Madison Valley beds" are both regarded as belonging to the "Loup Fork."

16. Douglass, Earl, Some new merycoidodonts: Idem, pp. 99–109, pls. 22–30, 1907. Describes eight species from Montana, one of which was found near Woodin on Divide Creek, one on Grasshopper Creek 10 miles above Bannack, one in a soft sandy deposit that overlies the lower White River beds at Stubb's old ferry on Missouri River, 11 miles northeast of Helena, and 5 at a locality near Canyon Ferry in Townsend Valley. Those from the Canyon Ferry locality (pp. 101–106, pls. 24–28) are *Merycoides cursor*, *Mesoreodon? latidens*, *Promerycochoerus hatcheri*, *P. grandis*, and *P. hollandi*.

17. Douglass, Earl, Rhinoceroses from the Oligocene and Miocene deposits of North Dakota and Montana: Idem, pp. 256–266, pls. 63–54, 1908. Describes one species from the "Flint Creek beds" (upper Miocene), exposed on the west (east?) side of Flint Creek valley near New Chicago, and two species from the lower Madison Valley, one of which was found in a bed of sand near the bottom of the upper Miocene ("Loup Fork") exposed on the east side of the valley.

18. Douglass, Earl, Fossil horses from North Dakota and Montana: Idem, pp. 267–277, pls. 65–68, 1908. Describes five species from Montana. Of these, two are from the lower White River ("*Titanotherium* beds") on Pipestone Creek near Whitehall, and one from the Miocene beds exposed at Woodin on Divide Creek. The two remaining species were found in Townsend Valley One, *Merychippus? missouriensis* (p. 295, pls. 61, 67, fig. 5, and 68, figs. 1–2), came from the upper Miocene ("Loup Fork") beds exposed in the bluffs east of Missouri River, north of Confederate Creek and east of Winston; the other, *Merychippus insignis* (pp. 275–276, pls. 67, figs. 1–2, and 68, figs. 3–5), was found in Miocene deposits on Deep Creek southeast of Townsend.

19. Douglass, Earl, Some Oligocene lizards: Idem, pp. 278–285, 1908. Describes one species from the lower White River ("*Titanotherium* beds") north of Big Hole River at the southeastern base of McCarty's Mountain, about 15 miles north of Dillon.

20. Douglass, Earl, Description of a new species of *Procamelus* from the upper Miocene of Montana, with notes upon *Procamelus madisonius* Douglass: Carnegie Mus. Annals, vol. 5, pp. 159–165, pls. 9–11, 1908. The new species is named *Procamelus elrodi*. It was found in a "pinkish fine-grained stratum beneath river deposits of conglomerate and sand, which are exposed in the bluffs on the east side of the lower Madison Valley in Montana nearly east of Hyde post office." Refers to the comparative size and points out the most striking features in the skull of *Procamelus madisonius*, which the author had previously described. (See No. 9.)

21. Douglass, Earl, *Dromomeryx*, a new genus of American ruminants: Idem, pp. 457–479, pls. 59–63, 1909. Proposes this name for certain of the fossil mammals previously described under the generic term *Blastomeryx*, as follows: *Blastomeryx borealis* Cope, *B. antilopinus* Scott, and perhaps *Palaeomeryx americanus* Douglass and *P. madisonius* Douglass. Remains of the first two species from the upper Deep River beds between Fort Logan and White Sulphur Springs are described by Scott. (See No. 7.) The other two, described by Douglass (see No. 9), are found in the "Loup Fork" of the lower Madison Valley.

22. Pardee, J. T., Coal in the Tertiary lake beds of southwestern Montana: U. S. Geol. Survey Bull. 231, pp. 229–244, pl. 14, 1913. Gives a map showing the area occupied by the Tertiary lake beds in southwestern Montana west of the Continental Divide and a generalized section (p. 233) of the beds in the Flint Creek valley south of Drummond. The lake beds are confined to the basin-like valleys. In Flint Creek valley beds that are regarded as of White River Oligocene age consist mainly of light-colored fine tuff or ash and clay, with interbedded layers of fine gravel, pure volcanic ash, limestone yielding fossils of fresh-water mollusks, and shale containing plant remains. Above these are beds of somewhat darker shades that consists of tuff, clay, sand, and fine gravel and are identified with the Miocene "Flint Creek beds" of Douglass. The Oligocene beds are estimated to attain a thickness of 2,100 feet and the Miocene beds 1,000 feet or more. As a rule the beds dip gently from the sides toward the interior of the valley. In places around the sides of the valley they are considerably disturbed. The coal is found in several of the valleys but apparently is limited to comparatively small areas near their sides. The coal beds that have been developed in the Flint Creek and Missoula valleys occur in the lower part of the Oligocene.

23. Jennings, O. E., Fossil plants from the beds of volcanic ash near Missoula, western Montana: Carnegie Mus. Mem, vol. 8, No. 2, pp. 385–427, pls. 22–33, 1920. Describes 23 species from collections made by Earl Douglass at localities north of Missoula in Missoula Valley and northeast of Winston in Townsend Valley. The fossiliferous beds near Missoula are interbedded with coal and occur about 1½ miles north of the city. Their flora contains 20 species and appears closely related to the flora of Florissant, Colo., and somewhat allied to the Mascall flora of Oregon. On the other hand, the flora from Missoula contains several genera in common with the floras of Yellowstone National Park; Green River, Wyoming and Utah; Bridge Creek, Oregon; and the Payette formation of Idaho. The author concludes that there is no reason why the beds of Missoula Valley should not be regarded as Oligocene and that the fossils might readily have been contributed to an Oligocene lake in a climate somewhat warmer than now prevails in that region, by plant associations ranging from those characteristic of wet meadows to those growing on rather dry rocky or sandy shores. The flora from Winston apparently belongs to the same general age as that from Missoula. It consists of *Equisetum insculptum*, *Equisetum* sp. undet., and *Aralia longipetiolata* (pp. 388, 398; pls. 22, figs. 1–2; 23, figs. 1–2). The *Equisetum* and *Aralia* both indicate a moist environment—the one an area of shallow water, the other a wet meadow or moist woods.

104142—25——4

STRATIGRAPHY

Beds of moderately hardened clay and incoherent or weakly cemented sand and gravel, commonly known as Tertiary lake beds, are exposed at many places in the ravines that cut into the benches and on the steep slopes or escarpments (Pl. I, *B*) that separate the benches from one another and from the valley bottoms. Over most of the benches these beds are concealed by later gravel, though it is evident from the distribution and extent of their exposures that they extend beneath this cover and form the bulk of the material of which the bench lands are composed. It is probable also that they occur beneath the alluvium of the valley bottom and therefore extend throughout Townsend Valley. The Tertiary beds lie upon the upturned and eroded edges of the older rocks and in turn are partly covered and concealed from view by the later or Pleistocene gravel and the Recent alluvium. They include a lower series of Oligocene age and an upper series of Miocene age.

LOWER SERIES (OLIGOCENE)

The lower series of Tertiary deposits in this area consists largely of moderately hardened light-colored fine claylike sediments with more or less fine-textured gravel or conglomerate. Apparently it underlies most of the valley, and its thickness in places ranges from 800 to 1,000 feet or more. The claylike beds consist chiefly of fine volcanic ash with a few layers of diatomaceous earth. In one place the series contains a few thin beds of coal, and in the neighborhood of Beaver Creek a thick lens of rather coarse-textured eruptive volcanic material. In the neighborhood of Toston the clay beds yield fossils of Oligocene age. The lithologic details available for this series are as follows:

Section of Oligocene rocks exposed 3 miles northeast of Toston, on the ridge north of Sixmile Creek, in sec. 12, T. 5 N., R. 2 E.

	Feet
Top eroded.	
1. Gravel or conglomerate; red clay matrix	100+
2. Clay, cream-colored to pale pink, rather soft	80
3. Clay, pale yellow or brown, hard; contains numerous small branching or dendritic veinlets of manganese oxides and small cylindrical concretions of clay	5
4. Clay, cream-colored to pale pink and pale brown, poorly exposed	200
5. Sandstone, light gray, rather soft	1
6. Clay, cream-colored to pale brown	60
7. Clay, cream-colored, hard	5
8. Clay, cream-colored to pale brown	50
9. Sandstone, light gray, rather soft	3
10. Clay, cream-colored to pale brown	50
11. Gravel, gray sandy matrix	70
Spokane shale.	
	624

The strike of these beds is N. 20°–25° W., and their dip 15°–50° NE. Bed 1 is made up of smooth pebbles from 2 to 4 inches in diameter inclosed in an abundant matrix of red clay. The pebbles consist chiefly of Belt red shale (Spokane) and quartzite and Paleozoic limestone. These materials are cemented together with lime (calcium carbonate). Beds 2 to 10 consist mostly of volcanic ash or glass with a moderate amount of lime cement and here and there small pebbles or grains derived from the older rocks. The beds designated clay are composed largely of very fine glass particles that are more or less clouded with decomposition products. The two sandstone layers, beds 5 and 9, consist of fine-grained water-laid tuff or volcanic ash. They contain a few grains of the older rocks and a small amount of lime cement. The pebbles in bed 11 are from 2 to 5 inches in diameter, are very smoothly washed, and consist mainly of quartzite, argillite, and limestone. These and the pebbles in bed 1 are evidently derived from rocks that crop out in the hills and mountains from 2 to 6 miles away on the south and east.

The above-described beds are identified as the "Toston beds" of Douglass, in which he found the remains of White River (Oligocene) mammals, including horses, tapirs, and rhinoceroses, as listed in paragraph 11, page 19.

About 2 miles southeast of the exposure just described a cut at the entrance of a caved adit on the south side of Sixmile Creek exposes gray and brown clays made up largely of volcanic ash and interbedded with thin layers of coal. The details of this exposure are as follows:

Section of Oligocene rocks exposed in open cut south of Sixmile Creek in sec. 17, T. 5 N., R. 3 E.

	Ft.	in.
Top eroded.		
Shale and sandstone (volcanic ash)	20+	
Coal and clay		6
Clay and ash	1	
Coal		6
Clay		1
Coal		3
Clay		1
Coal		8
Clay		6
Coal		5
Clay with five beds of coal from 1 to 2 inches thick	2	11
Coal	1	9
Clay		8
Coal and clay	1	4
Brown clay	5+	

These beds strike N. 35°–40° W. and dip 18°–20° NE. Apparently they belong to the same horizon as the section last described, the coal being of only local extent. The coal is black and mostly of a subbituminous variety similar to that found in Oligocene beds in some of the other valleys of western Montana.[9]

Between the coal prospect and the mountains conglomerate is exposed here and there in the slopes or terrace escarpments on either side of Sixmile Creek. These beds consist of rather smoothly washed pebbles of limestone and other rocks, most of which are from 1 to 4 inches in diameter, in a matrix of sand, the whole cemented rather firmly with calcium carbonate. Their composition indicates that they were derived from rocks that form the adjoining mountains on the east. They show dips ranging from the horizontal to 20° E., and their thickness is estimated to be at least 700 feet. The relation of these beds to the sections described is not clear, but from the degree of hardening and deformation they show, they are thought to belong to the same horizon.

In a ravine that cuts into the bench between Sixmile Creek and Dry Creek, from 2 to 3 miles north of the exposures described, the following section is shown:

Section of Oligocene rocks exposed south of Dry Creek along a ravine in sec. 36, T. 6 N., R. 2 E.

