

SOIL SURVEY

(RECONNAISSANCE)

Central Montana

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How to Use THE SOIL SURVEY REPORT

FARMERS who have worked with their soils for a long time know about soil differences on their own farms, and perhaps about differences among soils on farms owned by their immediate neighbors. What they do not know, unless soil surveys have been made, is how nearly their soils are like those on experiment stations or other farms, either in their State or other States, on which new or different farming practices or enterprises are in operation. Some of the risk and uncertainty involved in trying new crops and soil management practices can be avoided by using soil survey reports, for they give farmers an opportunity to compare their own soils with soils on which new developments have proved successful. This survey of central Montana is intended primarily to help ranchers and dry-land farmers with problems met in managing large tracts of land. The map is therefore not so detailed as some soil maps intended for use by irrigation farmers or by operators of smaller farms in the more humid sections of the United States.

SOILS OF A PARTICULAR FARM

The soils of central Montana are shown on the map in the envelope inside the back cover of this report. An inch on this map equals 4 miles on the ground. To learn what soils are on a particular farm or tract of land, first locate the boundaries of the farm or tract on the map by referring to section, township, and range lines and by noting roads, streams, villages, dwellings, and other landmarks. The next step is to identify the soils on the farm or tract. Each area of each kind of soil is shown on the map with a symbol and a distinguishing color. The map legend gives the name of each soil and the symbol and color used on the map to identify that soil. For example, all areas on the map marked with the symbol Mx are Morton silt loam, and all areas so marked are the same color, wherever they appear on the map.

If you wish to know what Morton silt loam is like, for what it is used, and to what uses and management it is suited, turn to the section on Description of Soil Units. If you want to know how productive this soil is, consult table 7. You will find the name of this soil in the left-hand column of this table, and in columns following you can read the yields of different crops this soil can be expected to produce. You can compare these yields with those given in the table for other soils in the area mapped.

SOILS OF THE AREA AS A WHOLE

A general idea of the soils in the area is given in the section on Soils, which tells about the principal kinds of soils, where they are found, and how they are related to one another. After reading this section study the soil map and notice how the different kinds of soils are grouped according to colors as farming, grazing, and farming-grazing soils. These groupings are associated with well-recognized differences in types of farming, land use, and land-use problems.

A newcomer to the area, especially if he considers purchasing a farm, will want to know about the climate; the types and sizes of farms; the principal farm products and how they are marketed; the kinds and conditions of tenancy; the kinds of farm equipment and machinery used; schools; roads and railroads; industries; cities and villages; and population characteristics. Information about these will be found in the section on General Nature of the Area and in the section on Agriculture.

Those interested in how the soils of the area were formed and how they are related to the great soil groups of the world should read the section on Morphology and Genesis of Soils.

This publication on the reconnaissance soil survey of Central Montana is a cooperative contribution from the—

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SOIL SURVEY (RECONNAISSANCE) OF CENTRAL MONTANA

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United States Department of Agriculture in cooperation with the Montana Agricultural Experiment Station

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¹ The Division of Soil Survey was transferred to the Soil Conservation Service on November 15, 1952.

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THIS reconnaissance survey of central Montana covers 10 counties—Lewis and Clark, Cascade, Judith Basin, Fergus, Petroleum, Musselshell, Golden Valley, Wheatland, Meagher, and Broadwater. The physiography is varied, and the climate midcontinental. Tall grasses and shrubs are predominant on the higher plateaus and tablelands, and short grasses on the plains and in the lower intermountain basins. The grasses, abundant water supply, and favorable climate and terrain make the surveyed area one of the most important for stock raising in the State. Sheep and beef cattle are the principal livestock. Only a small percentage of the total acreage is in crops and summer fallow, but returns from crops make up a sizable part of the total farm income.

The leading commercial crops are winter and spring wheat. Barley, oats, and hay are grown mostly as livestock feed. The irrigated land, most of it on the stock ranches, is planted largely to forage crops, but some sugar beets and potatoes are successfully grown. Abundant natural resources—water power, coal, crude oil, iron, copper, silver, lead, gold, sapphires, building stone, gypsum, and others—support industries that employ many residents. This cooperative soil survey was made by the United States Department of Agriculture and the Montana Agricultural Experiment Station to furnish a basis for determining the best agricultural uses of land in central Montana. Field work was completed in 1940, and, unless otherwise specifically mentioned, all statements in this report refer to conditions at that time.

GENERAL NATURE OF THE AREA

LOCATION AND EXTENT

The Central Montana area is made up of Lewis and Clark, Cascade, Judith Basin, Fergus, Petroleum, Musselshell, Golden Valley, Wheatland, Meagher, and Broadwater Counties, all located in the central part of the State (fig. 1). The area covered by these counties extends eastward from the main range of the Rocky Mountains for some 230

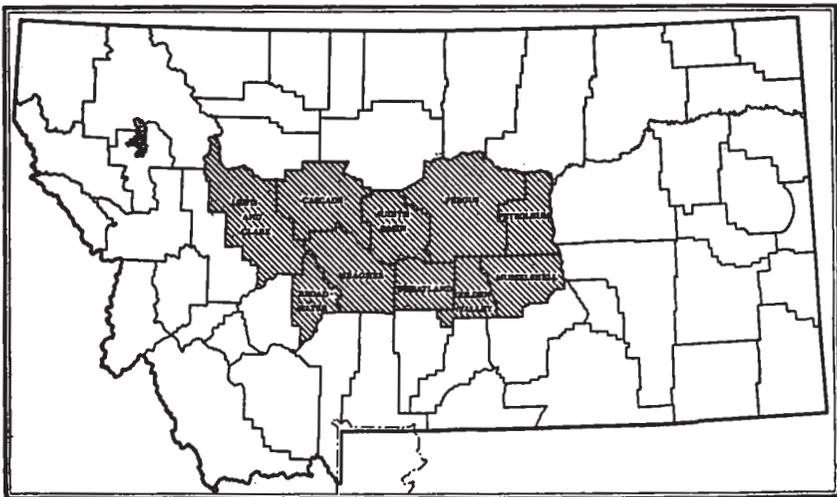


FIGURE 1.—Location of the Central Montana area in Montana.

miles and has an average width of 110 miles. Agricultural soils were mapped in detail in these counties, but steep mountainous tracts, largely in the national forests, were mapped as Rough mountainous land, and no attempt was made to classify the soils in areas so mapped. The survey covers 22,026 square miles, or 14,096,640 acres, which represent 15.1 percent of the total land area of the State.

PHYSIOGRAPHIC FEATURES

Central Montana occupies an area transitional between the main range of the Rocky Mountains and the vast continental slope known as the Northern Great Plains in Montana and the Dakotas (4, 10).^{1a} It consists of frontal ranges, intermountain basins, tablelands, plains, and badlands, or eroding stream breaks. The surface features in most of the area result from the dynamic and volcanic forces that produced the mountain ranges and warped the plains during the Cretaceous and Tertiary periods and from subsequent erosion and deposition of colluvial and alluvial materials. The mountains in the central and western parts of the area enclose intermountain basins. Those in the eastern part—chiefly isolated ranges separated by gaps and low divides—nearly surround such drainage basins as the Judith and Upper Musselshell.

Tablelands occur locally on the slopes of the mountain uplifts and extend north into the glaciated plains and east into the dissected plains of the State. Since the time of glaciation the streams in the plains have been actively entrenching their valleys and have cut deeply into the tablelands and plains to form tableland divides, high ridges, and badly dissected slopes. Nearly all the streams flow through relatively narrow valleys bordered by steep slopes and rugged breaks.

Physiography has greatly influenced industrial and agricultural development in central Montana. Before railways and highways were built through the passes and gaps, the mountain ranges prevented communication between sections. The early political subdivisions followed natural barriers such as mountains and entrenched stream valleys. Many of the present industries in this part of the State depend upon the natural resources found in the mountains and foothills.

The location, elevation, and extent of the different mountain ranges influence the moisture and temperature, the quantity of water available for irrigation and power, and the development of soil in the intermountain basins and on the tablelands. Much of the parent soil material in the intermountain basins and on the tablelands consists of stream- and alluvial-fan deposits washed from the mountains. There is, therefore, a close relationship between the physical features and the climate, soils, and types of farming.

MOUNTAINS

The main range of the Rocky Mountains (7, 1) forms the Continental Divide in the western part of the area surveyed and covers 1,740 square miles in that area; its more rugged timbered sections are in the Lewis and Clark National Forest. This range, extending southeastward through the western part of Lewis and Clark County, has an average elevation of 8,000 feet, but its higher peaks rise al-

^{1a} Italic numbers in parentheses refer to Literature Cited, p. 132.

most 9,500 feet above sea level. The divide lies 3,000 to 4,000 feet above the intermountain basins; the passes over it have elevations of 6,300 to 6,500 feet.

The more rugged mountains in this range occur in the northwestern part where metamorphosed shale, sandstone, and limestone of such geologic formations as the Quadrant and Madison are eroded into sharp peaks and parallel sawtoothed ridges. In the west-central and southeastern parts the divide and secondary ridges are more rounded and wooded, and the chief exposures are sedimentary rocks of Devonian and Carboniferous ages and local igneous intrusions. Andesite and other igneous rocks outcrop in or underlie such districts as Marysville and Helena, where principally gold and silver ores are mined.

The Elkhorn Mountains (14), which rise abruptly several thousand feet above the Helena and Townsend Basins in southern Lewis and Clark County and western Broadwater County, cover 326 square miles in the area surveyed and are included in the Helena National Forest. These mountains—formed by a massive igneous intrusion known as the Boulder Batholith—are characterized by serrated ridges and bald peaks. The average elevation is 7,000 feet, but the higher peaks range between 9,000 and 9,600 feet. The rocks exposed in the higher mountains are chiefly granite and andesite; slate, quartzite, and marble of Algonkian age are on the northern and western slopes. Winston, Rimini, and Radersburg are mining districts in the highly mineralized sections.

The Big Belt Mountains (9)—covering 1,122 square miles and included in the Helena and the Lewis and Clark National Forests—form the divide between the Missouri and Smith Rivers and extend northwest-southeast through Lewis and Clark, Cascade, Broadwater, and Meagher Counties for a distance of 75 miles or more. They vary in width from 8 to 20 miles. These mountains were formed by a broad folded-arched uplift, which has been eroded and dissected to produce rounded peaks and deep intervening stream valleys. Their average elevation is 7,000 feet, and the higher peaks lie between 9,000 and 9,500 feet. The rocks exposed on the main divide are chiefly Algonkian and Cambrian slate and quartzite; Carboniferous limestone is on the western, northern, and southwestern slopes. Intrusions of igneous rock often form the higher peaks; these rocks are exposed east of Craig in Lewis and Clark County and locally in other sections. The contact zones of the igneous intrusions are mineralized in places.

The Mission Range forms a northern spur of the Big Belt Mountains. It lies west of the Missouri River and north of the Dearborn River in Lewis and Clark and Cascade Counties, covers 158 square miles, and is not included in any of the national forests. The average elevation is 500 to 600 feet lower than that of the Big Belt Mountains, and the higher peaks have altitudes of 6,300 feet. The southern part consists largely of rugged traprock ridges, and the northern and western parts of isolated igneous ridges protruding through Cretaceous shale and sandstone.

The Little Belt Mountains (15) cover a large part of Cascade and Meagher Counties and extend east as a high ridge above the tableland in Judith Basin and Wheatland Counties. Their area is 1,648 square miles, and they are in Lewis and Clark National Forest. The range is highest to the west and covers an area 40 to 60 miles long

and 30 miles or more wide. The Little Belts have a geological history similar to that of the Big Belts, but their peaks and ridges are somewhat more rounded and their average elevation is a few hundred feet lower. Ancient crystalline sedimentary rocks, ranging in age from Archean to Jurassic, and local igneous intrusions are the more conspicuous outcrops. Carboniferous limestone is exposed on the northern and southern slopes of dissected deep rock-walled canyons. Gold, silver, lead, zinc, and sapphires are the chief minerals mined in the Barber, Hughesville, Neihart, and Yogo Creek districts.

