

# SOIL SURVEY OF THE GALLATIN VALLEY, MONTANA.

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## LOCATION AND BOUNDARIES OF THE AREA.

The Gallatin Valley lies slightly west of the south-central part of the State of Montana, and is agriculturally one of the most important and productive valleys of the northern Rocky Mountain States. The area surveyed consists of about 325 square miles, lying wholly within Gallatin County, and covers practically all the irrigated lands of the valley, together with a considerable extent of unirrigated farming and grazing land of the upper valley slopes or benches and the adjacent foothills. Upon the east and south it extends to the bald and rocky bases of the Bridger and Gallatin ranges or is separated from them

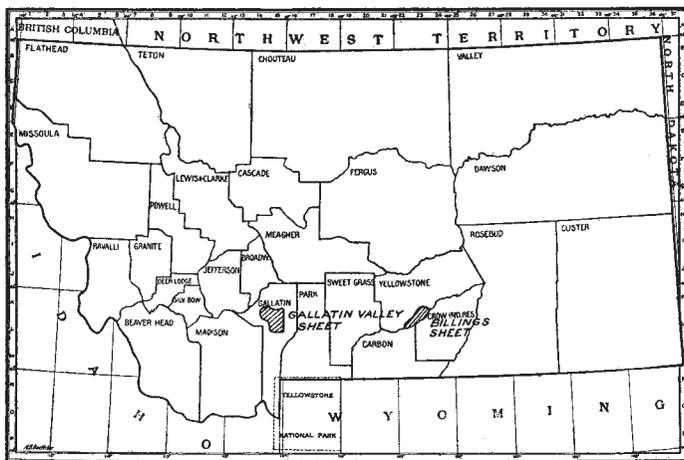


FIG. 42.—Sketch map showing location of the Gallatin Valley area, Montana.

by foothill and mountain slopes devoted to grazing and dry farming supplemented by irrigation from the smaller intermittent mountain streams. The northern boundary of the area is formed by a series of hills or ridges, partially devoted to dry farming. These are greatly dissected by numerous ravines and gullies and separate the Gallatin Valley from the valley of the upper Missouri, lying to the northwest. The western boundary is formed by a line arbitrarily drawn outside the limits of the irrigated lands, extending across the partially cultivated ridges and elevated rolling or dissected plains which separate the Gallatin Valley from the valley of the Madison River, only a few miles farther west.

## HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

Comparatively little has been written concerning the history of the early exploration and settlement of this section. Authentic history of the region begins with the explorations of Lewis and Clark. The entire Gallatin Valley was traversed in 1806 by Captain Clark in returning from the expedition to the mouth of the Columbia River. At this time and until many years later the valley was overrun with treacherous Indian tribes. Although no tribes made their home here, the valley and pass had been for years the natural highway of bands of Blackfeet, Crows, Flatheads, Nez Percés, Snakes, and other tribes on their periodical hunting expeditions to the Yellowstone and Snake River valleys. For years the white fur traders made visits to this region in quest of beaver and other furs. With the waning of the fur trade came the gold seekers, piloted by such men as Bridger and Bozeman. With the advent of the gold diggers agriculture was taken up in a small way. Frequently those who failed to find the precious metal found wealth in the rich, virgin soil, their farm products commanding high prices at the mines. The town of Bozeman and other permanent agricultural settlements were established in the early sixties. Agriculture flourished, but for many years the valley lacked outside communication, except by slow and costly wagon trains. With the coming of the Northern Pacific Railway in 1884 a new era in agriculture, made secure through the aid of irrigation, was inaugurated. Following the early settlers, who had traveled from Missouri and adjacent districts along the trail of Lewis and Clark, came immigrants from the Eastern and Middle States and from foreign ports. Farms multiplied, towns sprang up, and important manufacturing and shipping points were established.

## CLIMATE.

The average annual precipitation of the Gallatin Valley is between 16 and 17 inches, according to the records of the Weather Bureau station at Bozeman. Considerable of this is in the form of snow, there being usually from one to several months of sleighing at Bozeman during the winter. No data is available from other points in the valley, but the amount of precipitation in the lower part of the valley is believed to be slightly less than 16 inches, as the upper part of the valley, adjacent to the prominent mountain ranges, is subject to a heavier snowfall during the winter and a slightly greater precipitation from local thunderstorms and showers during the summer. The greater part of the annual rainfall comes during the late spring and the early summer months, the rains usually occurring as general storms with a gentle, steady precipitation. During the summer local

thunderstorms are of frequent occurrence, especially in the vicinity of the mountains, and are often accompanied by sudden high winds, dust storms, and hail. While sometimes violent and causing damage to growing crops, they cover a relatively small area and furnish an insignificant proportion of the yearly precipitation. The extremely violent cloud-bursts common in the Rocky Mountain region are practically unknown in the Gallatin Valley.

The average annual temperature at Bozeman is about 42° F., as shown by the monthly averages given in the table following. Warm and frequently hot days occur during the summer. The nights, however, are cool and pleasant, with but rare exceptions. During the winter fair, clear weather accompanied by extreme cold is of frequent occurrence, the thermometer sometimes registering as low as —30° to —50° F. These cold waves alternate with periods of moderate winter temperature. The extreme range of seasonal and daily temperatures is unusually high, a difference of from 30° to 40° sometimes occurring within twenty-four hours. Blizzards from the northwest are not uncommon, occurring generally during the late winter months. The last killing frost in spring is looked for about the latter part of May. It sometimes occurs considerably earlier, however, or it may come as late as the latter part of June. The first killing frost of the fall generally occurs about the middle of September.