	Feet
Top eroded.	
1. Clay, pale pink, in alternating hard and soft layers	100
2. Sandstone, light gray, rather soft	1
3. Clay, soft, light colored	10
4. Sandstone like No. 2	1
5. Clay like No. 3	10
6. Sandstone like No. 2	1
7. Clay, soft, cream-colored to pale brown	80
8. Gravel or conglomerate, gray sandy matrix	10
9. Clay, soft, pale buff, with streaks of light-gray sandstone	70
10. Gravel, gray sandy matrix	20
11. Clay, soft, cream-colored	20
12. Clay, hard, cream-colored	5
13. Clay, soft, cream-colored	10
14. Sandstone, light gray, soft	5
15. Clay, soft, light colored	9
16. Sandstone, light gray, rather soft	1
17. Sandstone and fine gravel in alternating layers (poorly exposed)	50+
Bottom not exposed.	
	403

All the beds designated clay in the above section are composed chiefly of very fine volcanic ash. In the lighter-colored beds the glass particles are generally clear; in the darker beds they are more less cloudy or opaque with decomposition products. The harder beds con-

[9] U. S. Geol. Survey Bull. 531, pp. 237–243, 1913.

tain a considerable amount of lime. Layers 2, 6, 14, and 16, called sandstone, are composed of coarser volcanic ash and little else except a few grains derived from the older rocks and a moderate amount of lime cement. They appear to be water-laid tuffs. The gravel beds 8, 10, and 17 contain very smoothly washed pebbles of quartzite an inch or two in diameter in an abundant matrix of sand with little or no cement. The composition of the gravel layers indicates they were derived from the mountains 6 miles or more to the east. This section appears to be almost exactly equivalent to that north of Sixmile Creek. Its gravel layers are a little finer, and it contains a somewhat larger amount of the coarser volcanic ash. About 5 miles farther north the following section is exposed in the bench lands north of Greyson Creek:

Section of Oligocene rocks exposed north of Greyson Creek along east line of sec. 13, T. 6 N., R. 2 E.

		Feet
	Top eroded.	
1.	Clay, light brown	20
2.	Sandstone, gray	20
3.	Gravel	50
4.	Clay, soft, buff	20
5.	Gravel	20
6.	Clay, soft, buff	30
7.	Gravel	10
8.	Clay, soft, buff	40
9.	Shale, pale, cream-colored	10
10.	Gravel	20
11.	Clay, soft, buff	30
12.	Gravel	10
13.	Mostly clay with a few interbedded layers of gravel (poorly exposed)	180
14.	Sandstone, light gray, rather soft	1
15.	Clay, soft, light buff	50
16.	Sandstone, light gray, rather soft	3
17.	Clay, light buff	50
18.	Sandstone, light gray	1
19.	Clay, light buff	10+
	Bottom not exposed.	
		575

Here, as in the preceding sections, the clay beds are made up chiefly of very fine partly decomposed volcanic ash, cemented with small or moderate amounts of lime (calcium carbonate). The sandstone layers are composed of coarser-textured ash with a few grains and pebbles of quartzite and argillite. They show evidences of having been assorted by water and are lightly cemented with lime. Bed 9 consists of minute siliceous skeletons of diatoms, with a little lime and glass. It is a somewhat impure diatomaceous earth. The several gravel beds of the upper part of the section are fine textured, well washed, and lightly cemented with lime, and their pebbles consist of rocks common to the neighboring mountains on the east.

In the bluffs north of Deep Creek, about 2 miles north of the exposure last described, the following beds are shown:

Section of Oligocene rocks exposed north of Deep Creek, in sec. 30, T. 7 N., R. 3 E.

	Feet
Top eroded.	
1. Conglomerate or gravel with interbedded layers of sandstone; gray sandy matrix	60
2. Clay, cream-colored to buff, with sandy layers	40
3. Conglomerate, like No. 1	50
4. Clay, like No. 2	30
5. Conglomerate, like No. 1	15
6. Clay, cream-colored to buff, with thin layers of conglomerate; exposures imperfect	140
7. Clay, cream-colored to buff	80+
Bottom not exposed.	
	415

Conglomerate beds 1, 3, and 5 consist of pebbles and grains of quartzite, argillite, and other rocks characteristic of the mountains at the east, cemented with lime (calcium carbonate). Most of the pebbles are waterworn and less than 2 inches in diameter, but scattered cobbles and boulders appear here and there, the larger of which are as much as 1 foot in diameter. These consist of limestone and other rocks that appear in place on a mountain spur about 3 miles to the southeast. The conglomerate associated with clay bed 6 is uniformly fine textured. One layer is made up largely of small rolled pebbles of clay similar to the clay of its associated beds. The clays, like those of the preceding sections, consist chiefly of very fine particles of volcanic glass that have become more or less clouded by decomposition. Most of the beds contain a considerable amount of calcium carbonate.

A comparison of the different sections so far described indicates that that part of the section northeast of Toston below bed 1, all of the section south of Dry Creek, and that part of the section north of Greyson Creek below bed 12 are more or less equivalent to one another. Their beds are arranged in similar sequence and are characterized by a great preponderance of light-colored clay composed of volcanic ash. The thickness of this part of the section as exposed northeast of Toston is somewhat more than 500 feet. Bed 1 of the section northeast of Toston, beds 1 to 12 of the section north of Greyson Creek, and beds 1 to 5 of the section north of Deep Creek likewise form a correlated series occupying a higher position and characterized by a rather large amount of gravel or conglomerate. As exposed in the section north of Greyson Creek the thickness of this upper part is nearly 300 feet, which added to the thickness obtained for the lower part gives 800 feet as the total minimum thickness of the Oligocene beds exposed in the southeastern part of Townsend Valley.

In the bluffs along Beaver Creek and the adjacent part of Missouri River, about 15 miles northwest of the section last described, are extensive exposures of Oligocene beds of which the following is a generalized description:

Section of Oligocene rocks exposed along Beaver Creek from 1 to 3 miles northeast of Winston, in the southeastern part of T. 9 N., R. 1 E.

	Feet
Top eroded.	
1. Volcanic ash or tuff; light gray to pale yellow with several dark-gray and brown layers; two thin layers of diatomaceous earth in the lower part	800
2. Volcanic conglomerate; coarse bouldery gravel interbedded and mixed with gray, brown, and olive-green tuffs	1,200
3. Volcanic ash or tuff, chiefly light gray; exposures imperfect; thickness estimated	700
4. Clay, pale yellow or buff, exposures imperfect; thickness estimated	100
	2,800

The beds strike N. 30°–40° W., dip from the horizontal to 30° NE., and rest unconformably upon andesite and quartzite.

This section differs strikingly from the others in Townsend Valley in its unusual thickness, which is due to the presence of a great mass of tuff and volcanic conglomerate that do not appear elsewhere. Bed 1 consists mostly of moderately fine volcanic ash with a few layers made up of coarser fragments of porous glass and denser lava. The layers of diatomaceous earth consist of very minute skeletons of siliceous diatoms. One layer is white and practically unmixed with other materials; the other is pale brown and contains a little glass and a few plant remains and shells of fresh-water snails. The volcanic conglomerate, bed 2, is indistinctly stratified, and most of it apparently came to place like a flow of mud or wet earth. Its cobbles and boulders are more or less angular, range from a few inches to 3 feet or more in diameter, and consist chiefly of andesitic lava, with a little quartzite. The matrix appears to be a tuff. It readily weathers to a product that when dry is a loose mealy powder and when wet an excessively soft and slippery mud. Probably it is made up partly of bentonite, a variety of clay having the property of absorbing much water and swelling to many times its original bulk. Bed 4 consists of very fine, partly decomposed fragments of volcanic glass like those that form the bulk of the light-colored clays in the other sections described.

Along the bluffs east of Lake Sewell, between Beaver Creek and Canyon Ferry, light-colored clay consisting mostly of fine partly clouded volcanic glass cemented with lime crops out in many places. These beds attain a thickness of at least 150 feet and appear to lie stratigraphically above the uppermost beds of the Beaver Creek section. At several places in the distance of a mile, extending northeast from a point a quarter of a mile east of the Canyon Ferry dam, light-colored clays are exposed that dip 10°–16° NE. At the beginning of this series of outcrops east of the dam a natural exposure shows the Tertiary beds resting upon granodiorite, a member of the older rock group. The two formations are separated by a few feet of greenish-gray material consisting of angular grains and fragments of the granodiorite embedded in a claylike matrix, the whole evidently an old soil or surface mantle produced by weathering of the granodiorite before the Tertiary beds were deposited. Both the old surface and the overlying Tertiary beds dip 15° NE., and the total thickness of the Tertiary in this section is estimated at 1,000 feet. Along Cave Creek northeast of Canyon Ferry gravel or conglomerate is exposed that consists chiefly of grains and pebbles of red and gray argillite and quartzite in an abundant matrix of lime (calcium carbonate). Most of the rock fragments are angular and less than 2 inches in their greatest dimension and evidently were derived from Belt (Spokane) shale and other rocks that form the adjoining mountains. The different exposures show that the conglomerate gradually takes the place of clay beds as the mountains are approached and is equivalent to the upper part of the Canyon Ferry section. Near the foot of the mountains a bed of light-gray tuff similar to some of the tuffs in beds 1 and 3 of the Beaver Creek section lies upon a surface cut across the older rocks. Above the tuff is conglomerate. Apparently the tuff overlaps the lower beds of the Tertiary section and is in turn overlapped by the conglomerate. The dip of the surface on which the tuff beds lie is about 25° SW., and the tuff and the overlying conglomerate dip 15°–20° SW. The total thickness of the Tertiary beds in this locality is estimated to be not more than 500 feet.

Except for the volcanic conglomerate and tuff exposed at Beaver Creek, which apparently form a lens of local extent, the beds in the foregoing sections are similar in appearance and composition to those in the southeastern part of the valley determined as Oligocene and are therefore correlated with them.

In the middle and southwestern parts of Townsend Valley beds that presumably are to be correlated with those described above appear here and there but form no very extensive exposures. In this category are beds of pale-yellow or buff clay exposed at the east side of the valley between Gurnett Creek and Ray Creek that rest on an eroded surface of the older rocks and are themselves overlain by sand and gravel of local derivation; the thickness of the whole series is less than 100 feet. These beds and the surface beneath dip gently southwestward, or toward the axis of the valley. Half a mile out in the valley the beds dip 7° in the opposite direction, or toward the mountains. On the west side of the valley, in the bluffs facing the river 3 miles south of Beaver Creek, 40 or 50 feet of the light-colored clay appears. The beds dip 10° or less toward the northwest and are overlain unconformably by later gravel. Opposite Townsend are a few very small exposures of similar clay. West and south of Radersburg clay is exposed over a considerable area from which the overlying alluvium has been stripped by placer mining. Here it rests upon a somewhat uneven surface of andesite and varies in attitude from the horizontal to a dip of 5° E.

UPPER SERIES (MIOCENE)

The upper or Miocene series of Tertiary beds of this area is poorly exposed. Apparently it lies in valleys eroded in the lower (Oligocene) series and is of less extent than that series. It occupies a small area south of Deep Creek and a comparatively large one north of Confederate Creek and probably extends over part of the bench land and area on the west side of the valley south of Winston. The series attains a thickness of at least 500 feet and consists chiefly of incoherent sand and gravel derived from the older rocks that compose the neighboring mountains. Presumably it yielded the Miocene fossils listed in paragraphs 16 and 18, page 20.

The best exposures observed of the Miocene beds occur a short distance south of Deep Creek in a ravine known as Dry Gulch, in secs. 11 and 14, T. 6 N., R. 2 E. Here most of the beds consist of light-brown to buff incoherent sand and gravel; a few contain more or less clay and are lightly cemented with calcium carbonate. Some of them exhibit the cross-bedding characteristic of sediments deposited by streams in slack water. In places the gravel contains cobbles or boulders as large as 1 foot in diameter, but most of it is fine textured. The cobbles and pebbles are more or less angular and consist chiefly of quartzite, limestone, and other rocks common in the mountains about 4 miles away on the east. The beds dip 8°–12° SW., and their total estimated thickness is between 500 and 700 feet. A short distance east of this area beds typical of the lower or Oligocene series appear, and their attitude strongly suggests an angular discordance or difference in dip of 4° to 8° or more between them and the upper series.

The remains of a Miocene horse (*Merychippus insignis*, referred to in paragraph 18, p. 20), described by Douglass as having come from deposits on Deep Creek southeast of Townsend, are assumed to have been found in this upper series of Tertiary beds and probably within or near the area here considered.