The Castle Mountains (16) (20 miles long and 2 to 15 miles wide) lie between the forks of the Smith and the Musselshell Rivers in the eastern part of Meagher County. They are included in Lewis and Clark National Forest and cover 156 square miles. They range in elevation from 5,000 to 6,000 feet and are highest near their western limits. Granite and diorite, eroded into fantastic forms, are exposed in the higher mountains; exposures of Carboniferous limestone occur on the northern, eastern, and southern slopes; and Algonkian slate and quartzite are on the western slopes. In the vicinity of Castle and in other locations a mineralized zone occurs at the contact of the igneous and limestone rocks.

The Crazy Mountains (18), with their sharp bald peaks and ridges covered with slide rock, are among the more rugged ranges in the State. They are 30 or more miles long and 10 to 20 miles wide, occur in Meagher, Wheatland, Park, and Stillwater Counties, cover 151 square miles, and are included in Gallatin National Forest. They were formed by igneous intrusions in sedimentary rock, and from a geological standpoint, do not constitute a range. The isolated igneous peaks and ridges protrude through Cretaceous shale and sandstone that have been elevated by volcanic forces. The average elevation is 8,000 feet, but the higher peaks range between 9,000 and 11,000 feet.

The Highwood Mountains (11) are a group of volcanic peaks in Cascade, Judith Basin, and Chouteau Counties that do not exceed an elevation of 7,000 feet. Their area in central Montana is approximately 300 square miles, of which 32 square miles lie within the area surveyed. The timbered sections are included in the Lewis and Clark National Forest.

The Big Snowy Mountain uplift (12) covers a large area in central Montana. The higher part of it, known as the Big Snowy Mountains, is in the southern part of Fergus County and in the northern parts of Wheatland and Golden Valley Counties. This part is 24 miles long and 6 to 10 miles wide and is capped by Madison limestone. The backbone of the mountains is a sinuous limestone ridge having an average elevation of 8,000 feet. Several of the higher peaks rise 500 to 600 feet above the general level. The Big Snowy Mountains cover 232 square miles and are included in the Lewis and Clark National Forest.

The Little Snowy Mountains (12)—part of the foothills of the Big Snowy Mountains—consist of a high ridge from which steep dissected southern slopes extend eastward for a distance of 10 to 12 miles. North of this ridge lies a high tableland, sloping gently to the north and east and traversed by deeply entrenched stream valleys. The areas between the stream courses are known locally as the Alaska, Middle, and South benches and have elevations of approximately 5,000 feet. Quartzite and crystalline limestone of the Quadrant and similar geological formations are the chief exposures on the benches.

The Judith Mountains (17) lie 18 miles northeast of the Big Snowy Mountains in central Fergus County and cover an irregular area 18 miles long and 3 to 12 miles wide. They cover 92 square miles, and their timbered sections are not included in the national forests. They rise several thousand feet above gravel-capped tablelands. Elevations range from 5,000 to 6,000 feet, and the rugged slopes are seamed with limestone canyons. The range was formed by those igneous intrusions that raised Jurassic and Carboniferous limestone on the slopes of the Big Snowy Mountains uplift. Mineralized districts occur near Brooks and Gilt Edge.

The Moccasin Mountains (2) (13 miles long and 3 to 5 miles wide) lie 8 miles west of the Judith Mountains in Fergus County and cover 38 square miles within the area surveyed. The entrenched valley of Warm Spring Creek divides these mountains into two short ranges, the North Moccasin and the South Moccasin. These ranges were formed by igneous intrusions that raised limestone formations several thousand feet above the present tablelands. The higher peaks and ridges have elevations of 5,500 feet. The contact zones of the limestone and igneous intrusions are mineralized in the vicinity of Kendall.

The Bull Mountains Upland (19) forms the divide between the Musselshell and Yellowstone Rivers in central Montana. This upland covers approximately 600 square miles in Musselshell County and includes the Bull Mountain coal fields. The upland is capped by massive sandstone of the Fort Union formation and occupies two distinct levels of about 500 feet difference in elevation. The highest level, known as the Bull Mountains, is 12 miles long and 3 to 8 miles wide and occurs chiefly in Musselshell County. It consists of a group of high mesas and flat-topped ridges that have been eroded to their present form by the dissection of a high plateau. Four main ridges and a number of outlying buttes, ranging in elevation from 4,500 to 4,700 feet, are the principal mountains. The mesas have a protective cover of scoria, and their slopes are bold sandstone escarpments incised with deep coulees.

The lower levels of the Bull Mountains Upland are in Musselshell and Golden Valley Counties. The elevation is 3,500 to 4,000 feet. The land slopes gently to the north and east and is eroded into flat-topped ridges separated by deep canyons. The larger stream valleys are bordered by high sandstone cliffs and rimrocks, making access to the higher levels difficult in most places.

FOOTHILLS

The mountain ranges in the eastern part of the area are bordered by belts of broken foothills, 3 to 6 miles or more wide. These foothills consist of high igneous and sedimentary ridges that often have a protective covering of stony outwash. The ruggedness of this foothill zone depends upon elevation, slope, and the resistance of the exposed geologic formations to erosion. The resistant red sandstone of the Kootenai formation often forms encircling ridges, and it caps many of the divides between the different ranges. In many places the mountains in the western part of the area do not have a foothill zone that can be readily identified.

The foothill area between the main ranges of the Rocky and Big Belt Mountains begins south of the Dearborn River and extends to the Helena Basin. It is mountainous (elevations 5,500 to 7,000 feet),

and consists of broken slate and quartzite ridges and, near the river, of igneous dikes and outcrops. The trough, or basin, between the Big Belt and Crazy Mountains in southern Meagher County is characterized by low shale ridges and by an occasional igneous dike. In the central part of the area surveyed stream gorges or small basins often form the boundary between one mountain range and another. In the eastern part, Judith Gap separates the Little Belt and Big Snowy Mountains; Belt Divide, the Little Belt and Highwood Mountains; and McDonald Divide, the Big Snowy and Judith Mountains.

INTERMOUNTAIN BASINS

According to geologists the intermountain basins along the Missouri and Smith Rivers in the western part of the area were sites of inland lakes during Tertiary (Oligocene) time, or before the accumulated water eroded outlets through the mountains. Lake-bed sediments of sand, silt, clay, gravel, and volcanic ash are at the surface or underlie the more recent alluvial-fan materials in many of the basins. Along the Missouri River the elevation of these sediments varies from 3,600 feet in the small basin at Craig to 4,400 to 4,800 feet in the Townsend Basin; and along the Smith River the elevation ranges from 4,800 to 5,200 feet. These sediments form the tablelands in many of the basins and the hanging shelves on the mountain slopes along the Missouri River.

The Townsend Basin, between the Elkhorn and Big Belt Mountains in Broadwater County, is 40 miles long and 8 to 10 miles wide. It is characterized by different erosional levels and by long coalescing alluvial fans. Igneous dikes and ridges of sedimentary rock extend into the basin from the mountains, and isolated buttes and limestone rocks outcrop locally within the basin. The southern part of the basin is undulating and slopes gently toward the poorly drained land along Crow Creek. High dissected tablelands occur locally on the mountain slopes. These have a protective covering of stony outwash over the lake-bed sediments, which outcrop at lower elevations. These tablelands are 4,000 to 5,000 feet above sea level and 75 feet or more above the level of the larger streams. They have smooth surfaces and gradients of 40 to 60 feet to the mile. Lower benches or terraces border the Missouri River valley north of Toston. They lie 500 to 600 feet lower than the high tablelands and consist largely of coalescing alluvial fans below the high tablelands and mountains. They also have smooth surfaces and slopes of 30 to 40 feet to the mile and lie 25 feet or more above the level of the streams.

The Helena Basin in the southeastern part of Lewis and Clark County is 15 miles long and 9 miles wide. It is another intermountain basin in which the lake-bed sediments are covered deeply in most sections with gravelly outwash from the mountains. The elevations of 3,400 to 4,000 feet slope gently toward Lake Helena with a grade of 40 feet or more to the mile. The lake-bed sediments in the southeastern part of the basin are eroded into undulating tablelands, which are dissected by deep coulees along Spokane Creek.

Small intermountain basins occur along the Missouri River from Canyon Ferry to the mouth of the Dearborn River. In these basins the lake-bed sediments, covered with stony outwash in places, occur as hanging benches on the mountain slopes 100 feet or more above

the level of the stream. Loesslike deposits of a silty texture similar to that of the lake-bed sediments occur locally on the western slopes of the Big Belt Mountains.

The Little Prickly Pear valley, 15 miles northwest of Helena, is a small intermountain basin 7 miles long and 5 miles wide. It has an average elevation of 4,300 feet and is covered by gravelly wash, which forms terraces along some of the larger streams. This basin slopes gently to the north and grades into the wet bottom lands along Little Prickly Pear Creek.

The Smith River Valley in Meagher County occupies an intermountain basin between the Big Belt and Castle Mountains. This basin is 40 miles long and 2 to 8 miles wide; its elevation ranges from 4,800 to 5,200 feet. It is characterized by smooth gently sloping benchlands, which are separated by small intervening stream valleys and by ridges of sedimentary rock extending out from the mountains. A few ridges and outcrops of igneous rocks occur locally in the basin. The protective covering on the benchlands consists of limestone and argillite fragments, which overlie lake-bed sediments in most sections. The gravelly wash in the basin along Battle Creek in the uplands west of Ringling also is underlain by lake-bed sediments, which outcrop in places. High dissected tablelands, capped with angular argillite and quartzite rock fragments and gravel, occur on the eastern slopes of the Big Belt Mountains west of White Sulphur Springs. These stony tablelands have gradients of 40 to 60 feet to the mile and lie 100 feet or more above the level of the streams.

The Big Blackfoot Basin lies west of the Continental Divide in Lewis and Clark County. It is a small enclosed basin 8 miles long and 5 miles wide. Its slopes are covered with hummocky drift.

The Judith Basin is a high tableland roughly enclosed by the Big Snowy, Little Belt, Highwood, Moccasin, and Judith Mountains in Judith Basin and Fergus Counties. It is approximately 40 miles long and 30 miles wide. Dissected by deep stream valleys, the tablelands extend northward beyond the limits of the Basin proper almost to the breaks of the Missouri River. The tablelands have smooth surfaces, slopes of 40 to 60 feet to the mile, and elevations ranging from 3,500 to 4,000 feet or more. The stream valleys are entrenched 50 to 100 feet near the mountains and 300 feet or more in the northern part of the basin. The protective covering on most of the tablelands consists of well-rounded water-worn limestone gravel locally mixed with some fine material. Near the mountains the material is cobblestones. This protective gravelly deposit varies from a few feet thick on the flat-topped divides in the northern part of the basin to more than 80 feet thick near the mountains. In most sections the gravel deposit is underlain by Colorado shale, which at the lower elevations forms the steep escarpments of the tablelands. Most of the tablelands have a shallow covering of silty loesslike material, or material of this kind is mixed with the upper layer of the gravel.

The upper Musselshell River basin extends eastward from the Castle Mountains for 80 miles or more and lies between the Little Belt, Big Snowy, and Little Snowy Mountains on the north and the Crazy Mountains and the Bull Mountains Upland on the south. The basin averages about 30 miles wide and ranges in elevation from approximately 3,000 feet in Musselshell County to more than 5,000 feet in

Wheatland and Meagher Counties. The mountains north of the Musselshell River, except for a few small local areas of foothills, rise directly above the gravel-capped tablelands that occupy the upper Musselshell River basin and extends east of the Little Snowy Mountains for a distance of 20 miles or more. The gravel-capped tablelands are dissected by deep narrow stream valleys, occupy different erosional levels, and slope gently to the south and southeast with gradients of 30 to 40 feet to the mile.