The average annual humidity is low, greatly decreasing the sensible temperatures of both the hot days of summer and the intense cold sometimes reached during the cold waves of winter. The winds are extremely variable in movement and direction, being subject to great changes in both regards within short periods of time. There is, in general, a moderately brisk wind movement. This is especially noticeable in the lower part of the valley, where the upland plains during the fall are generally swept by daily winds of considerable velocity. During the winter months the warm southwest "Chinook" winds are of frequent, but variable, occurrence, often causing the sudden disappearance of the snow by direct evaporation. Considerable cloudiness occurs during periods of local thunderstorms, general rains, and the winter months. As a whole, however, the proportion of clear days is great. Fogs are practically unknown, except in the immediate vicinity of the larger streams. The general climatic conditions are such as to promote vigor and healthfulness and are favorable to crops.

The following table shows the mean annual temperature and precipitation at Bozeman:

*Normal monthly and annual temperature and precipitation.*

Month.	Agricultural College. <sup>a</sup>		Month.	Agricultural College. <sup>a</sup>	
	Temperature.	Precipitation.		Temperature.	Precipitation.
	° F.	In.		° F.	In.
January.....	23.3	0.80	August.....	63.4	0.63
February.....	22.4	1.11	September.....	52.1	1.51
March.....	29.0	1.16	October.....	46.0	1.04
April.....	40.6	1.91	November.....	31.1	1.27
May.....	51.1	2.74	December.....	26.9	.93
June.....	59.3	2.19			
July.....	63.2	1.31	Year.....	42.4	16.60

<sup>a</sup> Post-office, Bozeman.

#### PHYSIOGRAPHY AND GEOLOGY.

The Gallatin Valley, extending in a northwestern and southeastern direction, is about 25 miles long and has an average width of about 12 miles. The elevation ranges from about 5,600 feet at the southeastern extremity to about 4,200 feet at the northwestern end, the grade being steepest in the upper end of the valley. It is drained by the West Gallatin and East Gallatin rivers. These unite near the lower end of the valley and form the Gallatin River, which is a part of the headwaters of the Missouri. On the east the valley is bordered by the Bridger Mountains and on the south by the Gallatin Range. The former range of mountains is a most conspicuous feature of the landscape, presenting a bold valley border notched by canyons and natural passes. The range is formed mainly of stratified rocks and presents, when seen from the valley, a series of ledges, crags, and sharp pinnacles of light-colored rock, culminating in the smooth, rounded form of Bridger Peak and the more precipitous outline of Ross or Liberty Peak, these points reaching an elevation of about 9,000 feet.

The Gallatin Range, composed of volcanic material, is farther removed and less conspicuous, but its peaks are of sharp, precipitous outline, some of them reaching an elevation of more than 10,000 feet. The slopes of both these ranges are moderately well forested and favor precipitation and the conservation of winter snows until late in summer.

Upon the northwest there is a series of rough, greatly dissected hills, nearly barren of vegetation, composed of conglomerates, sandstone, quartzite, limestone, and shale. Extensive sloping terraces or fans, formed by the wash of material from canyon mouths, and plateaulike plains of ancient lake sediments form the remainder of the valley boundaries upon the northern and western sides.

The lands of the area surveyed fall naturally into two physiographic divisions—the valley bottoms or main valley depressions and the uplands, bench lands, or terraces. About one-half the area is covered by the valley bottoms. These have an average width of about 7 miles, extend across the area in the line of drainage, and are quite suddenly contracted at the lower or northwestern extremity, where the Gallatin River cuts through the inclosing hills in a narrow gorge. In addition to the two main branches of the Gallatin River several minor creeks of more or less regular flow traverse this part of the area. A heavy growth of cottonwood and willow, occurring as dense thickets, frequently borders the stream channels. In well-watered areas native grasses of rank growth sometimes appear.

Under normal conditions the main streams are of perennial flow, discharging their maximum floods during the months of May and June.

In the vicinity of the lower valley trough the stream banks are often poorly defined, the waters making their way through the bottoms by a series of interlacing, meandering streams. Natural drainage in these lower-lying sections is frequently deficient. Gravel, consisting of small, rounded pebbles and cobblestones, is usually found in abundance along the stream channels, and extensive stream-formed gravel beds occur.

The material covering the valley bottoms consists of well-worn rock fragments and fine alluvial soil formed by degradation of a variety of rocks occurring in the adjacent mountains and transported by running water from the surrounding benches, foothills, and mountain slopes. In the southeastern part of the area considerable gneissic colluvial material, derived from the lower slopes of the Gallatin Range, has been commingled with the alluvial earth and river gravels.

The uplands or bench lands extend to the north as long, uniformly sloping terraces or fans to the spurs and lower slopes of the Bridger Range. The surface is generally smooth, except where dissected by numerous ravines formed by mountain creeks or intermittent streams. Alluvial fans occur in the vicinity of the canyon mouths, while outcropping ledges of gneiss and accumulations of boulders, probably derived in part from glacial morainic material, are not infrequently seen along the margins of the mountain slopes and in the vicinity of the canyons. Thickets of willow and cottonwood usually occur in the ravine bottoms bordering the larger streams.

In the western part of the area the bench lands extend as a large, unbroken body southward from Manhattan to the boundary of the area. Here the slopes are less uniform and the land more deeply cut by intermittent stream channels, some parts being so rough and hilly as to be unfit for cultivation. The bench lands are usually separated from the river bottoms by lines of prominent bluffs or terraces. Gravel and cobblestones occur in profusion upon the more eroded surfaces and in the vicinity of bluff and terrace lines. The material

forming these upland benches or elevated parts of the valley consists principally of alluvial material laid down in the waters of an ancient lake at one time occupying the entire valley, modified and augmented by great quantities of pumiceous volcanic dust ejected from distant craters and by alluvial wash of recent date.

## SOILS.

In general the soils of the Gallatin Valley are fine-textured, heavy alluvial or silty loams. They are frequently marked by extensive accumulations of cobblestones and gravel occurring either upon the surface or as underlying deposits. Many of the soil types are quite similar in color, texture, and structure and merge or blend one into the other by imperceptible gradations. In such cases the boundaries separating the soil types are more or less arbitrary and unsatisfactory. Nearly all the types are subject to considerable local variation in depth, color, and structure, such variations usually occurring as small and relatively insignificant spots, but in the aggregate often covering a considerable extent of territory.