In the bench lands north of Confederate Creek are several small exposures that apparently belong to the Miocene series of Tertiary beds. One of these, in a ravine half a mile southeast of Brown's ranch, in sec. 27, T. 10 N., R. 1 E., shows, beneath a thin layer of later gravel, about 10 feet of fine pale-yellow sand that tends to stand in vertical faces. Below the sand is 10 feet or more of fine-textured gravel composed of flat pebbles of Belt rocks in a rather firm and dense matrix of clay and fine sand. The bedding is nearly horizontal. In the bluffs east of Missouri River, at the county bridge south of Beaver Creek, is exposed 50 feet or more of lightly cemented, rather fine gravel that consists of smoothly washed pebbles in an abundant light-colored dense matrix of sandy clay. The remains of a Miocene horse (*Merychippus missouriensis*, referred to in paragraph 18, page 20) described by Douglass as having come from the bluffs east of Missouri River north of Confederate Creek and east of Winston were probably found in these beds or in beds associated with them. On the bench west of Cave Creek, about three-quarters of a mile north of Canyon Ferry, placer-mining excavations expose beneath the gold-bearing bench gravel 40 feet or more of loose or incoherent sand and fine gravel. The composition of these beds indicates that they were derived from the mountains at the northeast. They lie nearly horizontal, and their altitude is less than that of some of the beds of the lower series exposed in neighboring areas—facts which indicate them to be in a valley eroded in the lower series after it had been slightly tilted. The remains of several species of Miocene mammals (see par. 16, p. 20), described by Douglass as coming from Canyon Ferry, are presumed to have been found in these or similar beds near by.

In the bluffs west of the river, 2 or 3 miles south of Beaver Creek, near Hahn's ranch, is exposed 30 to 40 feet of rather fine horizontally bedded gravel with streaks and lenses of sand and clay. The deposit lies unconformably upon light-colored clay beds of the lower series and appears to form the lower end of a group of coalescing alluvial fans that, in this part of the valley, cover most of the bench-land area. Whether it is to be correlated with the Miocene or the still later Pleistocene deposits is not clear. Possibly it is equivalent to parts of both.

STRUCTURE

When newly deposited the beds of clay and other fine sediments must have lain horizontal or nearly so. Possibly the layers of stream-deposited gravel had a slight inclination, and the coarser volcanic products in the Beaver Creek section may have assumed a considerable dip. In general, however, the beds are regarded as having been essentially flat-lying at first, their present attitude, which commonly departs 20° or more from the horizontal, being the result of subsequent movements within the crust of the earth. The outstanding structural features are a zone of anticlines that extends northwestward across the valley from the neighborhood of Toston to the Spokane Hills and a monocline or persistent dip toward the northeast shown over most of the area east of this zone. Less prominent features include small synclines and steplike faults that, locally at least, cause the outcrops of the different beds to be repeated.

FOLDS

From a point south of Dry Creek in sec. 30, T. 6 N., R. 3 E., an anticline may be traced northwestward to the bench north of Deep Creek in secs. 35 and 36, T. 7 N., R. 2 E., a distance of about 6 miles. Dips on its east side range from 10° to 20° and on its west side from 8° to 15° (fig. 3). Along its axis the light-colored clays of the lower or Oligocene series appear, and at a considerable distance to the east these give place to conglomerate. The beds forming the west side of the anticline are generally concealed from view. Along Dry Gulch south of Deep Creek they belong to the upper or Miocene series, as described on page 29. South of Dry Creek the anticline ends in an area occupied by several small folds that rise toward the south and disappear in that direction. North of Deep Creek it is concealed by gravel and other alluvium younger than the Tertiary. About 2 miles north of Winston an exposure of horizontal beds of buff clay belonging to the lower series or Oligocene appears to mark the crest of another northwestward-trending anticline. On the eastern flank of this fold the dip, as shown by numerous exposures in the bluffs west of Missouri River, is 15°–25° NE. The beds forming its west side are generally concealed, but an exposure about 8 miles northwest of Winston shows a dip of 15°–20° SW. This fold and the Deep Creek anticline have about the same trend, and their axes are nearly in line. Both are included in a rather narrow zone extending northwestward across the valley from Sixmile Creek to the Spokane Hills. Between these two areas is a space of 15 miles or more, forming a middle section of the zone in which the Tertiary beds are concealed. However, the attitude of beds exposed to the east of this section indicates that the anticlinal structure probably persists throughout the zone.

Throughout most of Townsend Valley east of the zone described the lower series of Tertiary beds shows a persistent eastward dip that ranges from 10° to 20°. As a rule, no change from this attitude is apparent to a point within a mile or two of the mountains. Beyond this point, however, the beds gradually decrease in dip, become horizontal, and in places incline in the opposite direction. Along Cave Creek and Magpie Creek at the foot of the mountains the beds dip 20° or more toward the valley (fig. 5). Half a mile below they become horizontal, and a little farther on they assume the usual dip to the northeast. The trough or syncline thus shown trends nearly east and extends for a distance of at least 3 or 4 miles. At the edge of the valley east of Canton a similar small syncline is indicated, but on Sixmile Creek the Tertiary beds dip eastward near the foot of the mountains and are in fault contact with the older rocks.

West of the anticlinal zone the attitude of the beds is indicated only at Radersburg, at the western edge of the valley, where the dip is gently eastward. Presumably the beds are bent into a shallow syncline.

FAULTS

Faults that cut and displace the Tertiary beds appear in the section exposed northeast of Toston (fig. 4). Here a fault is shown that strikes N. 30° E., dips 45° W., and cuts through layers of gravel and light-colored clay belonging to the Oligocene. Its walls are smooth and regular, being separated by only an inch or even less of gouge. The western or hanging wall has fallen at least 40 feet, bringing a bed of gravel opposite one of clay. In the adjoining area repeated outcrops of the same beds together with sudden changes in the dip make certain the presence of at least four faults within the distance of a quarter of a mile. Apparently the faults strike northwestward and dip steeply to the southwest, and their west or hanging walls have dropped relatively. The displacement on each fault ranges from 50 to 150 feet or more and on all aggregates at least 350 feet. One effect of this faulting is to reduce the apparent thickness of the Tertiary beds.

At the point where Sixmile Creek leaves the mountains Tertiary beds that dip 20° E. abut against the older rocks. The boundary between the two is a fault (fig. 3) that strikes north and has caused a relative downward displacement of the block on the west or valleyward side.

Elsewhere within the valley no definite evidence of faulting was obtained, but it is considered probable that step faults like those northeast of Toston occur in other areas. East of the anticlinal zone the thickness of the Tertiary beds, as indicated by the persistent dip in one direction, is excessive. For example, in the bench north of Deep Creek a northeastward dip of 15° is shown for a distance of 6 miles or more. Therefore, unless the effect of this dip is offset by faulting or some other unsuspected structural feature, the beds must be assumed to attain the improbable thickness of 7,000 or 8,000 feet and fill a trench or basin of equally improbable depth. In the western part of the valley south of Winston a northwestward-trending fault is possibly indicated by a line of springs.

AGE AND CORRELATION

The lower or Oligocene series of Tertiary beds in Townsend Valley is similar in appearance and composition to the beds in the neighboring basin-like valleys of the mountainous region of western Montana regarded as of Oligocene (White River) age and is apparently their general equivalent in time. It includes the fossiliferous beds near Toston which are regarded by Douglass[10] as corresponding in part to both the lower or *Titanotherium* zone and the middle or *Oreodon* zone of the White River. In the other valleys beds belonging to the *Titanotherium* zone have been identified, as described in the reports listed on pages 19–20 (Nos. 11–14), at Thompson Creek northwest of Three Forks, at Pipestone Creek near Whitehall, and east of McCarty's Mountain, north of Dillon. Beds determined with more or less certainty as White River without indicating the subdivisions to which they may belong occur in lower Madison Valley south of Three Forks, in Beaverhead Valley on Blacktail Creek southeast of Dillon, in Blackfoot Valley near Helmville, in Flint Creek valley southwest of Drummond, and in Missoula Valley north of Missoula.

The correlation of the beds under consideration with the White River formation of Nebraska and South Dakota has been indicated. In addition they correspond closely with the Oligocene deposits of the Cypress Hills in southwestern Saskatchewan, Canada. The Cypress Hills deposits attain a thickness of 5000 feet at the east and consist of conglomerate, usually formed of quartzite pebbles cemented together with carbonate of lime, associated with beds of sandstone, sand, clay, and marl.[11] Fossils found in these beds consist of more than 50 vertebrate species, including fishes, reptiles, and mammals, of which the mammals preponderate in numbers and variety. Among them are *Titanotherium*, rhinoceroses, oreodonts, horses, dogs, rodents, and a cat. These deposits are regarded by Matthew[12] as probably of about the same age as the "*Titanotherium* beds" at Pipestone Springs, Mont., and by Lambe[13] as belonging, in a general sense, to the *Titanotherium* zone of Montana, though some of their upper members may be synchronous with the *Oreodon* zone.

---

[10] Douglass, Earl, Am. Philos. Soc. Trans., new ser., vol. 20, p. 243, 1902.

[11] Lambe, L. M., The Vertebrata of the Oligocene of the Cypress Hills, Saskatchewan: Contr. Canadian Paleontology, vol. 3, pt. 4, p. 5, 1908.

[12] Matthew, W. D., Am. Mus. Nat. Hist. Bull., vol. 19, p. 202, 1903.

[13] Lambe, L. M., op. cit., p. 8.

The upper or Miocene series of Tertiary beds in Townsend Valley bears a strong resemblance in composition, occurrence, and other features to the "upper beds" in the neighboring Smith River (Deep River) valley as described by Scott.[14] The fauna from Townsend Valley is referred by Douglass to the middle or upper Miocene and that from Smith River valley is regarded by Scott to mark a distinct horizon at the base of the "Loup Fork." Compared with those in Townsend and Smith River valleys the "Loup Fork beds" in most of the other valleys differ noticeably in appearance and composition, owing to the fact that they generally contain a large amount of clay or volcanic ash. Whether these differences mean that the beds represent more than one horizon apparently has not been determined. Miocene fossils have been found most plentifully in lower Madison Valley near Hyde post office and in Flint Creek valley near New Chicago, and the beds are regarded as generally corresponding in time to the Miocene beds of Nebraska and neighboring regions. Parts of them may prove to be equivalent to the Flaxville gravel in northeastern Montana, described by Collier and Thom.[15]

The "lower beds" in Smith River valley are correlated by Scott[16] with the summit (lower Miocene) of the John Day formation of Oregon and therefore appear to be rather widely separated in age from the lower series (Oligocene) in Townsend Valley.

Concerning the differences between the Tertiary fauna of the mountain province and that of Nebraska and neighboring parts of the Great Plains, Douglass[17] observes that the evidence thus far obtained seems to show either that the two regions during Oliogcene and Miocene time were faunally distinct or that the preservation of mammalian remains seldom, if ever, exactly coincided in time in the two areas.

QUATERNARY DEPOSITS

Townsend Valley is overspread generally with a layer of loose or unconsolidated gravel, sand, and silt that was deposited by streams upon surfaces eroded across the deformed Tertiary and older rocks. Most of the deposits on the two higher benches, which evidently are older than those at lower levels, are described herein as bench gravel. The deposits that underlie the valley bottoms and bench No. 3 form a younger group called valley gravel. Associated with both groups are a few deposits classified as of glacial origin. Except the soil

[14] Scott, W. B., Am. Philos. Soc. Trans., new ser., vol. 18, p 58, 1895.

[15] Collier, A. J., and Thom, W. T., jr., U. S. Geol. Survey Prof Paper 108, pp. 179–184, 1918.

[16] Scott, W. B., Am. Philos. Soc. Trans., vol. 18, p. 59, 1895.

[17] Douglass, Earl, Carnegie Mus. Annals, vol. 4, p. 268, 1908.

that forms the present surface, deposits younger than the Pleistocene are of comparatively small extent. They include some of the alluvium on the valley bottoms and on the benches next to the mountains and wind-blown sand that occupies a small area south of Crow Creek.