The tablelands of the Musselshell basin extend down to the Musselshell River valley in Meagher and Wheatland Counties, but in Golden Valley and Musselshell Counties they are eroded into flat-topped ridges and buttes at a distance of 15 to 20 miles from the mountains. The protective covering on these tablelands consists of water-worn limestone gravel that grades into cobblestones near the mountains. Much of the surface layer of gravel contains a fair percentage of fine earth material, and in places the tablelands have a thin covering of silty aeolian, or loesslike, material on the surface. The gravel deposit—only a few feet thick on the divides and about 80 feet thick near the mountains—has about the same thickness as in the Judith Basin. Cretaceous shale and sandstone underlie the gravel deposit and in many places form steep escarpments between different levels of the tablelands and where the tablelands are dissected by streams.

The Crazy Mountains are bordered on the north by high tablelands that extend almost to the Musselshell River valley in Wheatland and Meagher Counties, and the larger streams heading in these mountains are entrenched in lower benchlands along most of their course below the mountains.

TABLELANDS

Tablelands, other than those already referred to as occurring in the intermountain basins, extend out from the mountains into the plains. High tablelands traversed by wide stream valleys extend 30 to 40 miles east of the main range of the Rocky Mountains north of the Sun River. These tablelands have about the same gradient as the present stream valleys, have smooth surfaces, and lie 500 feet or more above the level of the larger streams. Their protective covering consists of water-worn quartzite and argillite gravel. The Greenfield and Ashuelot Benches occupy the extreme eastern part of one of these tablelands in the northwestern part of Cascade County. These benches, however, lie at a lower erosional level; they have an elevation above 3,900 feet and are dissected by deep coulees. Isolated benches, capped with similar gravel and having the same elevation as the Greenfield and Ashuelot Benches, border the Sun River Valley in Lewis and Clark County.

The area east of the Missouri River and north of the Little Belt Mountains in Cascade County is a broad dissected plateau extending north into the glaciated plains. It has an elevation of 3,800 to 5,000 feet, is smoothly undulating, and is capped with Kootenai sandstone, which lies near the surface where it occurs close to the mountains.

Gravel-capped tablelands extend east from the Judith and Little Snowy Mountains into Petroleum County. The valley of Flat Willow Creek is bordered by high benches, which occupy different erosional

levels below the mountains along most of its course. Shales underlie the gravel deposit on most of these Flat Willow Creek benches at comparatively shallow depths. In many places the benches are characterized by depressed bare spots. Similar dissected benches occur north of the Moccasin and Judith Mountains in Fergus County. Most of these benches form the flat-topped divides between the streams. In places in Petroleum County and in other localities gravel-capped flat-topped ridges occur in the uplands. Their surfaces are usually scabby; that is, they contain numerous micro-depressions in which the soils are extremely heavy and support little or no vegetation.

GLACIATED PLAINS

The northern part of the area below the mountains and tablelands lies chiefly in the glaciated plains of north-central Montana. During the Wisconsin glaciation, the Keewatin ice sheet covered northern Cascade County and deposited a layer of drift on the divide north of the Sun River and on the divide west of Belt Creek. This ice sheet dammed such streams as the Missouri, Sun, and Smith Rivers and formed the Great Falls glacial lake, which covered a large part of Cascade County below the mountains. Sediments of this lake, chiefly of sand, silt, clay, and gravel, occur at elevations of 3,400 to 3,900 feet.

Erosion has removed most of the glacial sediments from the uplands, but they are more than 100 feet thick in places in some of the preglacial valleys such as those of the Missouri and Sun Rivers and Muddy Creek.

An ice sheet, considered by some glacial geologists to be older than Wisconsin Age, covered northwestern Fergus and northern Petroleum Counties, but it apparently did not change the surface configuration greatly. The old dissected surface, consisting of steep shale ridges, was smoothed out somewhat by the movement of the ice and the uneven deposition of till, and shallow depressions were formed in the flattened ridges. These glaciated areas lie at an elevation slightly below 3,000 feet. The benchlands along the Musselshell River in northern Petroleum County are thinly covered by glacial lake sediments.

The main divide of the Rocky Mountains was a collecting ground for ice during the glacial periods. The glaciers moving down the valleys of the Sun River, Willow Creek, and other such streams in northern Lewis and Clark County, coalesced below the mountains, and then extended eastward into the plains for some 20 miles. This glaciated area consists of recessional moraines and gravelly lake basins. Similar moraines occur below the mouth of the Dearborn River canyon. The western slopes of the Continental Divide were more uniformly glaciated, and in the vicinity of Lincoln the slopes of the Big Blackfoot Basin have a morainic relief. Ice also accumulated on the higher peaks and ridges in other mountain ranges, but only in the Crazy and Castle Mountains did it extend down to the mouth of the larger canyons. Well-defined moraines occur on the slopes of the higher peaks in the Big Belt and Elkhorn Mountains. Outwash gravel from the glaciers covers small tracts at the mouth of the Sun, Dearborn, and Big Blackfoot River canyons and occurs in places along the streams heading on the higher peaks. The moraines on the eastern slopes of the mountains lie chiefly between 4,500 and 5,000 feet above sea level.

DISSECTED PLAINS

The eastern part of the area below the mountains and tablelands is a broad dissected plateau sloping gently to the north and east. The topography of the plateau varies according to the elevation and the resistance of the exposed geologic formations to erosion. The weakly consolidated Bearpaw shale occurring in northeastern Fergus and eastern Petroleum and Musselshell Counties has been strongly dissected into clay hills and ridges separated by relatively wide saline flats or basinlike valleys. The exposures of the Lance sandstone and shale in eastern Fergus and western Petroleum Counties have eroded to form high ridges and deep valleys or depressions. Some of the depressions, apparently formed by the wind carving the soft rocks, have no drainage outlets. In many areas the relatively hard Judith River and Eagle sandstones occur as a caprock over the shale. This caprock above the shale escarpments forms benchlike uplands with undulating surfaces. The Lance formation near the Crazy Mountains is strongly indurated and has been eroded to form high ridges and buttes. The unglaciated part of northeastern Lewis and Clark County and the western part of Cascade County is characterized by broken ridges resulting from erosion and faulting. Locally in the northeastern part of Lewis and Clark County the softer shales occupy areas of undulating to gently rolling relief, and in these places moderately to strongly saline soils have developed in the swales, flats, and narrow valleys between the low ridges.

The plateau in the eastern part of the area, a belt 3 to 8 miles wide along the Missouri and Musselshell Rivers, is eroded into rugged breaks that form badlands bordering the valleys of these rivers. The breaks in northern Fergus and Petroleum Counties consist largely of steep eroding shale ridges and deep coulees sparsely covered with dwarfed yellow pine. The ridges rise 300 to 500 feet above the level of the streams and locally are capped with sandstone at the higher elevations. Similar shaly breaks also border the valleys of the Judith River and Arrow Creek in northern Fergus and Judith Basin Counties. High broken sandstone ridges separated by deep U-shaped valleys form the breaks of the Musselshell River in the east-central part of Petroleum County. Barren incised slopes of benchlands and stream valleys and dissected upland tracts occur locally in Cascade and other counties.

MINOR PHYSICAL FEATURES

A number of minor physical features have locally influenced the formation of soils and development of agriculture in the area. Among these are buttes of igneous and sedimentary rocks lying below the mountains, igneous dikes radiating out from volcanic centers, and badly faulted areas.

A number of geologic domes occur in the area, most of which have been prospected for petroleum and natural gas. Devils Basin lying north of Roundup and surrounded by high rimrocks and broken slopes is such an area, and the place where petroleum was first discovered in central Montana.

Natural depressions occur in the eastern and northeastern parts of the survey, and in them are found intermittent lakes, as Mason Lake in Musselshell County and Wild Horse and War Horse Lakes in Petroleum County.

High ridges rise locally in the intermountain basins and form secondary divides. The hills along Spokane Creek form a rugged argillitic and quartzitic ridge rising 1,000 feet or more above the Missouri River between the Townsend and Helena Basins in Broadwater and Lewis and Clark Counties. Barren limestone ridges cover a large part of southern Broadwater County and other sections in the western part of the area. Numerous mountain parks and high basins occur in the mountainous sections.

DRAINAGE BASINS

The Missouri River and its branches drain nearly all of central Montana. A few streams heading on the southern slopes of the Crazy Mountains and the Bull Mountains Upland flow south into the Yellowstone River; those west of the Continental Divide unite with the Big Blackfoot River, a tributary to streams that flow into the Pacific Ocean. The mountain ranges divide the area into five drainage basins: (1) The Missouri, (2) the Smith, (3) the Judith, (4) the Musselshell, and (5) the Big Blackfoot. The flow of these streams is important to irrigation and power development. They are at flood stage during the spring runoff (usually in March and early April) and again in May and June when they are swollen by seasonal rainfall and snow melting in the mountains.

The Missouri River enters the area in a deep limestone canyon in southern Broadwater County and flows north through the western part of the Townsend Basin in a flood plain 1 to 3 miles wide that is bordered by gravelly slopes from the benchlands. North of Townsend the channel is braided and meanders through a low poorly drained flood plain. Through the mountains the course is characterized by cascades, rapids, and rock-walled canyons. North of the mountains the river flows through an open valley, and at Great Falls it enters a sandstone-walled gorge that extends beyond the Cascade County line. Within 10 miles beyond Great Falls the stream drops more than 500 feet. In the northeastern part of the area the river follows its post-glacial course through a deeply entrenched valley, which averages less than a mile wide and is bordered by rugged breaks. In this part of its valley the river follows an extremely meandering course through a flood plain consisting chiefly of heavy alluvium washed from the adjacent eroding shale breaks and uplands.

The Missouri is a fast-flowing stream 75 to 100 yards wide. During low water it flows 5 to 10 feet below its flood level. Above the town of Cascade it drains an estimated 18,295 square miles, and its flow ranges from 2,000 to 22,000 cubic feet per second. Springs at Great Falls and other perennial springs issuing from limestone formations in the gorge south of Toston are among the largest of their kind in the State.

The Sun and Dearborn Rivers head on the Continental Divide and emerge from the mountains in deep limestone canyons. They have a swift flow, carry a fair volume of water, and are the larger branches of the Missouri River in the western part of the area. Other streams carrying a comparable quantity of water for irrigation are Crow, Deep, and Confederate Creeks in Broadwater County; Willow, Little Prickly Pear, and Prickly Pear Creeks; the Middle and South Forks of the Dearborn River; and the South Fork of the Sun River in Lewis

and Clark County. The preglacial valley of the Dearborn River is occupied by Flat Creek.

The smaller mountain streams, locally meandering in wet bottom lands, cascade through wooded canyons. During periods of low flow some of these streams enter the intermountain basins and sink into the stream gravel and sand at the mouth of the canyons, but during floods they spread over the lower benches and terraces.

The Smith River is a perennial stream of fair size that drains the intermountain basin between the Big Belt Mountains and Little Belt and Castle Mountains. It rises in the Little Belt Mountains, follows a circuitous route through wooded canyons in the mountains, and meanders through wet bottom lands in the basin before turning northward to join the Missouri River in Cascade County. At Fort Logan it enters a canyon that becomes a gorge 800 to 1,000 feet deep in northern Meagher County. The larger branches of the Smith River flow through deep canyons and rock-walled gorges. Its South Fork heads in the Castle Mountains and flows through an open valley before it enters the main river. Below the mountains the South Fork is an intermittent stream most of the year. Water from sulphurated springs at White Sulphur Springs flows into the Smith River.