The following table shows the total area and relative extent of each type mapped:

*Areas of different soils.*

Soil.	Acres.	Percent.	Soil.	Acres.	Percent.
Bozeman silt loam .....	76,608	36.8	Gallatin fine sandy loam .....	6,464	3.1
Yakima silt loam .....	53,824	25.9	Bridger clay loam .....	1,472	.7
Gallatin gravelly loam .....	32,576	15.7	Gallatin clay loam .....	896	.4
Gallatin silt loam .....	23,808	11.4			
Bridger gravelly loam .....	12,544	6.0	Total .....	208,192	.....

## GALLATIN GRAVELLY LOAM.

The Gallatin gravelly loam consists of a compact, moderately heavy and sticky loam, dark-gray or brown in color, ranging in depth from a few inches to 3 feet. An appreciable amount of sharp particles of medium to coarse sand usually occurs throughout the soil section. Well-rounded pebbles and cobblestones are frequently thickly scattered over the soil surface, the larger fragments having to be removed to permit successful cultivation. The soil is underlain by a light-gray, sticky, silty loam, containing many flattened or well-worn pebbles or by great beds of cobblestones and pebbles mixed with river sands and extending to great depths. Frequently these beds occur within a few inches of the surface, the soil constituting merely a thin, superficial covering.

The Gallatin gravelly loam occurs most prominently as a single large body extending from the upper courses of Middle Creek and the West Gallatin River northward nearly to the valley trough, about 2 miles north of the town of Belgrade. Other small irregular-

shaped bodies occur in the vicinity of minor creeks and washes, grading into the loams of the valley bottoms. This soil type occurs as nearly level or slightly sloping areas, except in the vicinity of the larger streams, where it is occasionally marked by pits, local depressions, or minor terraces. A heavy growth of the shrubs and trees commonly found in the river bottoms obscures the course of the larger streams. Except in the immediate vicinity of the stream channels, however, the soil is generally devoid of tree growth.

Owing to the presence of underlying gravel beds the soil is usually well drained and often requires the application of large quantities of water in order to insure profitable growth of crops under irrigation.

The material from which the Gallatin gravelly loam is derived probably owes its origin and mode of formation principally to the degradation and the distribution by streams in flood of coarse materials gathered from the extensive gravel sheets of the Bozeman lake beds, augmented by finer alluvial material derived from the lake beds or from the rocks of the hills and mountains bordering the valley.

This soil is free from injurious amounts of alkali salts, and owing to the restricted depth of the productive soil it is frequently deficient in plant foods. Under sufficient irrigation and with proper attention to rotation of crops and with the application of green and stable manures, the soil where not too stony or shallow is fairly well adapted to the growing of grain, hay, or root crops, and to hardy fruits requiring well-drained soils. Wheat, oats, and barley, and occasionally clover and alfalfa are the principal crops grown, the yields being fair or even heavy under favorable conditions.

The average mechanical composition of the fine earth of this soil is shown in the following table:

*Mechanical analyses of Gallatin gravelly loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
13808, 13809.....	Soil.....	<i>Per cent.</i> 3.5	<i>Per cent.</i> 6.2	<i>Per cent.</i> 5.8	<i>Per cent.</i> 19.7	<i>Per cent.</i> 16.3	<i>Per cent.</i> 39.4	<i>Per cent.</i> 9.4

GALLATIN FINE SANDY LOAM.

The Gallatin fine sandy loam is subject to considerable variation in depth, texture, structure, and in the nature of the subsoil. It consists typically of from 18 to 30 inches of light-colored sandy loam of medium to fine texture, the coarser particles being rather sharp in character. It is slightly sticky when wet, but under cultivation assumes a loose, friable texture. A light sandy phase occurs, which will be described later. The soil is underlain by a light-gray, silty subsoil, frequently containing a large amount of well-rounded gravel and pebbles. The subsoil often grades into sheets of coarse river

gravel and sand, and sometimes the soil is underlain directly by this latter material.

The Gallatin fine sandy loam occurs only in the vicinity of the town of Manhattan, in the extreme northwestern part of the area, and extends downward with a moderate slope from the vicinity of the bluffs marking the upper slopes and bench lands to the Gallatin and West Gallatin River bottoms, from which it is separated by a prominent bluff or terrace. The surface is devoid of tree growth and is generally smooth in outline, except in the vicinity of the bluff lines and streams, where the plain is somewhat dissected by small ravines and gullies. Gravel consisting of well-rounded pebbles is of frequent occurrence upon the surface, and outcrops of the underlying rocks occur upon the bluff line bordering the Gallatin River bottoms in the extreme northwestern part of the area of this soil.

Owing to its position and texture and the nature of the underlying material, this soil is well drained and requires generous applications of water under irrigation.

The material forming this soil is probably derived from a variety of sources, consisting of stream-borne sands and fine sediments gathered from adjacent mountain ranges, mixed with material derived by degradation of the Bozeman lake beds. The soil is deficient in organic matter and is improved by the addition of green or stable manures. It is free from injurious alkali salts. The Gallatin fine sandy loam is generally not adapted to the growing of dry-farmed crops. Under rather copious irrigation it is fairly well adapted to the growing of alfalfa, clover, forage crops, grain, and fruits requiring a light and well-drained soil and adapted to the existing climatic conditions. A considerable portion of this soil type is devoted to grazing. Upon the remainder a fair to heavy yield of barley, oats, and leguminous crops is produced under irrigation.

There is a sandy phase of the Gallatin fine sandy loam covering the eastern-central part of the main soil body. Here the soil is of a looser and slightly coarser texture, resembling under cultivation a sand of medium fine texture. It is of a more leachy character than the typical soil and somewhat less productive. In depth, character of subsoil, physiography, and other features it follows the preceding description.