BENCH GRAVEL

On the higher benches north of Deep Creek a layer of gravel from 10 to 20 feet thick is exposed near the mountains. It contains many rough and moderately waterworn boulders that range from 1 to 3 feet in average diameter, and its matrix is an abundant sandy clay. It lies on a surface of erosion that cuts across the Tertiary and older rocks, and the pebbles it contains are of the same kinds as the rocks that crop out in the adjoining mountains. Away from the mountains the gravel becomes thinner and finer textured. Somewhat similar gravel is exposed on the bench south of Confederate Creek near the point at which the stream leaves the mountains. In the neighborhood of Diamond City, several miles above this point, gravel that lies on narrow benches bordering Confederate Creek has been extensively mined for gold. The benches apparently are to be correlated with Nos. 1 and 2 of Townsend Valley. The gravel, though evidently deposited by a stream, is not as a rule highly waterworn nor, except for the presence of a few large boulders, very coarse textured. It consists mainly of quartzitic rocks similar to those common in the Belt formation of the surrounding area. In a low bench at the mouth of Boulder Creek this gravel is overlain by a coarse-textured gravel that is barren of gold and is made up chiefly of granitic material. This gravel is much fresher looking than the other and presumably belongs to the younger valley gravel.

For a considerable distance north of Confederate Creek the surface of the bench lands is thinly overspread with alluvium that apparently was brought out from the adjoining mountains in comparatively recent time. Probably the most of it is to be classified with the bench gravel. Near the north end of the valley, on Magpie Creek and Cave Creek, the bench gravel has been mined for gold. Here, as a rule, it is of moderately coarse texture, moderately waterworn, and, as elsewhere, made up of materials derived from the mountains near by. The gravel adjacent to Cave Creek, however, is distinguished by the presence of unusually large boulders distributed here and there for a distance of a mile or more out from the foot of the mountains. These boulders are rough or subangular, consist mainly of quartzite, and range from 4 to 8 or 10 feet in average diameter. Their size is so much out of agreement with the general texture of the gravel that incloses them that they could hardly have been transported and deposited by the same stream. Probably they were carried out from the mountains by some unusual flood or by a glacier, and in that event they composed part of a deposit that was afterward reworked by streams into the gold-bearing gravel described.

In the western part of the valley rather coarse gravel is exposed by placer-mining excavations on the benches north of Indian Creek and west and south of Radersburg. It is composed of materials carried out from the adjacent mountains and otherwise is like the bench gravel described. South of Winston the bench lands are covered with a sheet of gravel composed of extensive coalescing fans deposited by ephemeral streams from the adjoining mountains. Probably the upper part of this sheet is made up of bench gravel and later deposits.

The bench gravel was deposited after the Tertiary beds had been deformed and eroded and therefore is considerably younger than Miocene. Because of its close association with a relatively old glacial moraine described on the following pages, it is regarded as chiefly of early Pleistocene age.

VALLEY GRAVEL

The valley bottoms and the lowest or No. 3 bench are composed of gravel derived from a number of sources, including the bench gravel, the Tertiary beds, and the older rocks of the mountains. In general this gravel is very open textured and much more loose or incoherent than the bench gravel. Along the middle part of the valley it is rather fine textured and smoothly waterworn; toward the mountains it becomes coarser and more angular. As exposed in a road cut in No. 3 bench about a mile east of Townsend this formation consists of smoothly washed pebbles and cobbles of quartzite and other resistant rocks in a loose and open sandy matrix. In places it is lightly cemented with calcium carbonate; elsewhere it falls apart freely. Similar material is exposed by wells in most of the lowlands adjacent to Missouri River, where its minimum depth is from 20 to 40 feet. Probably its total thickness is considerably greater.

Toward the mountains this gravel becomes coarser, though along several of the streams, including Deep Creek and Greyson Creek, it decreases in thickness and within the mountains is as a rule of comparatively small bulk. Along Confederate Creek, however, a rather thick sheet of coarse gravel extends 5 or 6 miles within the mountains to Boulder Creek and thence continues up that stream. Unusually thick and coarse bouldery gravel occurs also along Beaver and Crow creeks for considerable distances above and below the points at which they issue from the mountains.

In areas where few or no permanent streams cross the bench lands alluvial cones and fans deposited by short-lived streams are spread out for considerable distances from the mountains. In the stretch of 10 or 12 miles between Indian Creek and Winston fans of this kind cover practically all the bench lands to a considerable but unknown depth. An incomplete section of this formation exposed in the bluff west of Missouri River about 3 miles south of Beaver Creek, described on page 30, shows 30 feet or more of rather fine stratified subangular gravel containing streaks and lenses of sand and clay. The beds dip about 3° E., or practically the same as the slope of the surface. Toward the mountains the gravel becomes coarser and thicker, and the fragments more angular. Apparently it has been accumulating without interruption for a long time and probably is equivalent in age to parts of the upper or Miocene series of Tertiary beds, the bench gravel, and the valley gravel. North of Confederate Creek and in places elsewhere small gravel cones or fans, corresponding in age with the valley gravel, occur on bench No. 1 where it adjoins the mountains.

Because it includes outwash from glaciers of a late stage the valley gravel is thought to be late Pleistocene. Gravel that evidently is of Recent age includes a few small areas of alluvium and wind-blown sand.

GLACIAL DEPOSITS

Near Smith's ranch, at the foot of Mount Baldy, in sec. 13, T. 8 N., R. 3 E., a small moraine lies on top of bench No. 1. It forms a semicircular ridge about half a mile long and 50 feet high that shows the uneven topography, unassorted rock débris, and large boulders characteristic of glacial material. The exposed material appears considerably weathered, and no striated surfaces were seen. At the back or east of the deposit a small valley extends part way up Mount Baldy. At the north and south are longer valleys, occupied respectively by branches of Gurnett and Ray creeks that are cut well below the bench level. If at the present time a glacier should form on the upper slope of Mount Baldy, it would flow down either of these valleys rather than the one leading to the moraine. Therefore it is concluded that the moraine was deposited at an early stage of glaciation, before the deeper valleys were cut. Though no direct evidence of glaciation was found in the neighborhood of Cave Creek, the unusually large boulders in the bench gravel adjacent to that stream suggest the possibility of glaciation at a similar early stage.

The mountains surrounding Townsend Valley have not been examined in detail, but it is evident from distant views and available maps[18] that they contain several cirques from which at a late stage small glaciers may have descended for moderate distances. Glaciers

[18] U. S. Geol. Survey topographic map of Fort Logan quadrangle, 1914; U. S. General Land Office plat of T. 9 N., R. 3 E. Montana meridian.

of this type are indicated to have existed at the heads of Boulder Creek, Crow Creek, and Beaver Creek, and the unusually coarse and bulky gravel along the lower courses of these streams is thought to be chiefly outwash of the late stage.

PHYSIOGRAPHY

Townsend Valley and the adjoining mountains have been fashioned from an ancient surface, part of which is yet preserved beneath the Tertiary sediments.

As described on page 28, the Oligocene beds lie upon a surface that cuts across strongly deformed rocks of the older group, which range in age from Cretaceous to pre-Cambrian. Near the Canyon Ferry dam and at a few other places natural exposures show that this old surface, though somewhat uneven, is without sufficient relief to class it as mountainous. The line that separates the Oligocene and older rocks around the margin of Townsend Valley is nearly everywhere the trace of this old surface where it meets the present one. This trace shows some broad curves where it passes around projecting mountain spurs, but in most places its course is free from crooks or indentations such as it would show if the old surface were roughened by hills and valleys of sharp or considerable relief. Evidently the old surface is the product of erosion that continued for a long time without interruption. It was cut across a variety of rocks, from which an aggregate thickness of several thousand feet must have been removed. The youngest of the eroded rocks are middle or perhaps late Cretaceous. Therefore, so far as the records in Townsend Valley show, all of Eocene time, at least, was available for this work, including the preliminary folding and elevation of the rocks.

The present general form of the old surface is like that of a dish or shallow bowl. At all its exposures around the margin of the valley it dips toward the interior. Thus near Canyon Ferry, at the northwest side of the valley, the dip is about 15° E. (fig. 5). At Cave Creek, on the opposite or northeast side, the dip is 20°–25° SW. At the east along the middle strech of the valley the dip is about 12° W., and in the southwestern part, south of Radersburg, the old surface dips 5° or more toward the northeast. If these dips are projected inward and decreased somewhat as they approach one another they carry the old surface to a depth of 2,000 feet or more in the central part of the valley (figs. 4 and 5). There appears to be no deep channel leading away from this basin through which it could have been drained, and its hollow or dishlike form is therefore thought to be the result either of downwarping or depression of this particular part of the earth's surface or an upward movement of the surrounding lands. The truth of this supposition is indicated by the fact that the overlying Oligocene beds now dip inward around the margin of the valley, the same as the old surface, except that in places their inclination is somewhat less. Evidently the Oligocene beds, which were horizonal when they were deposited, and the old surface have been depressed or otherwise deformed together. Additional evidence that the old surface has been deformed by structural movements is afforded by an exposure along Sixmile Creek near the foot of the mountains. Here a fault, described on page 32, cuts both the old surface and the overlying Tertiary beds, causing them to be dropped on the west or valleyward side or elevated on the other side (fig. 3). It is probable that in the interior of the basin the old surface has been deformed in the same manner as the Oligocene beds. Doubtless the small step faults northeast of Toston dislocate it, and there is reason to think that in the anticlinal zone that extends from Sixmile Creek northwestward to the Spokane Hills the old surface is arched or otherwise elevated the same as the overlying beds. In fact, definite proof of this appears to be given by the section exposed across the Spokane Hills from Canyon Ferry to Prickly Pear Valley (fig. 5). On the east side of the hills both the old surface and the overlying beds dip eastward. On the west side the beds dip westward toward Prickly Pear Valley and, though the old surface is not here directly exposed, its trace along the foot of the hills near by indicates a similar dip. Thus the Spokane Hills appear to be an arched portion of the old surface from which the overlying Oligocene beds have been worn away.

If the irregularities described as caused by structural movements were smoothed out and the Tertiary beds removed, or, in other words, if the conditions at the beginning of Oligocene time were restored, the old surface would appear as a wide lowland surface sloping gently upward along the east, where now is the foot of the Belt Mountains. Doubtless it would show a similar upward slope along the west, at the foot of the present Elkhorn Range. The Spokane Hills and the ridge that now bounds the valley on the southwest would not be in view, and the low surface would extend without interruption into Prickly Pear Valley on one hand and Madison-Gallatin Valley on the other, but the conical hill south of Radersburg known as Lone Mountain, the small ragged granite ridge southeast of Warm Spring Creek, and part of the hills southwest of Toston were in existence.

Beneath the Tertiary beds of the other basin-like valleys of western Montana are old surfaces that are similar to that in Townsend Valley and are thought to be generally correlatable with it. The information so far available suggests that most if not all of these valleys were preceded in Oligocene time by lowlands like the old surface beneath Townsend Valley, and that these lowlands were originally continuous with one another but later, as a result of earth movements, became more or less definitely separated into parts, as at present. Presumably the Oligocene lowlands were bordered by mountains that occupied essentially the same positions as the principal ranges of to-day. An elevated area along the east of Townsend Valley corresponding to the present Belt Mountains is indicated by the fact that before the post-Oligocene folding the old surface rose in that direction. Later on, when sediments were accumulating on the old surface, gravel was washed in from the east, giving further indication of the existence of high land. Similar evidence elsewhere indicates that the Oligocene lowlands were bordered by mountains. Little information tending to reveal the contour of these ancient mountains is available. Because no coarse gravel was carried into the lowlands it is thought that the Oligocene streams had low gradients, which in turn may be regarded as evidence that the mountains had become well dissected and worn down to a moderate height.