The Judith River and Arrow Creek drain the Judith Basin in Judith Basin and Fergus Counties. The Judith River takes a northeasterly course below the mountains, and in the western part of Fergus County turns due north to the Missouri River. It is a good-sized stream that flows through a narrow valley, which is bordered by rugged breaks in the northern part of the area. Arrow Creek heads in the Highwood Mountains and drains the western part of Judith Basin. It is a perennial stream carrying a fair volume of water during the spring runoff. Its small valley is entrenched in shaly bedrock along most of its course below the mountains.

Most of the branches of the Judith River and Arrow Creek emerge from the mountains in rock-walled canyons. In the northern part of Judith Basin their valleys are deeply entrenched. Nearly all these tributary streams flow the year around in the mountains, but in the basin the water often sinks into stream gravel late in summer and in fall, and surface flow becomes intermittent. The normal flow of Warm Spring and Big Spring Creeks is maintained chiefly by several large perennial springs issuing from limestone formations.

The Musselshell River and its branches drain most of the southeastern and eastern parts of the area. This river, formed by the union of its North and South Forks east of the Castle Mountains, takes a general easterly direction for 80 miles or more before turning north to join the Missouri River. It is one of the fastest flowing streams in the area, having a fall of 10 to 20 feet or more to the mile west of Roundup. The normal flow of the Musselshell River is diverted onto irrigated lands along its upper course, and during the irrigation season the flow in its lower course becomes intermittent. The valley of this stream, averaging less than a mile wide, is bordered by sandstone rimrocks and rugged shaly breaks along most of its course.

The larger branches of the Musselshell River traverse the tablelands south of the Little Belt and Big and Little Snowy Mountains in narrow steep-walled valleys. Those entering the Musselshell from the south

flow through narrow valleys bordered by sandstone rimrock in many places. American Fork Creek meanders in a broad stony basin south of Harlowton, and the rimrock-bordered valley of Big Coulee Creek is several miles wide south of Ryegate. Flat Willow and McDonald Creeks are the largest perennial streams uniting with the Musselshell in Petroleum County. Crooked Creek is an intermittent stream draining an area of heavy clayey soils in Fergus and Petroleum Counties. It carries a large volume of water during the spring runoff and after heavy rains. Nearly all the larger streams tributary to the Musselshell flow the year around in the mountains and on the higher divides, but in the basins and plains many of them become intermittent late in summer and in fall. The soils of many of the stream valleys are high in soluble salts, and unless the water holes are occasionally flushed by showers the water becomes stagnant and too foul and salty for livestock.

The Big Blackfoot River is one of the largest streams heading on the western slopes of the Continental Divide. It rises near Flesher and flows southwestward in a deep wooded canyon. Above the mouth of Landers Fork it enters a brush-covered and timbered morainic basin, and about 3 miles west of Lincoln it cascades through the Big Blackfoot River canyon. The larger perennial branches of this river, as North Fork and Landers Fork, drain wooded mountain basins and slopes.

CLIMATE

The climate of central Montana is midcontinental. It ranges from semiarid in most of the intermountain basins and plains to subhumid in the mountains. Over most of the agricultural sections it is semiarid and is characterized by moderately low rainfall, great extremes in summer and winter temperature, many sunny days, and relatively low humidity. The midsummer temperatures are not oppressive because the humidity is low, and the harshness of winter is often tempered by warm winds. The climate on the high tablelands is more like that of the plains than that of the mountains.

The high tablelands, foothills, and mountains have more uniform temperatures, a greater rainfall, and a larger number of cloudy days than the low intermountain basins and plains. With increased elevation, rainfall normally increases and temperature decreases. In some of the higher mountain sections subhumid conditions prevail. East of the Continental Divide the more general storms and winter chinooks came from the north and west. The descending chinook winds have a lower humidity than the ascending air currents; therefore the tablelands and plains south and east of the mountain ranges have a lower rainfall and higher temperature than tablelands and plains of the same elevation north and west of the mountains. The mountain ranges and larger canyons to some extent influence air drainage and the paths of local storms; consequently, some sections are more subject to early and late frosts and hail than others.

The normal monthly, seasonal, and annual temperature and precipitation for three United States Weather Bureau stations—Adel, Helena Airport, and Flat Willow—are given in table 1. Adel is in a high mountain basin, Helena Airport in an intermountain basin, and Flat Willow in the valley of Flat Willow Creek in the eastern part of

the area surveyed. The climate in the Helena Basin resembles that in the Townsend Basin. White Sulphur Springs (Meagher County) and Lewistown (Fergus County) are also in intermountain basins and have about the same temperature and precipitation as Helena. The climate at Flat Willow resembles that in the lower Musselshell River basin and the plains. Great Falls (Cascade County) is in the southern part of the glaciated plains.

The mean average annual temperature varies largely with the elevation. It is about 6 degrees lower in the high mountain basins than on the plains. January is the coldest month, and July is the warmest. The midsummer maximum temperatures range from 98° F. in the high mountain basins to 107° in the lower intermountain basins and plains. The midwinter minimum temperatures vary from -42° to -51°. Since Weather Bureau records have been kept, Adel shows the lowest midwinter temperature, but weather data recorded at military posts during the 1870's show lower midwinter temperatures in the intermountain basins and plains.

The kinds of irrigated and nonirrigated crops grown in the area are influenced by the average summer temperature and the length of the growing season. The average summer temperature varies with

TABLE 1.—Normal monthly, seasonal, and annual temperature and precipitation at three weather stations in central Montana

ADEL, CASCADE COUNTY, ELEVATION 5,200 FEET

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total for the driest year	Total for the wettest year	Average snowfall
December.....	° F. 24. 2	° F. 62	° F. -46	<i>Inches</i> 1. 15	<i>Inches</i> 0. 03	<i>Inches</i> 2. 13	<i>Inches</i> 16. 1
January.....	21. 2	58	-45	1. 13	. 56	. 99	15. 0
February.....	23. 0	60	--51	1. 16	. 12	1. 71	14. 9
Winter.....	22. 8	62	-51	3. 44	. 71	4. 83	46. 0
March.....	29. 0	70	-39	1. 57	1. 64	2. 49	19. 2
April.....	39. 8	84	-9	2. 10	1. 46	4. 52	15. 5
May.....	46. 8	90	7	3. 35	1. 48	10. 82	7. 7
Spring.....	38. 5	90	-39	7. 02	4. 58	17. 83	42. 4
June.....	54. 2	98	21	4. 01	. 52	1. 73	. 6
July.....	61. 0	97	25	1. 80	. 25	2. 44	0
August.....	59. 7	97	22	1. 65	. 65	8. 02	. 1
Summer.....	58. 3	98	21	7. 46	1. 42	12. 19	. 7
September.....	51. 0	93	-5	2. 29	. 50	2. 34	4. 3
October.....	42. 8	85	-16	1. 79	1. 21	2. 93	16. 0
November.....	33. 5	75	-36	. 99	(¹)	2. 91	11. 6
Fall.....	42. 4	93	-36	5. 07	1. 71	8. 18	31. 9
Year.....	40. 5	98	-51	22. 99	² 8. 42	³ 43. 03	121. 0

See footnotes at end of table.

TABLE 1.—Normal monthly, seasonal, and annual temperature and precipitation at three weather stations in central Montana—Con.

HELENA AIRPORT, LEWIS AND CLARK COUNTY, ELEVATION 3,893 FEET							
Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total for the driest year	Total for the wettest year	Average snowfall
	° F.	° F.	° F.	Inches	Inches	Inches	Inches
December.....	22. 7	64	-40	0. 47	(¹)	0. 38	9. 0
January.....	18. 7	63	-42	. 56	0. 39	2. 96	10. 7
February.....	21. 6	65	-41	. 37	. 16	. 51	8. 2
Winter.....	21. 0	65	-42	1. 40	. 55	3. 85	27. 9
March.....	31. 7	73	-20	. 79	1. 14	(¹)	9. 2
April.....	43. 5	86	3	1. 12	. 70	1. 55	6. 2
May.....	51. 6	95	22	1. 98	. 66	1. 60	2. 2
Spring.....	42. 3	95	-20	3. 89	2. 50	3. 15	17. 6
June.....	59. 2	102	31	2. 04	. 59	3. 51	(¹)
July.....	65. 7	103	36	1. 14	1. 03	1. 95	0
August.....	64. 6	99	29	. 77	. 62	1. 78	(¹)
Summer.....	63. 2	103	29	3. 95	2. 24	7. 24	0
September.....	55. 4	92	-6	1. 25	. 11	2. 49	. 9
October.....	43. 8	84	-1	. 61	. 71	2. 04	4. 2
November.....	31. 8	71	-22	. 45	. 17	1. 27	6. 9
Fall.....	43. 7	92	-22	2. 31	. 99	5. 80	12. 0
Year.....	42. 5	103	-42	11. 55	² 6. 28	⁴ 20. 04	57. 5
FLAT WILLOW, PETROLEUM COUNTY, ELEVATION 3,200 FEET							
December.....	24. 5	66	-48	0. 42	0. 04	0. 28	7. 8
January.....	21. 6	64	-40	. 28	. 05	. 08	6. 1
February.....	23. 6	69	-31	. 35	. 17	. 58	6. 2
Winter.....	23. 2	69	-48	1. 05	. 26	. 94	20. 1
March.....	31. 8	78	-21	. 62	. 36	1. 58	7. 7
April.....	44. 0	86	-3	. 82	. 32	. 81	4. 3
May.....	53. 8	97	17	1. 92	. 74	4. 51	1. 3
Spring.....	43. 2	97	-21	3. 36	1. 42	6. 90	13. 3
June.....		104	30	3. 14	. 84	3. 88	(¹)
July.....	70. 8	107	34	1. 56	. 72	3. 15	0
August.....	68. 2	104	31	1. 11	. 43	1. 04	0
Summer.....	69. 5	107	30	5. 81	1. 99	8. 07	0
September.....	57. 6	97	8	1. 05	. 83	1. 66	. 7
October.....	46. 5	88	-18	. 96	. 02	. 63	3. 7
November.....	34. 0	81	-29	. 41	. 33	. 48	6. 2
Fall.....	46. 0	97	-29	2. 42	1. 18	2. 77	10. 6
Year.....	45. 5	107	-48	12. 64	⁶ 4. 85	⁶ 18. 68	44. 0

¹ Trace. ² In 1935. ³ In 1927. ⁴ In 1881. ⁵ In 1931. ⁶ In 1942.

the elevation and location and is highest in the plains and in the lower protected stream valleys in the eastern part. Table 2 gives frost data at various weather stations in the area.

TABLE 2.—*Frost data collected over a period of years at several stations in central Montana*

Station	Average date of last killing frost in spring	Average date of first killing frost in fall	Average frost-free period	Latest recorded killing frost	Earliest recorded killing frost
			<i>Days</i>		
Helena.....	May 5	Sept. 28	145	June 9	Aug. 25
Great Falls.....	May 20	Sept. 14	116	May 27	July 27
Roundup.....	May 8	Sept. 24	138	May 31	Sept. 11
Lewistown.....	May 26	Sept. 14	110	June 25	July 30
Adel.....	June 9	Sept. 7	89	June 30	Aug. 9
Flat Willow.....	May 17	Sept. 24	129	June 17	Sept. 18
Stanford.....	May 20	Sept. 19	121	June 14	Aug. 14

As shown in table 2 the frost-free period ranges from 89 to 145 days. Killing frosts have occurred at almost all the stations in every month of the year. In several of the intermountain basins growing seasons are relatively long but average summer temperatures are comparatively low. Small grains are usually seeded on the lower tablelands, in the intermountain basins, and on the plains late in April and early in May, and on the higher tablelands and mountain slopes late in May and early in June. Small grains are rarely injured by late spring frosts, but early fall frosts occasionally damage crops in the irrigated areas, as well as the moderately late maturing crops in the non-irrigated.