The results of mechanical analyses of this soil type appear in the following table:

*Mechanical analyses of Gallatin fine sandy loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
13806 .....	Soil.....	0.6	4.8	7.7	23.1	30.1	24.8	7.9
13807 .....	Subsoil.....	2.9	13.9	14.6	32.8	18.9	9.6	7.1

## YAKIMA SILT LOAM.

In extent of area covered and in general productiveness the Yakima silt loam is probably the most important soil type of the Gallatin Valley area. Like the other soils of the area, it is subject to some variation in texture and structure, but consists typically of from 10 inches to 3 feet of light-buff or brown loam of fine silty texture and somewhat compact structure. It becomes very sticky when wet and has a slight tendency to puddle, but under favorable conditions it is friable and easily cultivated. A compact stratum only a few inches thick frequently occurs immediately below the surface. This is, however, readily broken up by the plow. The subsoil consists of a fine, sticky, silty loam of light-buff color or more frequently of a light-gray loam of very fine ashy texture and moderately compact structure. Gravel usually occurs only in the vicinity of bluff and terrace lines, and upon eroded surfaces of marked slope.

The Yakima silt loam occurs most typically and extensively as a great uniform soil body lying along the western margin of the area. Other less extensive areas occur as elongated or irregular bodies throughout the south-central part of the area surveyed, and in the vicinity of the southern, eastern, and northern boundaries. This soil type covers the higher elevations of the area. In the eastern section it usually occurs as elongated, gently sloping, slightly elevated mounds or ridges. The southern and western bodies occur as elevated plateaulike ridges or plains, frequently marked by prominent bluffs and terraces, rounded hills, and gently sloping surfaces. The main body, lying to the south of Manhattan, is deeply cut by numerous ravines, gullies, and stream channels. In a few localities of higher elevation erosion has been carried on to so great an extent that a considerable proportion of the land is unillable.

Owing to the elevated position and well-developed slopes, the drainage of this soil is generally ample, although there is considerable loss by seepage from irrigation canals and ditches traversing the higher and often extremely gravelly terrace slopes.

The Yakima silt loam owes its origin mainly to the deposition in the ancient lakes of vast quantities of fine sediments, augmented by a considerable amount of finely-divided volcanic ash. Much of this material has since been reworked and redeposited by the waters of streams. Considerable fine alluvial material has also been added in certain districts to that originally deposited in the lake beds. While generally productive, the soil is somewhat deficient in organic matter and is benefited by green manuring and the rotation of the usual crops with alfalfa and clover. Much lime and volcanic ash material frequently occurs in the subsoil, which often carries small amounts of alkali salts. Owing to the natural drainage conditions, these salts are

in most cases readily removed from the soils and do not occur in injurious quantities within the zone of root development, and it is unlikely that material damage from alkali will ever result upon this soil type.

The Yakima silt loam is well adapted to the growing of grain, with or without the aid of irrigation, and when irrigated is adapted to alfalfa, clover, forage crops, sugar beets, and other root crops, and probably to hardy fruits. Wheat, oats, and barley are the principal crops grown. Under irrigation and with good management the yields are generally high. Alfalfa is also grown to a considerable extent and gives good returns. In favorable seasons excellent crops of grain are produced without irrigation.

The average results of mechanical analyses of this soil type follow:

*Mechanical analyses of Yakima silt loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
13810, 13813.....	Soil.....	0.1	0.4	0.4	2.3	22.8	65.9	8.0
13811, 13814.....	Subsoil.....	.2	.4	.3	1.8	20.8	66.3	9.5
13812.....	Subsoil.....	Tr.	.2	.3	1.4	13.2	69.4	15.0

BOZEMAN SILT LOAM.

The Bozeman silt loam consists of about 1 foot of brown to nearly black, heavy, sticky, silty loam of compact structure, but usually moderately friable when cultivated in proper condition. Some variation, both in texture and structure of soil and subsoil, frequently appears. The soil often shows a marked tendency to puddle under unfavorable drainage or cultural conditions, and small local puddled spots often appear in which the structure of the soil is very dense. These spots, locally known as "buffalo wallows" or as "gumbo land," are difficult to till and are generally unproductive. Rather coarse, well-rounded gravel and cobblestones frequently occur in both soil and subsoil. The subsoil to the depth of about 3 feet consists of a dark-brown, tenacious, heavy silty loam or silty clay loam of compact adobelike structure. This in turn is usually underlain by river gravel, or by a light-yellow or light-gray silty loam of fine ashy texture, extending to the depth of 6 feet or more.

The Bozeman silt loam is of wide distribution in the Gallatin Valley area. It occurs as numerous irregular-shaped areas which are most prominent and extensive throughout the central, eastern, and northern parts of the area surveyed. Along the northeastern margin of the area a large body of this soil covers a great portion of the foot slope extending to the base of the Bridger Mountains. This slope is much dissected by many ravines and the channels of intermittent streams.

The surface is generally gravelly, devoid of tree growth except in the vicinity of larger streams, and is unmarked by rock outcrops. Nearly all the other soil bodies of this type occur upon the lower valley slopes and depressions, frequently in the vicinity of the larger streams, and are unmarked by relief or prominent physiographic features.

Natural drainage in some parts of the lower lying areas of this soil type is frequently deficient. Here are sinks or depressions which form natural basins for the collection of seepage and drainage waters from the higher slopes, and considerable valuable land has been greatly damaged in this way.

The material forming the soil has been derived by degradation and reworking of the finer sediments of the Bozeman lake beds, with the addition of large quantities of more recent alluvium from the waste of adjacent mountains and valley borders. The subsoil frequently contains large quantities of lime. Injurious alkali salts are also frequently present in small amounts. In the lower lying districts of deficient drainage, particularly in the vicinity of the valley trough in the northern part of the area, these injurious salts have accumulated within the zone of root development to such an extent as greatly to reduce or even to prohibit the production of ordinary crops.