While the lowlands and mountains described were being carved, the region had free and unobstructed drainage. No deposits representing this period of erosion are known within the region. Apparently the streams were able to carry all the products of erosion far beyond its borders. In Oligocene time, however, conditions changed so greatly that sediments began to accumulate on the hitherto cleanly swept lowlands. The deposition may have been the result of a change from a moist to an arid or desert-like climate such as would cause the streams to become intermittent and therefore unable to remove the sediments from the valleys as fast as they brought them in, or the deposits may have been caused by obstructions to the drainage, either lava flows or barriers elevated by structural movements. Whatever the true explanation, it is evident that the sedimentation began and continued without interruption until 1,000 feet or more of beds had accumulated in the central parts of the valleys. The features of these beds, as previously described, show that during the time they were accumulating the valleys contained alternately ponds, marshes, and areas of dry land on which lived strange species of lizards, rodents, camels, rhinoceroses, and other animals. When the Oligocene beds had attained their maximum thickness they overspread the valleys completely and lapped up on the flanks of the mountains, though there is no evidence that they ever submerged the mountains completely or covered the region generally as a blanket. On the contrary, there is much gravel in the upper part of the beds that evidently was derived from the erosion of the mountains, which therefore must have remained well above the area of deposition.

One of the most significant features of the Oligocene beds is the large amount of volcanic ash or tuff they contain. Most of this material is as fine grained as silt or clay and doubtless was brought from a distance suspended in the air. Part of the deposit in Townsend Valley, however, is coarser and came from a local volcano situated apparently near Winston. Some of the beds consist of pure or unmixed ash that remains as it fell. The others are mixed with sand or pebbles and are thought to represent material that fell upon the surrounding elevated or mountainous areas and was later washed into the basins.

It is significant as indicating a basin surrounded by highlands that fine materials like clay are more abundant in the central parts of the valleys and relatively coarse materials such as gravel are more plentiful around the sides. At this time, while the drainage was generally obstructed in southwestern Montana, a vigorous stream was transporting gravel from the mountains in the region of Glacier National Park eastward to the Cypress Hills, a distance of nearly 200 miles. This difference in drainage conditions between the two areas is puzzling and not easily explained.

After 1,000 feet or more of the Oligocene beds had accumulated in southwestern Montana the streams for some reason became more active and cut valleys in them, removing considerable material. Later the excavated areas were refilled with sediments that generally were coarser and in Townsend Valley consisted almost wholly of gravel and sand. With them were buried the remains of animals indicating a Miocene age and showing that considerable time had been covered by the preceding interval of erosion. As explained under "Structure" (p. 30), the Oligocene beds had been moderately tilted before the Miocene beds were laid down. After the Miocene deposits had accumulated to the depth of 500 feet or more in Townsend Valley the structural movements were resumed, and mountain building and erosion became the most active of the geologic processes. At first, no doubt, the structural forces were dominant. The Tertiary beds and the old surface on which they lay were together arched and faulted. Existing mountains grew higher, parts of the valleys became relatively depressed, and new ridges such as the Spokane Hills and the divide south of Warm Spring Creek were elevated. There is no evidence available to fix the date of this period very closely. Probably it occupied part or all of Pliocene time.

After the mountain-building movements died out there followed a period of rest or crustal stability during which erosion produced a plain over the area of Townsend Valley, the remnants of which now form bench No. 1. In most places this bench is 300 or 400 feet higher than the present streams and exhibits about the same slopes. Evidently the drainage of this plain escaped northward through a valley having the same position as the present gorge of Missouri River, north of Canyon Ferry. At an earlier time the Belt Mountains, as suggested by Atwood,[19] may have formed the Continental Divide; if so, Townsend Valley drained southwestward. Before it became dissected the plain composing bench No. 1 covered the entire area of Tertiary beds in Townsend Valley and, in addition, extended for short distances across the older rocks at the foot of the mountains. To some extent its remnants lean up against the mountains but do not pass over them nor merge with their slopes. Nearly everywhere the break between plain and mountain slope is sharp and distinct. During the erosion that produced this plain more or less of the Tertiary material was cut away, but as no remnants of it are now to be found above the plain the thickness removed is not apparent. It may have been considerable. Part, at least, of the plain was cut by the mountain streams working from side to side and reducing the area to grade at a level determined by the height of the drainage outlet at that time. While engaged in this work the streams brought out from the mountains considerable material described herein as bench gravel and spread it over the newly eroded surface, and at one place a small glacier from Mount Baldy descended upon the plain. Afterward the drainage outlet of the valley became lowered or the climate changed to such an extent that the streams were enabled to cut away most of bench No. 1 and develop a new plain about 100 feet lower, the remnants of which are described as bench No. 2. In time bench No. 2 was largely destroyed by renewed downcutting, which continued until the streams finally reached a point somewhat below their present level. After valleys had been excavated at this low level several of the streams, at whose heads were small glaciers, regarded as belonging to the latest or Wisconsin stage, brought in thick deposits of gravel. Finally, after the glaciers had disappeared, the streams reworked part of the gravel, producing the valley bottoms and the low terraces that compose bench No. 3.

The small gorge of Missouri River at Canyon Ferry, which forms an excellent dam site that has been utilized by the Montana Power Co. (fig. 5; Pl. II, *B*), is a result of the river having become intrenched or superimposed on the side of the Spokane Hills while bench No. 2 was in process of being dissected. Apparently just before the downcutting began the river, meandering across the plain,

[19] Econ. Geology, vol. 11, p. 702, pl. 27, 1916.

had set in against the hills at this particular point. As it deepened its channel the stream uncovered a small spur of resistant rock (granodiorite) that until then had remained buried beneath the softer Tertiary beds. As a result deepening of the channel at this point was delayed, and for a time no doubt a considerable fall existed. Eventually the stream cut through this difficult stretch, and the excavation of the valley was resumed and completed. During the last stage of erosion bench No. 2, in the valley alongside the gorge, has been worn away in places so that now if the gorge did not exist the river could not take its present course but would be compelled to remain out in the valley.

On the north side of the valley between Winston and Indian Creek and in some other areas no perennial streams issue from the mountains. Here the surface is covered with gravel deposited by ephemeral streams, which masks more or less completely whatever other features may have been developed. Apparently this gravel has been accumulating during most of the time represented elsewhere by the different benches and the valley bottoms.

Benches that in general are similar to those in Townsend Valley and probably are to be correlated with them are prominent features in most of the neighboring valleys in the mountainous region of southwestern Montana. In the Great Plains northeast of this region is a series of benches, described by Alden,[20] that resemble the benches of Townsend Valley sufficiently to make their correlation seem plausible, though a gap of 70 miles or more between the nearest known remnants of each remains to be bridged.

The presence of a moraine on bench No. 1 in Townsend Valley has been referred to. In Deer Lodge and Flint Creek valleys similar glacial deposits occur on the highest bench, and in the Great Plains near Glacier National Park the highest bench is extensively overlain by till. The plain represented by the highest bench must have been completed before these deposits, which are regarded as early Pleistocene, came to place. How much time was consumed in its making is not indicated by the information available, but it was not begun until after the Miocene beds had been tilted. From the evidence at hand it appears quite plain that the trenching of bench No. 1 and the development and trenching of bench No. 2 took place between early and late stages of the Pleistocene and that in Townsend Valley at least bench No. 3 and the present valley bottoms are of post-Wisconsin age.

[20] Alden, W. C., and Stebinger, Eugene, Pre-Wisconsin glacial drift in the region of Glacier National Park, Mont.: Geol. Soc. America Bull., vol. 23, pp. 687–708, 1912; vol. 24, pp. 529–572, 1913. Alden, W. C., Physiographic development of the northern Great Plains (in preparation).

MINERAL DEPOSITS

MARBLE

Several of the Paleozoic limestones that form conspicuous reefs on the mountain spur that projects into the west side of the valley opposite Townsend show the texture and other features of decorative marble. Specimens from the claims of D. P. Mumbrue are fine grained, show several attractive shades and patterns, and when polished appear remarkably pleasing and handsome. A common variety has a background of dark gray faintly mottled with brown and decorated with splotches and threads of white and pinkish buff. Other varieties exhibit shades of yellow, red, and pink. In many of the beds grays that range from almost black to almost white predominate.

The deposits are practically undeveloped, but the natural exposures show large faces of clean marble (Pl. II, *A*), and large blocks without cracks or flaws apparently could be quarried at several places. From points at which quarries could be opened the distance to a point on the Northern Pacific Railway 2 miles north of Townsend ranges from 4 to 6 miles. A down grade exists all the way from the deposits to the railway.

DIATOMACEOUS EARTH

Diatomaceous earth, a substance composed of the siliceous sheaths or skeletons of diatoms, a variety of extremely minute water plants, was observed at two places in Townsend Valley. It occurs in layers interbedded with the Oligocene clay and tuff and apparently accumulated at the bottom of a pond. One of the places is about a mile north of Beaver Creek, in a bluff facing Missouri River in sec. 27, T. 9 N., R. 1 E. Here two beds, each about a foot thick, crop out. In one the earth is almost chalk-white, of noticeably light weight, and unmixed with any foreign material. In the other it is pale brown as the result of a small amount of impurities. The remaining deposit is exposed north of Greyson Creek near the east line of sec. 13, T. 6 N., R. 2 E., about 5 miles southeast of Townsend. It consists of a bed 10 feet thick, light gray and thinly laminated like shale. Specimens show the earth to be mixed with a little lime and other substances. Possibly purer material exists below the surface, and it is likely that more extended search, particularly in the Beaver Creek area, will disclose additional deposits.

The uses of diatomaceous earth include the refining of sugar, deadening sound in walls, heat insulation in ceilings, boilers, etc., and the manufacture of light-weight partition tile.

OIL

Information on which to base a positive conclusion as to the presence or absence of oil in Townsend Valley is not available, but the following facts and considerations bear more or less directly on this subject.

The Belt series and all the granites and similar crystalline rocks, because of their age, metamorphism, or origin, may be excluded as possible sources of oil. Many of the remaining formations of the older group, however, which range from Cambrian to Cretaceous, are of the same age as formations that in other areas yield oil, but in Townsend Valley these rocks have undergone more severe folding and metamorphism than is common in the oil-bearing regions. The youngest (Cretaceous) and therefore presumably the most likely of these formations to contain oil crop out in places around the southern rim of the valley. Here they are moderately tilted, dislocated by faults, and intruded by igneous rocks.

Oil has not yet been found in deposits that correspond to the Oligocene and later formations in Townsend Valley. It is conceivable, of course, that oil might enter them from rocks with which they are in contact, such as the older group, but in Townsend Valley the two groups are separated by an unconformity that represents a long period of time during which the older group was deformed and deeply eroded. Presumably most of its oil escaped during this period and before the Oligocene beds were laid down.

COAL

A 21-inch bed of coal and several thinner layers are exposed in an open cut in sec. 17, T. 5 N., R. 3 E., on the south side of Sixmile Creek about 3 miles east of Toston. The coal is black, shows a few grains of amber-colored resin, and upon drying by exposure to the air slacks to a powder. It resembles the coals found in Tertiary beds elsewhere in southwestern Montana and probably is to be classed as subbituminous. Details of the exposure are given on page 23.

GOLD

Formerly, as described on page 4, gold derived from placer gravel was the chief product of Townsend Valley and the neighboring hills. Many years ago, however, placer mining in this region declined to relatively small importance. The last work of noteworthy extent was the dredging of a strip of valley gravel along the lower course of Magpie Creek east of Canyon Ferry. At present little is done except reworking or gleaning here and there in the old diggings. The total yield of gold in Townsend Valley and vicinity is estimated by persons familiar with the history of mining in that region to be several millions of dollars.

Since the decline of placer mining considerable quantities of gold and other metals have been produced from quartz lodes in the mountains that adjoin Townsend Valley. Most of the lodes are near Radersburg and Winston and in other parts of the Elkhorn Mountains, described by Stone.[21]

GROUND WATER

WATER IN PRE-TERTIARY ROCKS

Although the rocks of the older groups (Cretaceous to pre-Cambrian) are comparatively dense they contain numerous cracks, fissures, openings along bedding planes, and solution channels that allow water to circulate through them more or less freely and in the aggregate form capacious reservoirs. In the mountains surrounding Townsend Valley springs that issue from these rocks are, during the dry season at least, the chief source of the streams, which in turn supply most of the ground water contained in the Tertiary and later formations of the valley.