The annual precipitation varies. In the southern part of the glaciated plains at Great Falls it averages 14.85 inches; in the Judith Basin at Stanford, 14.78; in the high mountain basin at Adel, 22.99; and at Flat Willow in the eastern part of the area, 12.64. The total precipitation in the driest year ranges from 4.85 inches at Flat Willow to 11.08 inches in the higher mountain basin at Lewistown, and for the wettest year, from 18.68 at Flat Willow to 43.03 inches at Adel. Almost one-third of the total annual precipitation is received during May and June. In the period May 1 to September 1 the plains areas receive approximately 54 to 58 percent of their total annual precipitation, and in the same period the western intermountain basins and mountains receive 46 to 51 percent.

The quantity and distribution of the annual precipitation is important in areas of low rainfall. In most of the agricultural areas crops are grown under low rainfall, and only a small departure from normal rainfall may mean the difference between a good and poor crop year. Averages are often misleading. During the drought years of 1930 to 1937 the annual precipitation in some areas was about normal, but a larger part of it came as snow during winter and early spring when the ground was frozen rather than as rain during the growing season. Local showers are characteristic of much of the summer rainfall; some areas may receive good rains and others a few miles away may receive none.

Part of the precipitation falls as snow during fall, winter, and spring. Snow rarely lies in place in the lower agricultural areas; strong winds usually collect it in drifts on the leeward slopes of hills and ridges and in the coulees. The average yearly snowfall varies from 44 inches at Flat Willow in the plains to 121 inches at Adel in a high mountain basin.

Hailstorms—occasionally severe ones—occur in the agricultural sections. In most parts of the area they are no more frequent and severe than in other areas on the Great Plains, but the Upper Musselshell River basin and local sections in the intermountain basins are somewhat more subject to hail damage than others.

Brisk westerly and northwesterly winds are predominant in most sections. The winds are somewhat stronger and more constant late in winter and in spring than during the rest of the year, and occasionally small grains seeded early are damaged by soil drifting. In dry seasons hot winds rise in the south and southwest and have caused serious crop losses at the lower elevations. The area east of the Continental Divide lies in the paths of chinook winds, which often prevent the accumulation of snow on the lower tablelands, in the intermountain basins, and on the plains in winter and early in spring. These warm drying winds influence the effectiveness of the winter precipitation. The normal evaporation from a free-water surface for the period April 1 to October 1 at the Judith Basin Branch Experiment Station is 33.23 inches.

WATER AND FUEL RESOURCES

Excellent water for domestic use is generally found in the mountains, in the foothills, in the higher intermountain basins, and on the high tablelands, but in the eastern part of the area where the Bear Paw, Claggett, Colorado, and similar geological formations are exposed, the water often is too brackish for human use or livestock. Where the water is unsatisfactory or in short supply, surface runoff is impounded in ponds and reservoirs for livestock and in cisterns for household use.

The more massive sandstones of the Kootenai, Eagle, and Fort Union formations contain good water near the mountains, but on the plains the water from these formations is usually highly mineralized. Artesian water is obtained from the Kootenai formation in Cascade, Petroleum, and northern Fergus Counties and locally from other formations in different parts of the area. In a few of the upland sections livestock are grazed only late in winter and in spring when water in the form of snow is available. Sheep are often trailed from one grazing area to another as the water holes dry up. Under Federal and State programs for conserving the range lands, many reservoirs for livestock have been and are being constructed where grass is available and the water supply is short or of poor quality.

Coal obtained from the coal fields in Musselshell, Cascade, Fergus, and Judith Basin Counties and wood from the mountains are the chief fuels used in the area. Crude petroleum and natural gas, however, are a part of the fuel supply in some of the towns.

VEGETATION

The kinds of native plants, their density, and their value as forage are largely determined by the climate prevailing in the different parts of the area, but locally the soils and their degree of development cause

some variation. The mountain peaks and ridges lying above timber line are covered with slide rock or talus and are largely barren. The stand of timber varies with the location and elevation and is usually more dense at higher altitudes on the northern and western slopes and on the western slope of the Continental Divide. Fair stands of merchantable timber occur locally, but much of the forest is inaccessible. The forests on the higher mountains consist chiefly of Engelmann spruce, Douglas-fir, and lodgepole pine. Western yellow pine grows at lower elevations on the mountains and is also conspicuous in the Big Blackfoot Basin. Quaking aspen occurs on the slopes of poorly drained gulches. The undergrowth in the forests consists largely of shrubs and ferns.

The lower mountain slopes bordering the Helena and Townsend Basins are lightly covered with juniper, rabbitbrush, and bunchgrass. An open stand of dwarf yellow pine and juniper covers the Bull Mountains Upland and the breaks of the Missouri and Musselshell Rivers. In many places creeping juniper is the chief vegetation on the more exposed sandstone outcrops.

In the open mountain parks, shrubs and upland sedges predominate in a mixed cover that includes mountain timothy and redtop grasses. The Big Belt and Little Belt Mountains have many parks and tracts of grassland on the broader divides and on the southern slopes. The browse, shrubs, and tall grass growing in the higher mountain sections is eaten more readily by sheep than by cattle, and during the 3 or 4 months these sections are free from snow, sheep are grazed in the higher areas. Both sheep and cattle are grazed on the lower mountain slopes and in the park lands. The vegetation in the mountains is not considered so nutritious as the short grasses on the plains and intermountain basins.

The high tablelands and foothills support a cover of tall grasses, shrubs, and forbs. The grasses belong to a number of species, of which the more important and valuable are western wheatgrass (*Agropyron smithii*), bluegrass (*Poa spp.*), Idaho fescue (*Festuca idahoensis*), and bluebunch wheatgrass (*Agropyron spicatum*). Rough fescue (*Festuca scabrella*) is relatively abundant in places on the lightly timbered mountain slopes in Lewis and Clark and Broadwater Counties. Numerous shrubs and forbs are associated with the tall grasses. The tall grass on the tablelands and in the foothills seems equally palatable to sheep and cattle, and both are grazed during the 6 to 8 months these areas are free of snow.

Short grasses predominate in the Helena, Townsend, Smith, Upper Musselshell, and similar intermountain basins and on the dissected plains. The short grasses are nutritious, palatable to all livestock, and can be grazed during the 9 to 10 months the areas supporting them are usually free from snow. Blue grama grass (*Bouteloua gracilis*) is associated in most sections with western wheatgrass, Sandberg bluegrass (*Poa secunda*), and threadleaf sedge (*Carex filifolia*). Other grasses, as needle-and-thread grass (*Stipa comata*) and Junegrass (*Koeleria cristata*), are prevalent, especially in the overgrazed sections. Prairie sandreed (*Calamovilfa longifolia*) is conspicuous on some of the sandy soils, and bluebunch wheatgrass on the breaks of the Missouri and Musselshell Rivers. Big sagebrush (*Artemisia tridentata*), commonly known as black sage in the area, and biscuitroot

(*Cogswellia* spp.) usually grow on the less mature heavy soils. Rabbitbrush (*Chrysothamnus lanceolatus*) is confined largely to the more semiarid intermountain basins and mountain slopes in the western part of the area. Such shrubs as fringed sagebrush (*Artemisia frigida*), curlycup gumweed (*Grindelia squarrosa*), and broom snake-weed (*Gutierrezia sarothrae*) are widely distributed but except for sheep have no value as forage. Pricklypear is abundant in some of the drier and overgrazed sections.

The lower flood plains of many of the larger streams support fair stands of native cottonwood, willow, and brush. The dense thickets along the mountain streams and on the canyon slopes are composed chiefly of chokecherry, serviceberry, and snowberry. Various grass and grass-like plants such as slough grass (*Beckmannia syzigachne*), rush (*Juncus* spp.), and sedge (*Carex* spp.) predominate in the sloughs and wet bottom lands. The more saline bottom lands in the intermountain basins and plains support a light stand of greasewood (*Sarcobatus vermiculatus*), saltbush (*Atriplex* sp.), winterfat (*Eurotia lanata*), inland saltgrass (*Distichlis stricta*), and silver buffalo-berry (*Shepherdia argentea*). Wild barley (*Hordeum jubatum*) is conspicuous in many depressed areas that are covered with water in spring. The heavy soils on the colluvial slopes of the Missouri and Musselshell River valleys in the eastern part of the area are covered with a stunted growth of big sage.

Poisonous plants are widely distributed but in most sections the loss of livestock is low. Loco and low larkspur are confined chiefly to the plains, intermountain basins, and lower tablelands; tall larkspur, deathcamas, lupine, and water hemlock are on the high tablelands, foothills, and park lands.

HISTORY OF THE AREA

Members of the Lewis and Clark expedition (1804-6) followed the course of the Missouri River through central Montana and were the first to describe the physiography, vegetation, wildlife, and Indian tribes in this part of the State. The Blackfoot Indians were in possession of the western part of the area; the eastern part was the hunting ground of the Sioux, Crow, Gros Ventres, and other tribes. After the expedition, agents of fur companies investigated the possibility of trapping fur-bearing animals in the area, and during the 1830's and 1840's trading posts were established along the Missouri River. Trapping and trading with the Indians were the chief enterprises until gold was discovered in western Montana. The Indians were forced out of the area during the early 1880's and placed on reservations north of the Sun and the Missouri Rivers.

Placer gold was discovered in gulches of the Elkhorn and Big Belt Mountains in 1864 and 1865. Later rich silver, lead, and gold lodes were found in these mountains and in the Little Belt, Castle, Judith, and Moccasin Mountains. Mining camps grew up around many of the washings, and squatters settled about the stage stations. Helena, Radersburg, White Sulphur Springs, and Gilt Edge have a continuous history dating from the sixties. The increasing number of prospectors and emigrants to the placer gold fields made necessary the construction of military posts at Fort Shaw, Fort Maginnis, Fort Logan, and at other places in eastern Montana in 1869 and 1870. The

military posts and larger mining camps were connected by military roads. The mining of gold-bearing quartz ore was not extensive until transportation developed, but greatly increased after construction of railways in 1883 and 1887.

The early miners drifted in from California and other western mining centers and were the first to establish law and order in the area. Most of the members of the Territorial and early State legislatures were miners; they wrote the constitution for the State, outlined legal procedure, and designated the type of political units. They established the Doctrine of Appropriation under which water rights are obtained in Montana. A few of the early mining companies imported foreign laborers—principally Scotsmen, Austrians, and Poles—to work in the mines, and Welsh to work in the smelters.

Mining, the chief industry for many years, greatly influenced agricultural development. Some of the early miners turned to stock raising and farming as less dangerous means of gaining a livelihood. Soon after the military forts were established, stockmen drove in herds from western Montana and later from the plains of Texas and Kansas. After the Indians were confined to the reservations, ranching spread to the more remote sections. Stock raising was somewhat less hazardous in the Upper Smith and Musselshell drainage basins during the eighties than in those sections bordering the Indian reservations, where losses from raiding Indian parties were high after the buffalo disappeared.

Most of the early livestock companies were large. They grazed their stock successfully on the open range without providing winter feed and shelter until the severe winter of 1886, when nearly 60 percent of the livestock in the area died of cold and starvation. These large companies were followed by smaller ones that acquired title to the bottom lands suitable for wild hay production, to winter grazing lands, and to lands on which water holes were located. Ownership of the water holes controlled the grazing in many sections. Some of these organizations developed irrigation on the home ranches. During the dry years of 1902 and 1903, many of these organizations failed or were dissolved and were succeeded by local stockmen who ran smaller herds.

The early stockmen, mostly of English and Scotch descent, contributed to the agriculture of the State by developing irrigation, establishing laws governing livestock on the open range, and practicing the branding of stock to designate ownership.