When well drained and free from alkali the soil is well adapted to the growing of grain, alfalfa, clover, root crops, and hardy fruits. The lower lying lands are better adapted to the production of timothy and clover. Under favorable conditions of drainage and cultivation grain, clover, and timothy yield heavily, the products being of excellent quality.

The average mechanical composition of the fine earth of the soil and subsoil of this type is shown in the following table:

*Mechanical analyses of Bozeman silt loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
13800 .....	Soil.....	0.2	0.7	0.5	1.4	8.1	71.3	17.8
13801 .....	Subsoil.....	.4	1.2	.7	1.6	9.3	69.4	16.8
13802 .....	.....do.....	Trace.	.9	.9	2.2	13.6	63.5	18.8

GALLATIN SILT LOAM.

The Gallatin silt loam consists of about 3 feet of black or very dark colored heavy sticky loam of fine silty or silty clay texture and is frequently gravelly. The soil is normally of a compact structure, sometimes assuming an adobelike character, but usually becomes friable under cultivation. In low, poorly drained districts it frequently assumes the properties of muck. The soil is underlain by a dark-brown, blue-black, or light-colored heavy loam or clay loam of fine silty texture, usually extending to the depth of 6 feet or more. This

underlying material is subject to much variation, sometimes resembling the light-gray, silty textured material normally underlying the Yakima silt loam and the Bozeman silt loam and sometimes being greatly restricted in depth or entirely displaced by the occurrence of gravel sheets. The main bodies of this soil type occur in the eastern and north-central parts of the area, in the vicinity of Bozeman Creek and the East Gallatin River, the most extensive area lying adjacent to the latter stream and in the district lying north of and between the towns of Belgrade and Manhattan. Other smaller bodies occur near the east-central part of the area.

The Gallatin silt loam occupies the lower valley depressions and river bottoms. The surface is nearly level and is frequently marked by meandering stream channels bordered by a heavy growth of willows and other shrubs and trees. A large portion of this soil type, occurring in local depressions and along the lower valley trough, is poorly drained, is marked by a growth of semiaquatic vegetation, and in its present condition is unfit for the production of ordinary farm crops.

The soil-forming material is a heavy alluvium, derived by complete weathering of the rocks of the adjacent ranges and by degradation of former alluvial deposits. This has been deposited in the form of finely divided sediments from stream waters and has been modified by chemical changes and the decomposition and incorporation of vegetable matter. The soil contains a large proportion of this well-decomposed organic matter. Alkali salts in injurious amounts sometimes occur in local districts of deficient drainage.

When well drained and properly cultivated the Gallatin silt loam is well adapted to the growing of clover, timothy, grain, forage and root crops, potatoes, and hardy vegetables. In its present condition a large proportion of this type is devoted to pasturage in connection with dairying. Some quite extensive sections produce large quantities of timothy, clover, and wild hay, while grain is profitably grown upon the better drained areas.

The results of mechanical analyses of this soil type are shown in the following table:

*Mechanical analyses of Gallatin silt loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
13803 .....	Soil.....	0.1	1.5	3.4	8.1	17.3	59.1	9.9
13804 .....	Subsoil.....	.4	1.1	1.2	5.5	16.3	62.1	13.3
13805 .....	.....do.....	1.1	1.4	1.8	12.0	26.3	40.9	16.5

GALLATIN CLAY LOAM.

The Gallatin clay loam is one of the least important soil types of the Gallatin Valley. It consists of about 3 feet of dark chocolate-brown, heavy, sticky, clay loam of compact adobelike structure, checking

upon exposed surfaces, and frequently containing numerous small angular rock fragments of the size of very fine gravel. It is normally underlain to the depth of 6 feet or more by a heavy silty clay loam of somewhat lighter color, or by beds of gravel. Both soil and subsoil are subject to considerable variation, and the type grades into the adjoining types without distinct soil boundaries. This soil type occurs as a few very small bodies of irregular shape, chiefly in the eastern and central sections of the area surveyed. It occupies local depressions of the valley floor or occurs as small bodies in the vicinity of the valley trough. The natural drainage of these small soil bodies is frequently deficient. The soil consists of the finest sediments and the heavy alluvial material gathered from a variety of sources and deposited from stagnant waters of overflowing streams or is formed by deposition from local intermittent streams of the finer washings from adjacent soil bodies. The Gallatin clay loam contains considerable organic matter. Small quantities of alkali salts frequently occur, but the damage resulting from this source has been relatively very slight. When well drained, this type is best adapted to the growing of grain and hay, to which purpose it is usually devoted. The yields are fair to heavy under favorable conditions.

The following table gives the average results of mechanical analyses of the soil and subsoil of this type.

*Mechanical analyses of Gallatin clay loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
13815 .....	Soil.....	0.2	1.1	1.4	6.5	10.9	49.6	30.0
13816 .....	Subsoil.....	.6	1.7	2.3	14.8	17.0	38.8	24.4

BRIDGER GRAVELLY LOAM.

Like the preceding soil types, the Bridger gravelly loam varies considerably in structure and texture and blends into the adjacent soil types without distinctive boundaries. It consists of from 1 to 3 feet of dark-brown to nearly black sticky loam of medium fine or fine texture, containing an appreciable amount of moderately coarse, sharp particles of stone. Gravel in variable amounts is of frequent occurrence in both soil and subsoil. It usually consists of flattened subangular or angular chips and fragments of small or medium size, while accumulations of cobblestones and boulders are not infrequent. The subsoil consists of a light-yellow or light-gray sticky silty loam of fine and sometimes ashy texture, frequently marked by the presence of the gravel of the overlying soil.