SPRINGS

Within the valley and just outside its limits are several springs in the older rocks, the most noteworthy of which are Big Spring, known also as Mammoth Spring, on the right bank of Missouri River about 5 miles south of Toston; Bedford Spring, on the bench north of Indian Creek, about 4 miles northwest of Townsend; and Mockel Spring, at the head of Warm Spring Creek, about 12 miles southwest of Toston.

Big Spring, which includes the water escaping at several places along a distance of 200 feet or more, issues from talus and gravel below a steep slope and collects in a beautiful transparent blue pool alongside the track of the Northern Pacific Railway. Its flow, which is said to remain fairly constant throughout the year, amounted in May, 1922, to 64.4 cubic feet a second, or considerable more than 3,000 miner's inches.[22] In July, 1921, the temperature of the water discharged at one of the larger openings was 59° F. By means of a concrete dam and a canal part of the water is diverted to irrigate lands near Toston; the remainder falls directly into Missouri River. The talus and gravel from which the water escapes evidently form a shallow deposit that overlies limestone belonging to the older

[21] Stone, R. W., Geologic relations of ore deposits in the Elkhorn Mountains, Mont.: U. S. Geol. Survey Bull. 470, pp. 75–99, 1911.

[22] The discharges of Big Spring, Bedford Spring, and Mockel Spring, as given herein, were measured May 18, 1922, by W. A. Lamb, of the U. S. Geological Survey.

group. Doubtless the water is discharged from an extensive solution channel in this rock. The spring is at the lower end of a horseshoe bend in Missouri River, the upper end of which is at Lombard, a distance of 1¼ miles in a straight line or 5½ miles following the course of the river. At Lombard is the mouth of Sixteenmile Creek, which drains the country back of the spring. Beds of limestone occur in the area between the spring and Lombard and extend into the area crossed by Sixteenmile Creek. At Lombard Missouri River is about 30 feet higher than the spring. These relations suggest that most of the water discharged by this spring may come through underground channels that tap the river or Sixteenmile Creek in the neighborhood of Lombard.

Bedford Spring includes several points of discharge distributed over an area of about an acre, but most of the flow comes from three openings spaced about 100 feet apart. The flow, which is used for irrigation and is said to remain practically constant throughout the year, aggregated in May, 1922, 3.09 second-feet, equivalent to about 150 miner's inches. During the last 30 or 40 years, however, the flow is said to have decreased gradually by an amount equal to about one-fifth the present discharge. In July, 1921, the temperature of the water coming out of the principal openings ranged from 73½° to 74° F. Although this spring issues from gravel that rests upon Tertiary beds, its temperature and constancy of flow indicate that its source is in the older rocks, far below the probable depth to which the younger formations extend.

Mockel Spring includes the water issuing at several places around a small area in which, by means of an artificial dam, it is collected in a pond. The flow, which is said to remain nearly constant throughout most of the year, amounted in May, 1922, to 9.7 cubic feet a second, or about 485 miner's inches. The water rises from the Madison limestone, a member of the older rock group, from which it gushes somewhat vigorously, as if it were confined under pressure. In July, 1921, the temperature at the principal points of exit was 62° F., a fact that indicates a rather deep source. The water is used for irrigation.

The analyses given on page 57 shows that the waters of these three springs are similar to most of the spring waters from limestone and dolomite such as occur among the older rocks. The waters may be classified as hard or moderately hard, but they are of excellent potable quality and suitable for most ordinary uses.

WELLS

Few wells have been made in the older rocks. One 100 feet deep, on the land of Hannah Harrison north of Crow Creek, penetrates the Spokane shale and yields a moderate amount of water. The shale dips 20° toward the valley, and the water it yields is probably contained in the bedding planes. No other wells in the older rocks were examined.

WATER IN TERTIARY AND QUATERNARY ROCKS

Except the clay or other fine-grained beds of the Oligocene series, most of the younger group of rocks contain within the saturated zone large amounts of water that is readily yielded to wells of ordinary size. Some of the Miocene beds and the valley gravel are very open textured and capable of yielding almost a third of their volume of water. The Oligocene sandstone and conglomerate are partly clogged with clay, but in places they are comparatively open and yield water rather freely.

The bench gravel is open textured, but because of its relatively high position it is devoid of ground water in most places. West of Missouri River, however, in the area between Beaver Creek and Indian Creek, gravel that probably ranges from Tertiary to Recent contains ground water that is the source of Antelope Springs and a few other small springs mentioned on page 53. The water-bearing layer rests upon Tertiary beds that, as indicated by the well of Clark Dewell, about 3 miles south of Antelope Springs, are dry. Similar perched bodies of ground water probably exist in the gravel that overlies the different benches next to the mountains between Deep Creek and Confederate Creek.

WELLS IN THE BENCH LANDS

More or less information concerning the ground water is given by the well records available, of which a number are listed in the accompanying tables.

The wells listed below are situated in the bench lands and derive water from sand and gravel in the Oligocene and Miocene beds. This table includes about three-fourths of the wells on the bench lands. Nearly all are drilled wells 5 or 6 inches in diameter, cased with iron pipe, and equipped with pumps operated by gasoline engines or windmills or, at a few, by both. Most of them were drilled within the period 1911 to 1919, at a cost for drilling and casing that ranged from $2 to $2.50 a foot. The wells south of Deep Creek end in gravel beds, some of which contain water under a slight pressure that causes it to rise a few feet. Most of the wells are on bench No. 1, from which the depth to water ranges from 150 feet to 250 feet or more. The yield of all may be rated as satisfactory in amount—that is, it equals or exceeds the capacity of the pumps installed, of which the most effective raise the water at the rate of about 6 gallons a minute. As shown by an analysis of the water from the well of John Doherty (No. 11, p. 57), the water, though moderately hard, is of good quality for domestic use and for irrigation.

The wells of the group southeast of Warm Spring Creek end in gravel beneath a layer of hardened clay or "cement rock," apparently a member of the Oligocene beds, and at several places the water-bearing layer rests upon the bedrock or surface of the older rock group. The ground water appears to be under little or no pressure. The wells are distributed over a surface that rises gradually from a low terrace bordering the valley bottom toward a range of hills and probably corresponds in part to benches Nos. 1 and 2. The depth to water ranges from less than 100 feet to more than 300 feet. With one exception all the wells listed yield as much water as their pumps, ranging in capacity from about 2 to 7 gallons a minute, can handle. The well of W. H. Hunt has only a small yield, apparently owing to the fact that it enters quartzite that forms a high point of the bedrock. An analysis of the water from the well of John A. Peugh (No. 10, p. 57) indicates that, though moderately hard, the water from these wells is suitable for all ordinary uses.

The wells between Duck Creek and Canyon Ferry penetrate water-bearing layers of sand and gravel, some of which belong to the Oligocene and others to the Miocene. The wells of Jeff Doggett, Todd & Lessing, J. A. Graveley, and W. H. Brown are on bench No. 2. Those of P. G. Gross and J. C. Thomas are on lower surfaces. All yield ample amounts of water for the needs of household and stock, except that at the time of examination the well of Mr. Graveley had become choked with sand. The analysis of water from the well of Todd & Lessing (No. 12, p. 57) is much like the other analyses and shows that the water is of good quality.

Records of wells in the bench lands

South of Deep Creek

Owner	Location			Depth of well	Depth to water	Yield[a]	Remarks
	Sec.	T.	R.				
				Feet	*Feet*		
Mrs. W. J. Boone	14	6 N.	2 E.	142	112	6.3	On bench No. 2. Penetrates Miocene gravel.
G. W. Gilham	12	6 N.	2 E.	130	100	L	In gulch below bench No. 1.
John Doherty	6	6 N.	3 E.	235	200	6+	On bench No. 1. Temperature 51° F. (Analysis 11, p. 57.)
Harry McCray	5	6 N.	3 E.	210	160	L	Bench No. 1.
J. C. Smith	9	6 N.	3 E.	210	160	7±	Do.
B. A. Klopton	4	6 N.	3 E.	210	190	6	Do.
Abner Melton	4	6 N.	3 E.	300	280	L	Do.
Geo. Ramspeck	8	6 N.	3 E.	190	170	L	Do.
Louis Perugin	18	6 N.	3 E.	105	65	L	In gulch below bench No. 1
L. S. Shearer	17	6 N.	3 E.	153	125	L	Below bench No. 1.
P. J. Meloy	16	6 N.	3 E.	253	190	L	On bench No. 1.

[a] L, M, and S indicate, respectively, yields estimated between 6 and 4, 4 and 2, and less than 2 gallons a minute. Figures give rates in gallons a minute at which the wells have been pumped.

Records of wells in the bench lands—Continued

Southeast of Warm Spring Creek

Owner	Location			Depth of well	Depth to water	Yield [a]	Remarks
	Sec.	T.	R.				
				Feet	*Feet*		
D. W. Jenkins	8	4 N.	2 E.	104	64	L	
G. F. Watkins	35	5 N.	2 E.	158	140	L	
Henry Byers	20	4 N.	2 E.	163	140	L	
Fred Schrader	4	4 N.	2 E.	168	148	L	
Fred Sharman	10	4 N.	2 E.	178	158	L	
W. H. Hunt	30	4 N.	2 E.	213	160	S	
J. A. Peugh	10	4 N.	2 E.	235	215	7	Temperature 51° F. (Analysis 10, p. 57.)
G. A. Tillson	16	4 N.	2 E.	300	220	L	
H. H. Peugh	10	4 N.	2 E.	303	280	L	

Between Duck Creek and Canyon Ferry

Owner	Sec.	T.	R.	Depth of well	Depth to water	Yield [a]	Remarks
Jeff Doggett	33	9 N.	2 E.	60±	50	M	On bench No. 2.
P. G. Gross	18	9 N.	2 E.	40	20	L	In valley below bench No. 2.
J. C. Thomas	31	9 N.	2 E.	75	57	L	Temperature 50½° F.
J. A. Graveley	6	9 N.	2 E.	210	200	M	Above bench No. 2. Flow choked by sand.
Todd & Lessing	35	10 N.	1 E.	144	130	6	On bench No. 2. (Analysis 12, p. 57.)
W. H. Brown	28	10 N.	1 E.	100	95	L	On bench No. 2.

[a] L, M, and S indicate, respectively, yields estimated between 6 and 4, 4 and 2, and less than 2 gallons a minute. Figures give rates in gallons a minute at which the wells have been pumped.

Elsewhere there are but few wells that penetrate the Tertiary beds. One of the wells of Mrs. Elizabeth Hartop at Canyon Ferry, in sec. 11, T. 10 N., R. 1 W., is just above the valley bottom and ends at a depth of 57 feet in hard Oligocene clay. This well receives an abundant supply of water from an open fissure in the clay. A well near by belonging to the school district is dug at the edge of the valley bottom and ends at a depth of 32 feet in water-bearing sand and gravel that lie below a bed of clay. The summer temperature of the water is 47½° F. The well of Frank De Witt, in sec. 34, T. 9 N., R. 1 E., at the foot of the bench lands east of Winston, is 100 feet deep and is in the tuff and volcanic conglomerate of the Beaver Creek section described on page 27. It yields a moderate amount of water which is noteworthy as being strongly mineralized and objectionable to the taste. The well of Charles Jacobs, in sec. 22, T. 6 N., R. 3 E., half a mile south of Greyson Creek, is in a gulch below bench No. 2 and ends at a depth of 120 feet in water-bearing gravel of the Oligocene beds. The water stands at about the same height as the creek. The well is drilled, cased with 6-inch iron pipe, and equipped with a windmill and gasoline engine and is estimated to yield 5 or 6 gallons a minute. The temperature of the water is 50° F.

A bored well belonging to C. R. Stevenson, in sec. 8, T. 5 N., R. 1 E., at Radersburg, is 3 inches in diameter, passes through yellow and brown clay of the Tertiary beds, and ends at 50 feet in a water-bearing layer of sand. It yields an ample supply of water which is shown by analysis No. 9 (p. 57) to be of good quality for general use. The temperature of the water as determined in July is 50° F.