The public domain was controlled largely by stockmen and miners up to the time the national forests were created and dry-land farming developed. Some sections, as the plateaus north of the Little Belt Mountains in Cascade County, were settled soon after the Great Northern Railway constructed a branch line through the western part of the area in 1887, and local tracts were placed under cultivation to supply farm products to the mining camps and military posts.

POPULATION

The area was sparsely settled when stock raising and mining were the chief industries, but with development of dry-land agriculture and growth of urban centers during the favorable crop years of 1906 to 1918, the population increased rapidly.

Droughts were somewhat more severe in central and north-central Montana than in other parts of the State in the period 1918-21. The census taken during this extremely dry period reported a total population of 109,350 in the ten counties of this survey. The 1930 census, taken after the agricultural depression, reported 101,313, or a loss of 8,037 since 1920. The drought prevailing in the Western States between 1930 and 1937 caused some migration from the more marginal farming areas and a corresponding decline in urban population.

The total population in the surveyed counties in 1950 was 110,741, or a gain of 11,535 since 1940. The gain was not uniform in all counties; those with industrial centers or greater irrigated acreage showed the most increase.

The largest town in each of the ten counties is the county seat. Great Falls (Cascade County), with a population of 39,214 in 1950, is the largest and most important distribution and manufacturing center in the area. Helena (Lewis and Clark County), the State capital, is the second largest city and had 17,581 inhabitants in 1950. Lewistown (Fergus County) had 6,573 inhabitants in 1950; Roundup (Musselshell County), 2,856; Harlowton (Wheatland County), 1,733; Townsend (Broadwater County), 1,316; Ryegate (Golden Valley County), 339; White Sulphur Springs (Meagher County), 1,025; Stanford (Judith Basin County), 542; and Winnett (Petroleum County), 407. A number of small towns and villages located on railways serve as local distributing and shipping points.

PUBLIC FACILITIES

The larger towns of the area have most of the modern municipal improvements—paved streets, electric lights, and gas, water, and sewage connections. The educational facilities in the larger towns and in the more prosperous dry-land and irrigated farming districts meet State standards. All the towns located on the railways and many of the mining districts are served by power and telephone companies. Many of the more progressive rural communities are served by rural electrification lines.

The State Capitol, Carrol College, and a number of charitable institutions are located in Helena.

INDUSTRIES

The more important industries in the counties of this survey are associated with natural resources. Lakes Sewell, Hauser, and Holter are storage reservoirs on the Missouri River and supply water to power plants located below the dams. At the city of Great Falls, waterfalls are used for the production of electricity. A network of power lines covers central Montana and adjacent areas.

The Kootenai and Fort Union geological formations carry workable beds of coal, which are mined in Cascade, Judith Basin, Fergus, and Musselshell Counties. The coal mines at Roundup (Musselshell County) provide employment for most of its residents. Crude oil from the Cat Creek field and from the fields in north-central Montana is refined in Great Falls and Lewistown. Natural gas is piped into the western part of the area and is available in Great Falls and Helena. Ores containing copper, lead, silver, and gold are smelted

in Great Falls and East Helena. A large custom smelter at East Helena serves mining districts in Montana and other States. Sapphires are obtained near Yogo Creek in Judith Basin County. Cement and gypsum plants are located near Lewistown.

Building and decorative stone, as granite and black marble, are found in many of the mountain ranges, and clay and shale suitable for making brick and tile occur in many sections. Undeveloped iron ore deposits occur in the Little Belt Mountains in Judith Basin and Meagher Counties. Copper is processed in a wire mill connected with the Great Falls smelter, and flour mills are located in Great Falls, Harlowtown, and Lewiston. Local repair shops and small processing plants, such as creameries, are located in most of the towns. The products of the farms and ranches are processed largely outside of the area, and their value exceeds that of the minerals produced in the area.

The wildlife and rugged scenery of the mountains and canyons attract many tourists to various pleasure resorts, including many dude ranches.

TRANSPORTATION AND MARKETS

Central Montana is well served by railways. The Northern Pacific Railway crosses the Milwaukee Road in the valley of the Missouri River at Lombard, passes through the Townsend and Helena Basins, and thence west through the mountains. The Chicago, Milwaukee, St. Paul & Pacific Railroad and its branch lines serve large parts of the eastern and southeastern parts of the area. This railroad enters the Musselshell River basin at Melstone and follows the course of the Musselshell River and its South Fork into Meagher County, where it follows Sixteen Mile Creek down to Lombard on the Missouri River. The Havre-Butte branch of the Great Northern Railway passes through Great Falls and Helena, and the Great Falls-Billings branch traverses Judith Basin and the Musselshell River valley from southeast to northwest. Branch lines of these different railways serve many ranching, farming, and mining districts, and with the main lines, provide facilities for the shipment of freight to St. Paul, Chicago, St. Louis, Spokane, Seattle, Portland, and other markets. Great Falls, Butte, Helena, and Billings are the chief markets in the State for the more perishable farm products.

The Montana Highway Commission has carried out a plan for connecting all county seats with hard-surfaced highways, and most of the main traffic courses are oiled or graveled. Most of the post roads and farm-to-market roads are improved, and in the more prosperous agricultural districts they are surfaced with gravel. The unimproved upland trails are passable most of the year, and the main trails in the national forests are usually kept in good condition during the tourist season. The graveled and improved dirt roads become very dusty late in summer and in fall.

AGRICULTURE

AGRICULTURAL DEVELOPMENT

The present agriculture is of four types: (1) Stock raising; (2) dry-land grain farming; (3) diversified farming—livestock, grain, feed crops, and stock feeding; and (4) specialized irrigated farming,

which includes production of sugar beets, potatoes, alfalfa, and hay for cash sale or for use in connection with stock feeding and dairy farming. Production of crops and livestock is changed to meet changing markets, to cope with drought cycles, and to meet local demands.

The present trend in agriculture began shortly after the turn of the century. Most of the larger irrigation projects were undertaken between 1903 and 1910, and much of the more desirable public range land was filed upon under the Homestead and Desert Acts and placed under cultivation between 1906 and 1915. During this period, localities north of Roy were colonized by Bohemians, and those southwest of Lewistown by Mennonites. The increase in the rural and urban populations during the homesteading period was largely the result of migration from the agricultural districts and industrial centers of the Central and North-Central States.

Stockmen withdrew from the more desirable agricultural districts during the homesteading period, and those in the foothills and in the more broken plains sections curtailed their operations. In the mountainous sections where stock grazed largely on privately owned land and on public domains, such as the forest reserves, homesteading of the tablelands and the intermountain basins brought some changes in management, but the stockmen were not greatly affected. During the droughts of 1918 to 1921, and especially during the severe winter of 1919, stockmen on the plains and intermountain basins suffered heavy losses and some of them failed. Since these droughts, much land in the more marginal farm sections that had been cropped was found unsuitable for small grains, and consequently the established livestock companies are again expanding operations.

LIVESTOCK

Central Montana, one of the more important stock-raising sections in the State, has terrain and range forage suitable for nearly all classes of livestock. Perennial streams provide abundant stock water in most sections, and the climate permits grazing on the range for most of the year. The ranches used more exclusively for cattle raising are in the tall-grass sections and have large tracts fenced for summer, fall, and winter grazing. Sheep are more generally run on open range and where farm land has been abandoned. The forage in these unfenced areas is somewhat more palatable to sheep than to cattle. In the mountain areas sheep are usually grazed at higher elevations during summer and in the intermountain basins and plains in winter. Many ranches combine the raising of sheep and cattle.

Most of the surveyed area is deficient in winter feed. More stock can be run on the summer grazing lands than can be wintered on the forage now produced on the irrigated and nonirrigated farms and ranches. The number of animals in most of the area is balanced against the winter feed supply, and it does not vary so greatly as in the plains of eastern Montana, where drought and other factors often necessitate the liquidation of livestock.

Many of the stock ranches in the foothills, intermountain basins, and plains are sound economic units with a good balance between land for summer and winter grazing and land for irrigated and flood-irrigated pasture and hay. These ranches have headquarters chiefly in the stream valleys, and they cover 10 to 20 sections or more of land

that is usually well supplied with perennial streams and water holes. During occasional protracted droughts, the supply of summer and winter feed is not enough to feed the stock and their number is reduced, but rarely are the breeding herds entirely lost as in some sections of the Great Plains.

Many of the stockmen who operate on 5 to 10 sections of land and run 100 to 200 head of cattle or an equivalent number of sheep control a limited acreage of summer and winter grazing land, but their irrigated and flood-irrigated hay land often is not dependable. During times of feed shortages they supplement their limited hay supply with commercial feed and with hay bought in the irrigated districts. Competition for grazing land makes the conditions under which some of these stockmen operate precarious, especially during periods of drought and occasionally during severe winters.

The consolidation of abandoned farm land into large ranch units and the creation of State grazing reserves have greatly reduced the number of transient sheepmen in the area. Most of the cattlemen operate on a cow, calf, and yearling basis. The average quantity of hay put up for winter feed per mature animal unit on these ranches varies from less than 1 ton in such plains counties as Musselshell and Petroleum to 1½ tons in a mountainous county such as Lewis and Clark. The feeding of livestock in the plains and lower intermountain basins usually starts in December and continues intermittently into April, and on the higher tablelands and in the foothills, from early November until about the first of May.

The total number of livestock in the area for selected years is given in table 3.

TABLE 3.—*Number of principal livestock¹ in 10 counties in central Montana in specified years*

County	Cattle		Sheep		Horses		Hogs	
	1940	1945	1940	1945	1940	1945	1940	1945
Broadwater.....	14, 496	25, 847	26, 864	29, 138	2, 235	2, 479	1, 478	3, 556
Cascade.....	37, 151	60, 293	91, 407	70, 747	5, 932	5, 284	3, 122	5, 363
Fergus.....	32, 280	76, 500	75, 155	62, 412	8, 496	8, 961	2, 394	6, 026
Golden Valley.....	7, 492	15, 831	54, 624	35, 762	1, 658	1, 751		457
Judith Basin.....	20, 952	38, 076	63, 818	55, 830	3, 250	2, 739	937	1, 580
Lewis and Clark.....	24, 116	33, 465	98, 145	65, 865	4, 006	3, 650	1, 961	2, 102
Meagher.....	20, 125	24, 927	137, 262	90, 824	2, 980	3, 349		315
Musselshell.....	8, 538	21, 872	34, 485	34, 976	2, 002	2, 536	571	1, 190
Petroleum.....	3, 994	14, 676	28, 345	29, 901	1, 804	2, 634	105	577
Wheatland.....	13, 499	23, 035	113, 493	77, 265	1, 941	1, 902	369	787

¹ The 1945 census reported livestock of all ages; the 1940 census, cattle and horses over 3 months old, sheep over 6 months old, and hogs over 4 months old.

The heaviest concentration of cattle in the State is in this surveyed area. Herefords and Shorthorns are the more important beef breeds, and on most of the ranches well-bred stock is kept. A few stockmen specialize in purebred herds from which foundation stock is obtained for maintaining the quality of cattle on the range.

Most of the milk cows on the nonirrigated farms and the ranches are crosses with the beef breeds. In the more diversified irrigated farm districts, as in the Helena and Townsend Basins, there are some fine dairy herds, including Holstein-Friesians.

Sheep were brought into the area as early as 1879 and have been an important source of income in Meagher, Lewis and Clark, Fergus, Wheatland, Cascade, and other mountainous counties. Most of the sheep belong to such fine wool breeds as the Rambouillet. Crossing of these breeds with mutton types to produce an earlier maturing and better meat-producing lamb is gaining favor among sheepmen. Since the droughts of 1918 to 1921, there has been a shift from dry-land farming to stock raising in the more marginal agricultural sections.

In the early days raising horses was important in some sections, as in the Townsend Basin and the Sun River Valley. In recent years, however, the number of horses in the agricultural areas has steadily decreased, especially with the increased use of tractors and trucks. In some of the counties where livestock raising is most important there has been some increase in saddle types. The swine industry is unimportant in nearly all the counties. Duroc and Belted Hampshire are the more popular breeds.