The most extensive and important bodies of the Bridger gravelly loam occur as irregular-shaped areas lying along the northeastern

margin of the area surveyed. Other smaller and less important, irregular-shaped bodies occur near the southeastern and southern boundaries. The larger bodies of this type occur upon the prominent foot slopes of the Bridger Mountains. They usually occur next to the mountains or as alluvial fans or partially eroded areas at a greater distance from the base of the mountains, upon which the washing of material from the mountains by canyon streams has been most active. The areas of this type are intersected by bodies of the Bozeman silt loam, and the surface, while generally of quite smooth, uniformly sloping outline, is frequently cut by ravines and canyon streams. The smaller bodies lying along the southern and southwestern margins of the survey occur as small fans or foot slopes adjacent to the mountains or hills or cover portions of the rough, hilly ridges along the southwestern boundary of the area. Rock outcrops and masses of boulders distributed by torrential mountain streams and the ice sheets of retreating glaciers occasionally occur on this type in the vicinity of the canyon mouths of the Bridger Range.

Owing to the elevated position, pronounced slope, and general character of soil and subsoil, the drainage of the Bridger gravelly loam is very good, and, where irrigated, considerable loss from run off and seepage frequently occurs. This soil is of colluvial origin, being derived from the weathering of rocks of the adjacent mountain slopes, washed down by heavy rains and intermittent mountain streams. This material is derived chiefly from the gneissic rock forming the lower slopes of the Bridger and the Gallatin ranges. In many of the areas of this soil type lying at some distance from the mountain slopes the overlying colluvial material is merely a thin covering deposited upon the fine sediments of the Bozeman lake beds.

The Bridger gravelly loam is devoid of alkali salts and is probably less rich in available organic and mineral plant foods than the finer alluvial soils of the bench lands and valley floor. Under efficient cultivation and with irrigation, it is generally adapted to the growing of grains, alfalfa, and hardy fruits. The less gravelly and more compact bodies of this soil are fairly well adapted to grain and hardy fruits, under careful methods of dry farming. Grain and, where capable of irrigation, alfalfa, are practically the only crops grown, the yields from the less porous and more compact bodies of the type being generally good in ordinary seasons.

The results of mechanical analyses of the fine earth of the soil and subsoil appear in the following table:

*Mechanical analyses of Bridger gravelly loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
13820 .....	Soil.....	2.7	5.1	4.3	16.7	19.5	36.3	15.4
13821 .....	Subsoil....	2.6	4.7	4.9	19.0	20.7	32.2	15.9

## BRIDGER CLAY LOAM.

The Bridger clay loam is a relatively unimportant soil type. It consists of from 1 to 3 feet of black, heavy clay loam, frequently containing considerable fine angular gravelly material, and has a compact, adobelike structure. It is usually underlain by a light-yellow or light-gray compact silty clay loam or silty clay, frequently gravelly, and often containing a high percentage of lime. The depth to the subsoil is subject to much variation, and the areas of the type are without definite boundaries.

The Bridger clay loam occurs as a few small, irregular-shaped bodies along the southeastern, southern, and southwestern borders of the survey. It occupies sloping terraces or slopes bordering the mountain slopes of the Gallatin Range and the flanking foothills. The natural drainage system is well developed, but owing to its peculiar structure and texture the soil is capable, under careful cultivation, of retaining a large quantity of moisture for long periods of time and supplying it to the crops in time of drought. In its origin and mode of formation this soil is similar to the Bridger gravelly loam.

Although somewhat heavy and refractory, under proper cultivation the soil becomes moderately friable and is well adapted to the growing of grain without the aid of irrigation and to grain and alfalfa under irrigation. Grain is the principal crop grown, the yields usually being good to very good.

The results of mechanical analyses of the fine earth of the soil and subsoil of this type are shown in the following table:

*Mechanical analyses of Bridger clay loam.*

Number.	Description.	Fine gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Clay.
		<i>Per cent.</i>						
13817 .....	Soil.....	0.4	1.3	1.1	3.6	9.5	58.1	25.8
13818 .....	Subsoil.....	.4	1.4	1.3	3.3	9.3	54.6	29.2
13819 .....	.....do.....	.8	2.1	1.4	3.7	11.9	44.1	36.0

## SOIL PROBLEMS.

The term "hardpan" as applied to soils refers to a more or less compact, impervious structural condition, due to physical or chemical agencies. Streaks, beds, and much broken sheets of this material are of common occurrence throughout the Gallatin Valley, and frequently exert considerable influence upon drainage, cultivation, and crop production. There is much variation in the extent and character of these sheets or beds of hardpan, but they are prohibitive of successful agriculture only in small local areas.

In the soils of the area surveyed there also frequently occurs near the surface a stratum of compact, adobelike structure a few inches

thick. This material is sometimes partially cemented by lime or other substances, offers some resistance to plowing, and resists washing by rapidly flowing water for long periods of time. Rains percolate through it slowly, and where it occurs on slopes and hillsides some loss of irrigation water may be caused by the hastening of surface drainage or run-off. It is, however, not a true hardpan, and even, where occurring at the surface, is capable of cultivation when in proper moisture condition. Upon dry-farmed tracts it may be of no little benefit in retarding percolation of rains to the more porous subsoil, and thus conserving the soil moisture for the use of crops during periods of drought.

In the light-gray subsoils of ashy texture, frequently occurring in the area, local streaks or bands of white hardpan, caused by indurated layers of fine river silts, clays, and volcanic dust, more or less cemented by lime or other substances, are of common occurrence. These frequently exert an unfavorable influence upon the percolation and drainage of subsoil waters, or may, like the so-called hardpan described above, prove of benefit when occurring in the higher dry-farmed soils with more porous subsoils.

The term "gumbo" as used in the Gallatin Valley has a local meaning, and refers to a puddled, untillable structural condition of the soils rather than to any particular type of soil. This condition occurs usually as small local spots or sinks, frequently only a few yards in diameter, and sometimes marked by the presence of the puddled depressions common to the plains of the Northwest, known as "buffalo wallows." Small quantities of alkali salts often occur in these spots, and their unproductiveness is commonly attributed to this cause. Their presence is, however, due to the poor drainage and the compact structure of the soil, and the alkali salts are not usually present in sufficient quantities to render the soil unproductive.