The drilled well of Philip Mockel, in sec. 10, T. 4 N., R. 1 E., on a low bench south of Crow Creek, is cased with 5-inch iron pipe and ends at a depth of 124½ feet in gravel belonging to the Tertiary beds. It is equipped with a gasoline engine and it is said to yield continuously as much water as the pump can raise, estimated at 4 or 5 gallons a minute.

WELLS IN THE VALLEY BOTTOMS

The valley bottoms and bench No. 3 contain a large number of shallow wells that receive practically inexhaustible supplies of water from the valley gravel. Most of them are dug wells 3 or 4 feet in diameter; the remainder are drilled or driven wells of small size. The kinds of casings include wood, stone, brick, tile, and iron pipe. Many of the wells are equipped with windmills or gasoline engines; in others the water is raised by hand power applied to pumps of different types, and at a few wells the old-fashioned sweep, windlass, or pulley was still in use. The summer temperature of the water determined in several wells is 47½° F., or a little more than 4° above the average annual temperature of the region. Twelve representative wells are listed in the following table. Analyses of samples from three of these wells (Nos. 6, 7, and 8, p. 57) show that the water is somewhat hard but is suitable for all ordinary uses.

Records of wells in the valley bottoms and on bench No. 3

Owner	Location			Depth of well	Depth to water	Remarks
	Sec.	T.	R.			
				Feet	*Feet*	
Parks Trail ranch	14	4 N.	1 E.	60	45	
John Hossfeldt	8	4 N.	2 E.	36	33½	
John Rothfus	28	5 N.	2 E.	40	30	
B. G. Norton	33	7 N.	2 E.	16	12	Temperature 47½° F. (Analysis 6, p. 57.)
Viola Hahn	23	8 N.	1 E.	25	20	Near slough.
G. N. Mires	6	8 N.	1 E.	50	20	Temperature 47½° F. Water level raised by irrigation. (Analysis 8, p. 57.)
W. C. Daniel	6	8 N.	2 E.	30	20	
W. J. Gaab	29	8 N.	2 E.	35	10	Temperature 47½° F. (Analysis 7, p. 57.)
G. P. Keene	8	8 N.	2 E.	87	75±	Water level raised by irrigation.
Chas. Lefler	26	9 N.	1 E.	12	10±	Water level rises and falls with the river.
Mrs. W. F. Fisher	15	9 N.	1 E.	20	14	
C. J. Sheriff	10	10 N.	1 W.	16	14±	

PUBLIC WATER SUPPLIES

Townsend obtains its public water supply from the valley gravel beneath the bed of Deep Creek by means of drains or infiltration galleries near the east line of sec. 36, T. 7 N., R. 2 E., about 5 miles east of the town. The galleries, which are lined with 24-inch split drain tile, aggregate 200 feet in length and lie a few feet below the stream level. They discharge into concrete-lined chambers or wells from which the water flows by gravity through a tile pipe into two open concrete reservoirs that have a combined capacity of 360,000 gallons. The reservoirs are about 220 feet above the town, to which the water is delivered under the pressure of gravity. This waterworks was constructed in 1912 at a total cost, including 3 miles of mains and several fire hydrants, of about $60,000. The daily consumption of water in 1921 ranged from less than 200,000 to nearly 300,000 gallons, practically all of which was used by the inhabitants for ordinary household purposes, including the watering of lawns and gardens. The amount of water yielded by the infiltration galleries was estimated to range from 240,000 gallons a day in the winter to 380,000 gallons a day in the summer, the summer increase probably being due to irrigation. Apparently the yield could be largely increased by extending the galleries and constructing a dam or using other means to cut off the flow that doubtless escapes through a lower layer of the gravel. The quality of the water is satisfactory, although the analysis (No. 4, p. 57) shows more dissolved solids and hardness than are found in most of the other waters analyzed. On account of the high sulphate the water will form hard scale in steam boilers if used without treatment.

The Toston public water supply is furnished by the underflow of Sixmile Creek, an intermittent stream. The water is diverted by a bedrock dam and drain at a point about 2 miles east of the town and flows by gravity to a covered concrete reservoir having a capacity of about 50,000 gallons. It is distributed to the town, which is about 150 feet lower than the reservoir, by the pressure due to gravity. The total cost of the waterworks, including mains and fire hydrants, was about $17,500. The amount of water available at the source varies from time to time but is estimated to average about 50,000 gallons a day during the summer. The chemical character of the water is shown by analysis (No. 5, p. 57) to be very similar to that of the Townsend supply.

SPRINGS

At many places in the valley bottoms the ground water rises, forming seepage areas and springs that in the aggregate discharge a considerable volume. Several springs of this kind in the bottom adjoining Missouri River west of Canton post office are estimated to discharge in all from 10 to 15 cubic feet of water a second; the flow is larger during or after the irrigating season than at other times. Springs in sec. 27, T. 8 N., R. 2 E., 2½ miles east of Canton, rise from the valley gravel and form a small creek. Water rising into the valley bottom adjoining the lower course of Crow Creek forms swampy areas in several places, two of which are the sources of considerable streams. A spring on the land of Adnah Kimpton in sec. 24, T. 5 N., R. 1 E., about 5 miles west of Toston, was estimated in July, 1921, to be discharging about 100 gallons a minute, or about 0.2 cubic foot a second. The water issues from sand and gravel and forms a shallow pool in which bubbles of an inert gas, apparently carbon dioxide (CO_2), are continually rising. The temperature of the water was 64° F., and its source is probably rather deep in the gravel or the Tertiary beds. On the south side of the valley bottoms adjoining Greyson Creek in sec. 17, T. 6 N., R. 3 E., is a developed or dug out spring that, at the time of examination, was estimated to be discharging about 60 gallons a minute. The temperature of the water was 47½° F., the same as that of the ground water generally at shallow depths.

Antelope Springs, on the A. B. Cook ranch, in sec. 27, T. 8 N., R. 1 E., west of the river, and two small springs 1½ and 3½ miles northwest of them rise in boggy areas. They discharge comparatively little water, and apparently their supply comes from the gravel that overlies the Tertiary beds in this area. The distribution of these springs along a northwest line suggests that they mark the position of a fault or fold that elevates a water-tight bed and thus cuts off the ground flow toward the river. Near the mouth of Avalanche Creek, in sec. 29, T. 10 N., R. 1 E., a small spring that rises at the edge of the bench lands yields water that tastes slightly bitter and upon evaporation deposits thin crusts of white "alkali." The temperature of the water was 49° F., and its apparent source is the valley gravel.

WATER TABLE

In Townsend Valley the water table or upper surface of the saturated zone is nearly level but generally slopes gently in the same direction as the land surface. The water table is continuous with the surface of Missouri River and, except possibly at flood stages, rises gradually from that stream toward the mountains. It is continuous also with the surfaces of most of the perennial streams that join the river, but instead of rising under the lands that border them it generally either slopes gradually downward away from the streams or maintains the same level. For a short stretch near Winston Beaver Creek lies wholly above the water table, being separated from it by an aerated zone of considerable depth. Possibly some of the other perennial streams and probably all the intermittent and ephemeral streams are similarly perched. In most places in the valley bottoms bordering Missouri River, Deep Creek, Crow Creek, and several other streams the position of the water table ranges

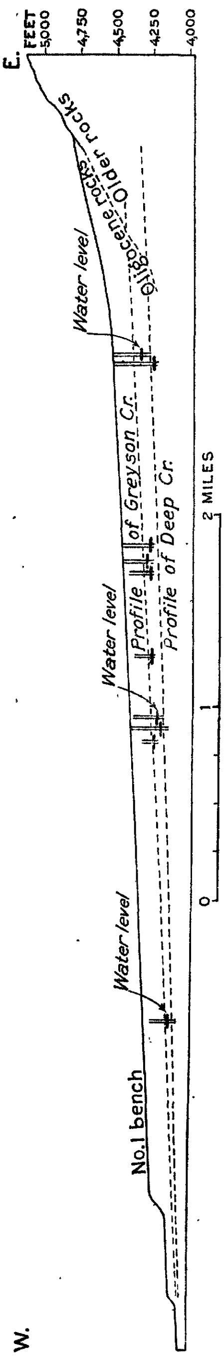


FIGURE 6.—Diagram showing water levels between Deep Creek and Greyson Creek

from the surface to a depth of 20 feet. At Winston, in the flat adjoining Beaver Creek, however, the depth to ground water is, or was before irrigation became general, as much as 50 feet below the surface. As it passes from the valley bottoms under bench No. 3 the water table does not change in form or slope, and its depth therefore ranges from 30 feet to 70 feet or more.

In some places in the bench lands between Deep Creek and Greyson Creek a water table is not present, owing to the occurrence of water-tight layers that confine the ground water. In these places the water rises in the wells to about the level of the water table in adjacent tracts. In the area between these streams the water in wells stands from 160 to 250 feet or more below bench No. 1 (fig. 6) and the head decreases toward the river with about the same gradient as Greyson Creek and also decreases away from Greyson Creek and toward Deep Creek, which flows at a lower level. Southeast of Warm Spring Creek the water table extends horizontally or with a slight descent under a rising surface (fig. 7). Between Duck Creek and Canyon Ferry the water table so far as known lies somewhat below the local streams, particularly in the area north of Confederate Creek, which is watered by several intermittent streams. As shown by existing wells it ranges from 100 to 200 feet below the surface of bench No. 2, and within a small area at least it stands 150 feet higher than Missouri River at a distance of 3 miles from that stream. In the remaining areas of bench lands little definite information concerning the water table is available. Between Greyson and Sixmile creeks its level as indicated by the well of Charles Jacobs, described on page 50 is near that of the local streams. West of Missouri River, in the area between Beaver Creek and Indian Creek, Antelope Springs and other small springs mentioned on page 53 rise from gravel that overlies the Tertiary beds. The distribution of these springs along a northwest line suggests that they mark the position of a fault or fold that elevates a water-tight layer. Between the springs and the mountains the water table doubtless rises, but its upward slope is less than that of the surface. This body of ground water, as mentioned on page 48, is perched above dry Tertiary beds. Whether another water body exists at a lower level in the Tertiary is not known.

In the area south of Radersburg and southwest of Crow Creek the water table as indicated by a few widely scattered wells is as low as Crow Creek or lower.

In the valley bottoms the height of the water table is not constant throughout the year. It rises during the high-water and irrigating seasons and falls at other times, the total fluctuation ranging from 5 to 15 feet or more. In many places a permanent rise of the water table has occurred since irrigation was introduced. As a result certain areas that are said to have been formerly well drained are now too wet for cultivation. A permanent rise in the water table of 30 feet is shown by the well of G. N. Mires at Winston. In the bench lands the water table appears to be not yet affected by irrigation, and, so far as known, its level does not change much with the seasons.

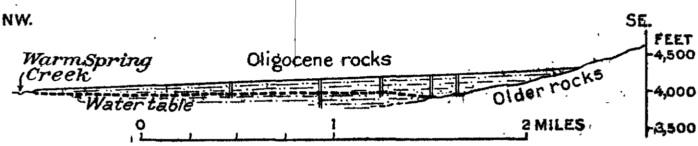


FIGURE 7.—Diagram showing water table southeast of Warm Spring Creek

SOURCE OF GROUND WATER

In humid regions most of the ground water is derived directly from rain or snow, a part of which sinks until it reaches what is called the zone of saturation. In these regions the water table conforms in a general way with the surface of the land. It is elevated and depressed, respectively, where there are hills and valleys, but its differences in elevation are somewhat less than those of the land surface. In Townsend Valley, owing to the comparatively dry climate, the amount of rain water that enters the ground is generally too small to sink very far, and, except where the water table is near the surface, it does not reach or add to the ground-water body at all but is soon absorbed by plants or drawn back by capillary attraction and evaporated. In this area the chief sources of the ground water are streams that flow from the mountains or other areas of greater rainfall, and in addition water probably enters the Tertiary beds from springs in the older rocks beneath them. As a result the water table is independent of the land surface, its slope and position being controlled chiefly by the streams. Between the mountains and Missouri River many of the streams lose considerable water to the gravels composing the valley bottoms. Several small streams, including Sixmile, Ray, and Gurnett creeks, sink entirely before they reach the river. Presumably all the larger streams contribute in the same way a part of their flow to the ground water, and since the settlement of the valley irrigation has added much water to the saturated zone.