DRY-LAND FARMING

Dry-land farming developed slowly until about 1906, when various State agencies undertook the development of the agricultural resources and influenced the settlement of a large part of the public domain considered suitable for farming. Much of the tillable range land was taken up under the Homestead Act in tracts of 160 acres between 1906 and 1912, and the more remote and less desirable lands were filed upon in units of 320 acres after the passage of the Desert Act in 1913. A small acreage was taken up under the Stock Raising Act at a later date. The land placed under cultivation was used largely for cash crops, chiefly wheat and flax. Crop yields were fair and farm prices good up to 1918, and the cropped acreage expanded rapidly. These yields and prices were reflected in the acquisition of land by farmers, the rapid rise in land values, the development of urban centers, and the construction of branch railway lines into many sections.

The cultivated acreage was greatly reduced after the severe droughts between 1918 and 1921, and the more marginal farm lands were largely abandoned. Good and poor crop years were interspersed between 1921 and 1930, and some of the abandoned farm land was again placed under cultivation. The homestead tracts were consolidated into larger farm and ranch units, farms were mechanized, summer fallowing of land was generally adopted, and the more marginal farm lands were retired for grazing purposes. Unfavorable climatic conditions between 1930 and 1937 appreciably reduced the cultivated acreage in some sections, but the abandoned farm districts were organized into State grazing reserves or were purchased by the Federal government as land utilization projects so that scattered units could be consolidated into ones of a size that could be operated economically.

Approximately 87 percent of the land under cultivation in the surveyed area is dry-farmed, chiefly to cash crops of spring and winter wheat, grown largely on the tablelands in Fergus, Judith Basin, and

Cascade Counties. The 1940 census reported the total cultivated land as 1,478,137 acres, of which 188,049 acres were irrigated. Of the total acreage under cultivation in 1940, 869,937 acres produced harvested crops; 560,267 were idle or fallow; and 47,933 were listed as crop failure. The acreages of cropland harvested, crop failure, cropland idle or fallow, and irrigated acreage for each of the counties of the area are given in table 4.

The farms on the tablelands used exclusively for grain usually cover one or more sections and have an annually cropped area of 200 to 400 acres. The more important cash crops of spring and winter wheat are grown on land that has been summer-fallowed the previous season for the purpose of storing moisture in the subsoil and controlling weeds. Winter wheat is occasionally grown on disked stubbleland if fall moisture supplies are favorable and the land is not too weedy. Most of these grain farms are mechanized; preparation of the land, seeding, and harvesting are done with tractor-drawn machinery.

Stock raising and grain farming are often combined along the borders of the tablelands, in the foothills, and in the sections less favorable to agriculture. These combination farms usually cover several sections, and a large part of the cropland is used to produce feed and forage crops.

Soil drifting has become increasingly more difficult to control in many sections. The block system of fallowing land is giving way to strip farming and to stubble-mulch fallow, which are more effective. The tillage implements formerly used in preparing the land for fallow and for seeding are being replaced with implements that leave the soil cloddy and rough, with part of the crop residue on the surface.

IRRIGATION FARMING

Some of the early stockmen constructed small dams on the streams to divert water onto bottom lands, adjacent slopes, and benchlands for irrigating pasture and wild hay. Nearly all the land brought under irrigation during the 1890's, as well as the bottom lands subject to overflow, was used to produce the pasture and hay needed to support the livestock industry. Early irrigation projects were carried out chiefly by individual enterprise or by a cooperating group of farmers. No extensive projects were undertaken, largely because stream flow was torrential during runoff periods. Larger projects, mostly carried out by cooperative associations, were initiated between 1900 and 1910 in Helena and Townsend Basins, Smith River Valley, and the upper Musselshell River basin. Some of these were later organized into irrigation districts with more costly diversion and distribution systems.

Work was started on the Sun River Reclamation project and on several Carey Act projects about 1903. The Sun River Reclamation project covers most of the Sun River valley and the tablelands north of this stream in Teton and Cascade Counties. Construction of the Carey Act projects in Lewis and Clark and Petroleum Counties was not completed, and they were abandoned. A part of the main canal of the Dearborn project constructed under the Carey Act, but later abandoned, is now used to divert water into stream valleys, as those of Flat and Auchard Creeks in Lewis and Clark County. After the droughts of 1918 to 1921, irrigation districts were organized in some

TABLE 4.—*Cropped acreage in 10 counties in central Montana in stated years*

Cropland and year	Broad-water	Cascade	Fergus	Golden Valley	Judith Basin	Lewis and Clark	Meagher	Mussel-shell	Petro-leum	Wheat-land
Cropland harvested:	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
1930.....	47, 146	231, 101	384, 287	54, 894	194, 061	69, 016	54, 928	61, 891	50, 181	54, 826
1940.....	36, 223	172, 202	276, 177	32, 041	159, 248	56, 462	49, 286	35, 006	17, 228	36, 064
1945.....	54, 592	218, 543	326, 309	34, 710	171, 194	66, 937	44, 718	37, 966	25, 440	43, 522
Crop failure:¹										
1930.....	7, 968	13, 668	25, 738	22, 451	21, 187	5, 781	9, 500	17, 679	10, 104	14, 882
1940.....	306	12, 105	19, 564	2, 116	3, 576	3, 379	233	3, 268	2, 093	1, 293
1945.....	85	17, 379	7, 485	1, 048	425	797	-----	6, 907	295	45
Cropland idle or fallow:										
1930.....	18, 469	100, 323	198, 716	27, 840	97, 589	15, 061	6, 676	37, 319	22, 313	26, 051
1940.....	20, 321	132, 082	204, 809	23, 536	103, 916	12, 385	3, 187	28, 044	16, 053	15, 934
1945.....	15, 280	139, 230	189, 547	16, 576	88, 702	14, 646	1, 735	21, 516	7, 557	6, 311
Irrigated land:²										
1940.....	25, 340	27, 666	16, 355	4, 377	7, 310	39, 014	39, 949	2, 714	3, 665	21, 659

¹ Includes land on which winter wheat did not survive the winter but which is usually reseeded to wheat in spring.

² Not reported in 1930 and 1945.

of the more marginal farm sections, and in a few districts bonds were sold to defray costs of preliminary engineering surveys. None of these proposed projects were developed.

The perennial flow and floodwaters of streams are used in all sections to irrigate stream valleys, adjacent slopes, and benchlands for the production of crops for cash sale, feed, and forage. The 1940 census lists 188,049 acres of irrigated land in the area, of which 15,807 acres were irrigated pasture. This acreage was distributed over 1,493 irrigated and partially irrigated farms and ranches, chiefly in Meagher, Lewis and Clark, Cascade, Broadwater, Wheatland, and Fergus Counties. Under direction of the State Water Conservation Board, storage reservoirs and canals are being constructed to provide supplemental water for some of the existing projects and to bring additional acreages under irrigation. Completion of this work will bring an estimated additional 25,000 acres or more under water.

The commission projects are located in Broadwater, Meagher, Wheatland, Golden Valley, and Judith Basin Counties. All except one of the larger irrigation projects in the area are of the gravity type. The Montana Reservoir and Irrigation Company in the Helena Basin was organized to supply water to 10,000 acres, of which 5,000 acres are irrigated by lifting the water with pumps to an average height of 110 feet. A few low-lift pumping plants have been installed along perennial streams for irrigating local tracts. The Missouri River and the larger streams heading in the mountains are the more dependable sources of irrigation water.

Most of the irrigated acreage is distributed over the surveyed area in isolated and "shoe-string" tracts along the streams; it is used chiefly for growing the pasture and hay needed on stock ranches. Only a small part is used for intensive farming and specialized crops. The size of the farms varies widely. Truck farms have only a few acres, but some of the stock ranches may have 1,000 acres or more. The farms producing grain, hay, and livestock as a joint enterprise range from 160 to 320 acres in size and occur chiefly in the Townsend Basin. The more intensive types of irrigated farming—dairying, poultry raising, and truck farming—are practiced along irrigation systems located near the larger towns. The truck and poultry farms are only a few acres in size; the dairy farms, 80 acres or more.

On the combination farms sale of grain and livestock provides most of the income, but occasional winter feeding of cattle and sheep is an additional source. The income on farms used more exclusively for production of hay varies according to the need for winter forage, and sometimes hay surpluses accumulate. Sugar beets, introduced on irrigation projects in the Townsend Basin and Sun River valley during the past few years, and potatoes grown in the Helena Basin, are also sources of income on the more diversified farms. Dairying is carried on locally, but in most sections the irrigated land does not occur in bodies large enough to encourage establishment of creameries or cheese factories. The income from the truck farms depends largely on the demand at local markets.

The major runoff in the area occurs a month or more before crops need irrigation. After mountain snow melts in the last part of June and early in July, stream flow falls very rapidly. Water for late irrigation of crops is lacking on many of the projects, and this influences

irrigation practices, types of farming, and crops grown. Flooding or wild flooding is the common way of spreading water on most of the farms and ranches, and much seeped land results because drainage outlets are lacking. Growing of sugar beets and potatoes on some of the projects has led to better irrigation and management practices. The construction of storage reservoirs on such streams as the Musselshell River would aid in controlling the torrential movement of floodwaters and regulate stream flow to irrigation requirements.

The irrigated soils in many of the intermountain basins and in the lower stream valleys are low in organic matter, and are often in poor physical condition when first brought under cultivation. The better drained soils improve in tilth with cultivation, applications of barnyard manure, and the growing of alfalfa, and they reach their maximum production when intertilled crops such as sugar beets and potatoes are included in a rotation. Definite crop rotations and fertilizer practices have not been established in the more diversified farming districts, but sugar beets produce the highest yields when they are grown on well-manured land, are treated with phosphate fertilizer at seeding, and are preceded by alfalfa in the rotation. Potatoes, and sometimes alfalfa, respond to phosphate fertilizer. The soils in many of the stream valleys are subject to seepage and subirrigation and are poorly drained. In the western part of the area, the soils in the stream valleys are comparatively free from soluble salts or alkali and are used for pasture and wild hay.

CROPS

The crops grown are chiefly those varieties of small grains and forage that mature in 90 to 110 days and are able to withstand late spring frosts. At higher elevations where the growing season is less than 90 days and frosts are likely to occur in every month of the year, wild and tame grasses are grown. Wheat is the principal small-grain crop, followed by oats, barley, and rye. The acreage of small grains, sugar beets, and potatoes was over one-half the total harvested acreage in 1944.

The acreages of principal cereal and forage crops grown in the area, without differentiation between irrigated and nonirrigated crops, are given in table 5.