The cause of this unfavorable condition of soil lies in the deficient drainage of these local spots, the trampling and puddling of the wet soils by animals, the outcropping of underlying impervious hardpan, or the cultivation of poorly drained bodies of heavy refractory soils when too wet. Artificial drainage and the application of large quantities of green or stable manure, straw, or other organic matter would probably improve the structural condition of such areas and render them productive.

#### WATER SUPPLY FOR IRRIGATION.

The principal source of irrigation water for the area is the West Gallatin River, from which the canals covering the main central and western parts of the area are taken. In addition, the waters of many creeks and small streams of more or less regular flow supply small,

independent irrigating systems or are led into the larger canals through natural or artificial channels. The West Gallatin River, with a drainage area of 860 square miles, had a mean discharge of 991 second-feet, or 718,260 acre-feet, during the year 1900, according to the records of the U. S. Geological Survey gaging station near Salesville. Its maximum discharge of over 5,000 second-feet occurred during flood periods of May and June.

The supply of water has usually been considered sufficient for the area under irrigation. During the past few seasons, however, limited snowfall in the mountains, coupled with the continued extension of irrigated area, has caused a marked shortage in supply and has greatly decreased crop production in certain districts supplied by canals taking their water from the lower courses of the streams. Loss from seepage is common, especially from those canals traversing bluff lines and the gravel beds of river bottoms.

The greater number of the smaller canals are constructed and maintained cooperatively by the patrons, the cost of water varying with the expense of maintenance. A few of the larger canals, like the two operated by the West Gallatin Irrigation Company, in the extreme western part of the area, supply water to their patrons at a flat rate. The average maximum cost of irrigating ordinary farm crops is about \$3 an acre.

Owing to the extension of the irrigation systems and to the limitations of water supply through natural agencies, the question of water rights is becoming a somewhat involved and disputed one. It is probable that considerable litigation will be necessary properly to establish the status of the various systems. A more careful construction of canals, headworks, flumes, etc., and the more economical use of water are urged, as by these means alone considerable saving of water could be made annually.

Since the irrigation water is derived largely from melting snows, its application in large quantities to young and tender plants, such as sugar beets or similar crops, early in the spring might cause a certain degree of chilling and temporary arrest of growth. In all other respects the quality of the water is excellent.

#### UNDERGROUND AND SEEPAGE WATERS.

The most prominent area of deficient drainage in the survey occurs in the vicinity of the East Gallatin and Gallatin rivers, north and northwest of the town of Belgrade. This large body of land, covering an irregular-shaped area of about 10 square miles, occupies the lower valley trough and is locally known as the "swamp." This was the first area to be cultivated after the settlement of the valley, and it was for a long time productive and valuable farming land. With the exten-

sion of irrigation the water table in this district has gradually approached the surface. In certain sections bordering this district irrigation is no longer necessary, as the soils are sufficiently wet by seepage or subirrigation arising through the application of large quantities of water upon higher lying lands, while upon extensive tracts within the district the land has become so water-logged that it is unfit for cultivation and large areas are now devoted only to grazing. In addition to this large district many smaller areas generally occupying former stream channels and extending in a north and south direction suffer from deficient drainage.

The accumulation of harmful quantities of soil water in these areas of deficient drainage is due to loss of water by seepage from canals or by run-off from slopes when irrigated. The remedy for this unfortunate condition consists in greater economy in the use of irrigation water, in preventing loss by seepage, and in thorough drainage of the subsoil. In the Gallatin Valley the conditions prevailing in much of the swampy lands and local areas of deficient drainage could be greatly improved by direct drainage, involving the cutting of a few open ditches or the laying of a few lines of tile. A more complete and thorough system of underdrainage would be necessary in the case of the lower lying areas in order to remove the fast accumulating subsoil waters. With the further extension of irrigation, conditions in these lower lying areas will become worse. If reclaimed, these tracts would form some of the most valuable and productive farming lands of the area surveyed.

#### ALKALI IN SOILS.

Only a relatively small proportion of the soils of the Gallatin Valley has been rendered unproductive by the presence of injurious amounts of alkali salts. In certain localities, however, considerable mischief has been wrought and the problem is becoming one of increasing importance. The main alkali areas occur in the vicinity of the valley trough, near the northern boundary of the survey. A small body of alkali land occurs a short distance south of Manhattan. A few other small spots or local areas occur in the central part of the area.

Of the alkali salts, sulphate of sodium is probably the most common in the Gallatin Valley. It is one of the least injurious of the common alkali salts, but is considered dangerous in concentrations greater than 0.20 per cent of the dry soil. Sodium bicarbonate is also of frequent occurrence in the soils and underground waters of the valley, while in certain districts the more highly injurious sodium carbonate or "black alkali" occurs in such quantities as either to reduce or prohibit the production of crops. The minimum limit of

concentration of this extremely noxious corrosive substance is placed at 0.05 per cent.

The subsoils of the Gallatin Valley commonly contain small quantities of injurious alkali salts, which when evenly distributed are not injurious to ordinary crops. Under the influence of seepage and excess irrigation waters much of this soluble material is dissolved and removed by the soil waters to the lower lying areas, where under the influence of rapid evaporation the soil solutions become concentrated and the salts accumulate within the zone of root development or are deposited upon the surface in the form of an alkali crust. Several methods have been proposed for the reclamation of alkali lands, but thorough underdrainage is the only method which removes the cause of the trouble. After drainage is established the occasional flooding of the surface leaches the salts into the subsoil, from which they are removed with the soil waters by drainage. The mere draining of the land without flooding would greatly mitigate the evil, and in time allow of the removal of the salts by natural leaching processes. In connection with drainage and flooding the growing as soon as possible of some cultivated alkali-resistant crop is of importance, as frequent cultivation of the soil surface, forming a loose soil mulch, tends to check evaporation and the further accumulation of the salts. Sugar beets and sorghum are among the most valuable crops for this purpose. Sorghum might, however, prove unsuited to the climatic conditions in the Gallatin Valley. The growing of sugar beets upon alkali soils is not recommended for factory purposes, as the excess of alkali salts may greatly affect the quantity and purity of the sugar content, but their value for feeding purposes is not impaired.