In the bench lands between Deep Creek and Greyson Creek the head of the water in wells indicates that the ground water moves from Greyson Creek diagonally downward through the bench toward both Missouri River and Deep Creek. Therefore Greyson Creek appears to be the chief source of the ground water in this area.

Southeast of Warm Spring Creek the height and relation of the water table (fig. 7) indicate that that stream is one of the sources of the ground water, another being small springs that rise in the neighboring hills and sink at the edge of the valley. Between Duck Creek and Canyon Ferry the ground water evidently is derived from a number of mountain streams, most of which are either intermittent or ephemeral. On the west side of the valley between Beaver Creek and Indian Creek a number of small springs and ephemeral streams from the mountains supply ground water to the gravels overlying the bench lands. The summer flow of Indian Creek, said to be as much as 75 miner's inches, or 1½ cubic feet a second, sinks before the stream leaves the mountains and doubtless forms a body of ground water, as yet undiscovered, in the bench lands below.

Springs are fairly plentiful in the older rocks where they are not covered or concealed by rocks of the younger group. Within the covered area, which comprises most of Townsend Valley, at least one spring, Bedford Spring, breaks out of the older rocks and makes its way to the surface through the overlying beds. It is probable that other springs issue within the covered area and add their flow to the ground water, though there is no basis for estimating the amount thus contributed.

QUALITY

The analyses given below show about the average composition of the ground water in most of Townsend Valley. The samples were collected in midsummer. Earlier in the season many of the shallow wells in the valley bottoms are said to yield softer water, chiefly as a result of irrigation with the water from snow-fed mountain streams. The wells in the bench lands probably show little or no change with the seasons.

Analyses of waters from springs and from public supplies in Townsend Valley

[Analyzed by C. S. Howard. Parts per million]

	1	2	3	4	5
Silica (SiO_2)	20	16	22	38	46
Iron (Fe)	Trace.	0.08	0.10	0.06	0.10
Calcium (Ca)	46	60	70	109	108
Magnesium (Mg)	17	19	34	37	37
Sodium and potassium (Na+K) (calculated)	17	18	32	60	45
Carbonate radicle (CO_3)	0	0	0	0	0
Bicarbonate radicle (HCO_3)	183	151	332	331	329
Sulphate radicle (SO_4)	57	127	92	241	192
Chloride radicle (Cl)	8.0	8.0	11	23	35
Nitrate radicle (NO_3)	.49	Trace.	Trace.	Trace.	Trace.
Total dissolved solids at 180° C	259	336	408	706	657
Total hardness as $CaCO_3$ (calculated)	185	228	314	424	422
Date of collection	Jan. 25, 1922.	Aug. 27, 1921.	Aug. 18, 1921.	Aug. 27, 1921.	Aug. 17, 1921.

1. Big Spring, SE. ¼ sec. 6, T. 4 N., R. 3 E., 5 miles southeast of Toston, on right bank of Missouri River near Northern Pacific Railway.
2. Bedford Spring, NE. ¼ sec. 23, T. 7 N., R. 1 E., about 4 miles northwest of Townsend.
3. Mockel Spring, NE. ¼ sec. 27, T. 4 N., R 1 E., about 12 miles southwest of Toston.
4. Townsend public water supply. Infiltration gallery below bed of Deep Creek, near east line of sec. 36, T. 7 N., R. 2 E., about 5 miles east of Townsend.
5. Toston public water supply. Drain below bed of Sixmile Creek in sec. 13, T. 5 N., R. 2 E., about 2 miles northeast of Toston.

Analyses of water from wells in Townsend Valley

[Analyzed by C. S. Howard. Parts per million]

	6	7	8	9	10	11	12
Silica (SiO_2)	14	26	17	26	29	19	14
Iron (Fe)	Trace.	0.11	0.14	0.09	0.10	0.08	0.09
Calcium (Ca)	48	80	61	57	41	36	41
Magnesium (Mg)	22	24	14	19	15	19	36
Sodium and potassium (Na+K) (calculated)	21	26	21	52	40	13	16
Carbonate radicle (CO_3)	0	0	0	0	0	6.0	0
Bicarbonate radicle (HCO_3)	188	325	132	170	179	189	265
Sulphate radicle (SO_4)	87	63	46	148	73	25	60
Chloride radicle (Cl)	8.0	15	67	21	27	3.0	4.0
Nitrate radicle (NO_3)	.50	2.8	5.6	13	.46	.96	.58
Total dissolved solids at 180° C	306	407	340	437	336	221	306
Total hardness as $CaCO_3$ (calculated)	210	298	210	220	164	168	250
Date of collection (1921)	Aug. 25	Aug. 26	Aug. 23	Aug. 24	Aug. 22	July 22	Aug. 19

6. Driven well 16 feet deep of B. G. Norton, in SW. ¼ sec. 33, T. 7 N., R. 2 E., about 2 miles east of Townsend.
7. Driven well 35 feet deep of W. J. Gaab, in SE. ¼ sec. 29, T. 8 N., R. 2 E., at Canton.
8. Dug well 50 feet deep of G. N. Mires, in SW. ¼ sec. 6, 8 N., R. 1 E., at Winston.
9. Bored well 50 feet deep of C. R. Stevenson, in SW. ¼ sec. 8, T. 5 N., R. 1 E., at Radersburg.
10. Drilled well 235 feet deep of John A. Peugh, in SW. ¼ sec. 10, T. 4 N., R. 2 E.
11. Drilled well 235 feet deep of John Doherty, in SE. ¼ sec. 6, T. 6 N., R. 3 E., about 6 miles east of Townsend.
12. Drilled well 144 feet deep of Todd & Lessing, in SE. ¼ sec. 35, T. 10 N., R. 1 E., about 10 miles southeast of Canyon Ferry.

The analyses show that there are no unusual features in the composition of the waters examined. These waters contain the substances that are dissolved from rocks and soil by all natural waters. The main constituents are calcium, magnesium, bicarbonate, and sulphate. The calcium and magnesium cause the hardness that is the principal characteristic of the waters.

In Townsend Valley waters that have between 150 and 200 parts per million of hardness are generally regarded as slightly hard, and those with 200 to 300 parts as moderately hard. In some parts of the United States, where the hardness of the water regularly used for public and private suplies is less than 50 parts per million, water with 200 parts per million of hardness would be considered very hard. It is generally profitable for commercial laundries to install apparatus for softening water that has more than 100 parts per million of hardness. Softening of hard water is necessary for the efficient operation of steam-boiler plants. So far as the samples cover the area the softest water is found in the bench lands and the hardest in the gravels beneath Deep Creek and Sixmile Creek.

Except for hardness the waters for which analyses are given in the tables should be entirely satisfactory for all ordinary uses, both domestic and industrial. They are also suitable for use in irrigation.

ARTESIAN WATER

GENERAL CONDITIONS

Artesian water is ground water under sufficient pressure to rise above the water-bearing layer if, for example, this layer is penetrated by a well. Like ordinary ground water, artesian water usually occurs in the pores and cavernous spaces in an open-textured rock. The pressure, which is the distinguishing feature, is caused by the water being confined between impermeable beds or otherwise prevented from escaping from the layer that contains it. Commonly artesian conditions exist where a bed of sandstone or other permeable rock crops out on relatively high land and extends beneath an adjacent lowland. If the permeable bed is exposed at its outcrop to abundant rain or to the seepage from streams and if it is elsewhere properly incased or covered by layers of shale or other watertight material, it may become filled with water under artesian pressure. It is evident that little or no artesian pressure can arise in any part of a bed that lies above the lowest point of the outcrops or above the lowest point at which there is free leakage. It follows as a matter of course that flowing wells will be restricted to areas that are lower than such outcrops or leakages.

It appears that the Miocene beds, the bench gravel, and the valley gravel, because of their open texture and lack of confining layers, are generally incapable of holding artesian water. On the other hand, the Oligocene beds consist largely of clay in which are incased a few layers of sandstone and conglomerate of sufficiently open texture to hold considerable water and allow it to pass through them freely. These layers dip gently below the surface, and their outcrops are crossed by streams from which they doubtless receive abundant seepage. Therefore at least part of the conditions necessary to produce artesian pressure are present, and in places, as shown by wells in the bench lands south of Deep Creek, the water rises a little above the water-bearing beds. Nearly everywhere that they are to be seen, however, these beds crop out at levels lower than the lands they dip under. Along the zone of anticlines described on page 31 the water-bearing beds either crop out at the surface or beneath permeable gravel that underlies the lowest parts of the valley, and it is thus evident that in general they can not hold water under sufficient pressure to produce flowing wells. Possible exceptions to this condition may exist in small areas, such as the bench lands between Indian Creek and Winston, where the structure and other features of the Oligocene are obscure.

The fact that Mockel Spring gushes out somewhat vigorously suggests that bodies of water under artesian pressure probably exist here and there in the fissures or caverns of the older rocks. Except as their presence is indicated by springs, however, the discovery of such bodies, especially where the rocks are concealed by the Tertiary deposits, would be difficult if not impossible.

LOCAL CONDITIONS

Between Deep Creek and Sixmile Creek.—The Tertiary beds are bent into an arch, or anticline, along an axis that lies about 5 miles east of Townsend and that extends from Deep Creek to Sixmile Creek. East of this arch the beds dip toward the mountains, so that the outcrops of possible water-bearing beds are lower than the surface of the bench lands under which they dip, and therefore they evidently could not supply these lands with artesian water. West of the arch the beds dip westward, and where their outcrops are crossed by Deep Creek and other streams they doubtless receive abundant seepage. An artesian area therefore possibly lies west of the arch, but it is limited to the lowlands in the middle part of the valley, which are already irrigated. Townsend is in this possible artesian area.

North of Deep Creek.—From Deep Creek northward to the end of Townsend Valley, at Canyon Ferry, the possible water-carrying formations dip eastward, or toward the mountains, so that most of the points at which the outcropping beds could receive much water are lower than the lands for which flowing wells are desired. West of Missouri River along Beaver Creek below Winston the beds dip eastward, pass under the gravel flat along Missouri River, and extend beneath the bench lands beyond. Farther east they become thinner and finer textured and gradually give place to layers of sand and gravel that were brought down from the mountains. The lowermost beds, which crop out along Beaver Creek about 4 miles above its mouth, may carry water under artesian pressure eastward beneath Missouri River and under the bench lands beyond, though the tendency of the beds to thin out and the possible occurrence of faults or other causes of leaks make the limits of the possible artesian area decidedly problematic. In the benches immediately east and west of Missouri River the depth to the supposed water-bearing beds is estimated at 2,000 feet or more.

West of Missouri River.—Between Bedford Spring and Winston a rather thick sheet of gravel, which was evidently spread out by streams that issued from the mountains on the west, covers and conceals the Tertiary beds so effectually that their structure is not apparent. A clue to it is perhaps afforded by Antelope Springs and two other small springs, which break out along a line that trends northwestward and that probably marks the outcrop of an impervious bed which prevents farther movement of the ground water eastward. The ground water probably has its source in several small intermittent or ephemeral streams that head in the mountains at the west, and artesian wells may possibly be obtained in a part of the gravel slope between the springs and the mountains, though this is very uncertain.

The area south of Crow Creek comprises a wide flat along the stream and rather extensive low bench lands south of it. Tertiary lake beds appear to underlie most of this area, but as the older rocks project through them in places, their thickness is evidently not great. The structure of the Tertiary beds is concealed everywhere except on the western edge of the area, near Radersburg, where they dip gently eastward beneath gravel that covers the flat along Crow Creek. Within this flat, therefore, they may possibly contain artesian water.

INDEX