#### AGRICULTURAL METHODS.

The Gallatin Valley is not a district of diversified agriculture. The profitable crops are limited by climatic conditions and as yet little attempt has been made to grow field crops other than grain and hay. The growing of grain is by far the leading industry. Under these conditions of uniform production of a few common crops there is much similarity in the agricultural methods practiced. While considerable backwardness in the adoption of up-to-date methods is observed in certain sections of the valley, particularly in some of the earlier settled districts, the methods in vogue are generally well adapted to the soils, climate, and general economic conditions. The character of the crops produced, the farming of large areas, and the cost of labor have given rise to the widespread use of modern farm machinery and the development of labor-saving methods. The preparation of the land for crops is generally accomplished with greater thoroughness than is observed in many of the grain-producing districts of the West.

Deep and thorough plowing and harrowing is of importance in forming a favorable seed bed and in allowing of a ready percolation of the soil by rains, and is of special value in the case of dry-farmed tracts. If followed by surface cultivation immediately after heavy rains or during periods of drought, when the character of the crop permits, the soil reaches the greatest efficiency in the collection and retention of moisture.

Summer fallowing is generally practiced on the dry-farmed tracts. In irrigated districts the rotation of grains with alfalfa and clover is a matter of common practice, resulting in increased yields and permanent benefit to the land.

Harvesting is accomplished by the self-binder, shocks are rarely capped or otherwise covered, and thrashing is frequently delayed until well into the late fall or winter months. Grain is seldom stacked in the field, but is hauled directly to the machine and thrashed. The machines are of the modern type, automatically feeding the grain and stacking the thrashed straw. When thrashed, the sacked grain is piled in the field until hauled to warehouses or elevators. Although frequently exposed to fall and winter rains and snows, but little damage is said to result from this apparent neglect.

Irrigation is generally accomplished by flooding, and both the canal construction and the methods employed in applying water to the land are frequently careless and wasteful. The use of more and better constructed flumes and pipe conduits in crossing ravines and gullies, while an item of greater initial expense, would materially shorten the canal lines and prevent the loss of much water by seepage. The use of more moderate quantities of water in irrigating crops and greater care in the preparation of lands by leveling and checking for irrigation are also to be recommended. The washing and cutting of the hill slopes by ditches and laterals with an excessive degree of fall is a frequent cause of irreparable injury and disfigurement and might easily be avoided.

#### AGRICULTURAL CONDITIONS.

In general, the farmers in the Gallatin Valley are prosperous and contented. The early temporary farm buildings were mostly constructed of logs, but now these first dwellings upon newly settled tracts generally consist of board cabins or modest cottages. The old log houses are still common, but in general these temporary structures have been replaced by more substantial frame buildings, frequently of neat and attractive appearance and bespeaking a condition of thrift upon the part of the inhabitants. Large, well-built barns and other farm structures are also common in the older and more thickly settled districts. The farming lands are usually well fenced and the condi-

tion of the live stock is generally good. There is, however, opportunity for improvement by the breeding of better grades.

The most of the farms are operated by the owners, although the renting of lands upon a cash or crop percentage basis is not uncommon. The farms usually consist of from 80 to several hundred acres. The average size farm for Gallatin County according to the census of 1900 was 388.1 acres. For the area surveyed, however, the average size is undoubtedly much less. Farm labor is performed entirely by whites. The cost of labor is somewhat high, but it is generally of a reliable and efficient character.

The principal agricultural products of the area are wheat, oats, barley, and hay, the latter consisting of alfalfa, timothy, clover, and wild hay. Alfalfa, upon the higher and better-drained lands, and clover, upon the lower lands, are grown with excellent yields with the aid of irrigation. Timothy and wild hay are grown upon the wet lands of the lower depressions or valley bottoms. Hay generally brings good prices, either baled or in the stack. Grains generally yield abundantly and the quality of the product is excellent. The soft club wheat is grown in the irrigated districts, producing in favorable seasons from 35 to 45 bushels per acre, while yields of 60 bushels and upward are said to be not uncommon. The hard Fife wheat is produced in the dry-farmed districts. The yield is subject to considerable fluctuation, depending upon climatic conditions, but usually ranges from 20 to 45 bushels per acre. Oats are in good demand and are quite extensively grown, producing heavy yields. Barley is also grown to a considerable extent, especially in the western part of the area, frequently yielding 60 or 70 bushels per acre. It is of excellent quality, much of it being purchased at fancy prices for export and domestic use for malting purposes. Stock raising and dairying are of considerable importance and are capable of further development. Hardy fruits could probably be produced profitably, while there is also a considerable local demand for vegetables. The climatic conditions are, however, unsuited to the growth of the more delicate vegetables and fruits. But little attention is paid to the adaptation of soils to crops, the limitation and control of the profitable crops by climatic conditions being here of greater weight.

The condition of the country highways during the summer season is usually good. During the wet periods of late fall, winter, and early spring they frequently become extremely muddy and might be greatly improved. This condition is aggravated by the general use of narrow-tire farm wagons in hauling grain and other heavy loads during the fall and winter seasons. The area is traversed by the main line of the Northern Pacific Railway. Local freight and passenger service is capable of improvement, while freight rates upon farm products are high and are generally considered excessive.

Bozeman, the county seat of Gallatin County, is the largest town and offers a local market, as well as shipping facilities, for farm and dairy products. Other important shipping points are Belgrade, Central Park, and Manhattan. Bozeman, Belgrade, and Manhattan are provided with mills and elevators of large capacity and are equipped with modern machinery for milling or shipping the great grain crops of the valley.

While the crops suited to the climatic conditions of the area are somewhat limited in number, the lands of this district are undoubtedly capable of producing a greater diversity of crops, including hardy fruits and sugar beets, and of supporting a much greater population.

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