Wheat, the chief cash crop, was grown on almost one-half of the total harvested acreage in 1944. Cascade, Fergus, and Judith Basin are the wheat-producing counties. Comparatively low summer temperature, relatively short growing season, and dry atmosphere are more favorable to wheat than other crops, and the result is a grain high in protein content. In some years dry weather in fall and light snowfall in winter result in poor stands and severe winterkilling of winter wheat, especially at the lower elevations. Wheat production is confined largely to the high tablelands where the soils are mainly well-drained friable loams and silt loams containing a high percentage of organic matter and subsoil lime. The smooth relief of the tablelands permits use of heavy tractor-drawn machinery for seeding and harvesting. The yields of spring wheat often are greatly reduced by periods of dry weather in July and August. The climate in most sections, however, is more favorable to production of winter than spring wheat. Occasionally army worms, grasshoppers, and

TABLE 5.—*Acreage of the principal cereal crops threshed and forage crops grown in the central Montana counties in 1944*

County	Winter wheat	Spring wheat	Oats	Barley	Rye	Flax- seed	Wild hay	Alfalfa	Timothy and clover	Small- grain hay	Other tame hay ¹
	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>	<i>Acres</i>
Broadwater.....	7, 048	7, 327	5, 249	3, 028	27	-----	13, 747	11, 816	471	182	1, 297
Cascade.....	105, 058	19, 424	10, 889	13, 566	704	2, 177	13, 950	30, 312	8, 213	1, 705	4, 240
Fergus.....	128, 809	72, 765	14, 335	26, 527	101	203	16, 226	31, 746	6, 211	1, 747	19, 244
Golden Valley.....	14, 459	3, 477	3, 000	1, 579	40	11	3, 467	3, 735	1, 470	944	1, 117
Judith Basin.....	68, 103	34, 262	6, 537	18, 030	33	38	13, 786	13, 896	2, 481	750	10, 544
Lewis and Clark.....	8, 226	4, 196	3, 840	3, 086	145	-----	22, 445	18, 769	1, 087	1, 418	1, 752
Meagher.....	563	379	1, 478	499	264	-----	14, 220	7, 937	11, 992	481	6, 472
Musselshell.....	8, 215	5, 273	4, 272	2, 697	92	28	6, 532	3, 986	402	1, 221	2, 488
Petroleum.....	1, 433	4, 069	1, 925	945	37	279	3, 128	6, 229	70	172	3, 133
Wheatland.....	2, 521	6, 484	3, 673	1, 362	30	-----	14, 466	7, 216	2, 852	386	1, 239

¹ Excluding sorghums.

root rots injure wheat, but many insects and plant diseases common to the more humid regions cause little or no damage. Rusts seldom occur in this area.

Oats and barley, the main feed crops, are usually grown under irrigation on the very dark-brown soils of the tablelands and in the foothills. Average yields on the different irrigation projects are comparatively low. Corn growing is confined largely to the lower elevations in the eastern part of the area, and the acreage varies greatly from year to year, depending on feed shortages. Corn was grown on 4,163 acres in 1944; 1,353 acres were harvested for grain, and the rest was cut for fodder or grazed off by livestock. Rye is largely an emergency crop grown principally on nonirrigated land. Flax was an important crop in some sections after the range lands were placed under cultivation, but by 1944 it was threshed on only 2,736 acres.

Potatoes were produced on 2,877 acres in 1944, and average yields were low. Most of the acreage was in Lewis and Clark and Cascade Counties, and the normal yields in these counties was more than three times those of other counties. In some of the counties no potatoes are produced for home consumption. Sugar beets were grown on 2,880 acres in Broadwater and Cascade Counties in 1944. The beets are processed at beet-sugar factories in Missoula (Missoula County) and Chinook (Blaine County).

The hay land is in alfalfa, wild hay, timothy and clover, and miscellaneous forage crops. Alfalfa, the chief hay crop on the better drained irrigated lands, is also grown without irrigation in the foothills. The average yield of alfalfa is low, but on the better drained and deeper soils it is not unusual to get 2 to 3 tons or more an acre from two cuttings. On many of the stock ranches where the alfalfa stands are old and the fields are pastured late in fall, during winter, and early in spring, the yields often are less than 1 ton an acre. The wild grasses in the wet bottom lands produce from 1 to 1½ tons an acre. The yield of timothy and clover at higher elevations ranges between 1 and 2 tons an acre. Sweetclover is occasionally grown for pasture or hay on nonirrigated farms. Abandoned farm lands in the area are locally being seeded to crested wheatgrass and brome grass, which are utilized for both hay and pasture.

LAND USE

Since the droughts of 1918 to 1921, the submarginal farm land in all the counties has been reverting to range and being consolidated into large ranches and grazing reserves. State grazing districts have been organized in Petroleum, Musselshell, and Fergus Counties; others have been proposed in Golden Valley, Wheatland, and Broadwater Counties. The unappropriated public range lands have been organized into grazing districts under the Taylor Grazing Act. The more submarginal farm lands in Petroleum, Musselshell, and Fergus Counties have been retired from cultivation under the Federal land purchase program and organized into land utilization projects.

The less marginal agricultural lands—those on which alternative enterprises are feasible—are developing into combination livestock and grain farms. These combination farms are less hazardous than those on which grain is grown exclusively, for they may be expanded

either along grain or livestock lines according to weather and economic conditions. In the better farming districts the farms are being mechanized and regrouped into large, better balanced units. The adjustments on the grain and livestock farms in the foothills are chiefly connected with development of irrigation systems.

The more marginal farm areas—those on which spring wheat averages less than 7 or 8 bushels an acre on summer-fallowed land—are best used for livestock grazing. Marginal farm lands yielding 8 to 12 bushels of spring wheat an acre on summer-fallowed land may be profitably used for that crop when rainfall and prices are favorable, but variations in weather and prices periodically force these lands out of cultivation. The tablelands that produce yields of 12 to 20 bushels or more an acre on summer-fallowed land can compete with the better small-grain producing sections in other States and may profitably be used largely for production of cash wheat.

Many stockmen in the mountainous counties practice controlled grazing, but in the poor grazing and submarginal farm sections the land used for grazing is largely open range. The establishment of grazing districts should conserve the range lands by controlling the migratory movement of livestock, now a common practice in raising sheep, horses and, in some sections, beef steers. The seeding of the abandoned farm lands to crested wheatgrass, brome grass, western wheatgrass, and similar forage plants may influence the kind of livestock run on the range.

Irrigation farming in most of the area complements stock raising, and there seems to be need for an integrated use of irrigated lands and the range lands adjacent to them. In many sections the irrigated land and grazing land nearby are under different ownership and management, and stockmen purchase hay in the irrigated districts for the winter feeding of livestock only when their limited hay resources fail to last through the feeding period. The setting up of grazing reserves adjacent to many of the irrigated districts and the allotment of stock on the grazing reserves on the basis of feed and forage on the irrigated farms might assist in stabilizing the agriculture of the area. The chief purpose of the State Water Conservation Board water development program in the area is to stabilize the production of feed and forage for the livestock industry. Some of the land on the larger and more compact irrigation projects has possibilities for an intensive type of irrigated farming, but this acreage represents only a small part of the total in the area.

The total area in farms and ranches in the surveyed area, according to the 1945 census, was 10,205,131 acres, which was divided among 4,960 farms and ranches. The average area per farm or ranch ranges from 1,240.7 acres in Cascade County to 4,815.4 acres in Meagher. In the 1940 census there were 5,505 farms, 1,509 of which were wholly or partly irrigated. The abandoned farm and grazing lands and those held by mortgage companies have been slowly consolidated and incorporated into larger and more economic units, and the average size of all farms and ranches has steadily increased in all counties except those in which irrigation projects are being developed.

In 1937 the Agricultural Economics Department of the Montana Agricultural Experiment Station made a study of the effect of the economic depression and the 1930 to 1937 droughts on land ownership

in the State. The total acreage in the ten counties of this survey in 1930 was 14,094,720, of which 4,900,865 acres were public owned, 9,189,570 deeded (private) land, and the rest miscellaneous land. The public owned land included 3,336,831 acres in national forest and public domain, 965,070 acres of State land, and 598,815 acres of county or tax title land. The ownership of the deeded lands was as follows: 49.8 percent resident, 32.2 percent corporate, and 17.7 percent non-resident. Most of the corporate-owned land in Lewis and Clark, Broadwater, and Meagher Counties was in the mountains and was granted to the railways when they built into the area.

FARM TENURE AND LABOR

The 1945 census shows a few more owner-operated farms than were reported in 1940. In the area, an average 14.2 percent of the farms was operated by tenants. Broadwater County had the highest rate of tenancy on farms, 20.1 percent; Petroleum County the lowest, 9.9 percent. Most tenants operate on short-term leases, and where the tenant furnishes all the farm equipment and seed, his share varies from three-fourths to four-fifths of the crop.

The demand for seasonal farm labor has been greatly reduced by mechanization of the farms and ranches. Some seasonal labor is required, but it is usually met by transient and surplus labor in the towns. Truck gardeners depend upon such labor to fill their seasonal needs. The herding and shearing of sheep are done by men experienced in these lines. Mexicans and Filipinos are employed in the sugar beet fields.

FARM POWER AND MECHANICAL EQUIPMENT

Low prices for wheat in the 1930's tended to accelerate the change-over from horse-drawn to heavy tractor-operated labor-saving farm machinery. In 1945, 3,448 farms reported 4,497 tractors, and motor-trucks were in general use on most farms.

Mechanization of farms is having some effect on community life. Operators do not find it necessary to reside on the land, and many have moved into neighboring communities where there are better schools, more social life, and rural electrification services.

SOIL SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the field. Reconnaissance surveys are designed to cover a large area in a relatively short time, and the field work is necessarily general. The soil reconnaissance in Montana is conducted by traversing the farming sections at intervals of approximately 2 miles and the grazing sections at somewhat greater intervals, depending upon the character of the terrain. A sufficient number of examinations are made to determine the character of the soils at a given location, and the boundaries of each soil area are sketched on the map in relation to topography and other external and internal features. County road maps are used as a base, and the scale is $\frac{1}{2}$ inch to 1 mile. Notes are made of the soils, topography, and vegetation, and other information on crops, tillage methods, and carrying capacity of the

land for livestock is obtained from farmers, stockmen, and other agencies for preparing the final report. Samples of soil are collected for reference and for chemical analysis. The chemical data contained in this report are averages of a number of analyses.

The soil map is designed to show the location and extent of the various kinds of soil in a given area. It is based on such physical properties as color, texture, structure, and thickness and relative position of the different layers or horizons found in a soil profile under field conditions. Soils having the same subsoil consistence, color of surface soil, position, and similar character and sequence of horizons are divided into groups known as soil series, which are further divided into soil types on the basis of the estimated proportions of sand, silt, and clay in the surface soil to a depth of 6 inches, or plow depth.

The name of a place where a soil series was first found is chosen as the name of the series. Thus, Gilt Edge clay loam and gravelly clay loam, undifferentiated, and Winnett silt loam are soils named after villages in the Central Montana area.

In some places the soils form an intricate pattern of associated areas too small to show individually on a map of the scale used, and they are therefore shown as soil complexes. Examples are Ringling loam-shaly loam, Billings-Arvada clay loams, and Cushman-Bainville loams and silt loams.

Furthermore, in this reconnaissance survey, associated soils similar in most characteristics and in suitability for use were in some instances not separately mapped, but were combined into mapping units containing two or more undifferentiated soils. Examples are Orman clay and clay loam, undifferentiated; Farland and Fergus loams, undifferentiated; and Adel and Teton loams and stony loams, undifferentiated.

When the mapping unit comprises a complex of soils, the dual name of the soil unit is hyphenated; when the mapping unit comprises a group of undifferentiated soils the dual name of the soil unit is separated by the conjunction "and".

The soils developing in recent alluvium on the bottom lands and low terraces in the stream valleys were mapped as an undifferentiated group of soils except that the darker colored soils of the valleys in the mountains and foothills—Alluvial soils, undifferentiated (dark-colored)—were separated from the grayish soils of the valleys in the lower intermountain basins and plains—Alluvial soils, undifferentiated (light-colored). Areas of Rock outcrop, Riverwash, Bouldrey and gravelly outwash, and Badlands, which were of sufficient extent to be delineated, are shown on the soil map. Rough mountainous land is shown as such, with no recognition given to the various individual soil types.

SOILS

The soils of Central Montana differ greatly in character and average productivity. This variation is associated largely with their physical, chemical, and biological properties and with the climatic zone in which they occur. Data gathered by the Agricultural Economics Department of the Montana Agricultural Experiment Station show that in some sections the average yield of spring wheat on summer-fallowed land is less than 8 bushels an acre, whereas in other sections the yield is 15 to 20 bushels or more. Sections producing less than 8

bushels an acre characteristically have shallow soils with a light-brown to brown surface soil and lime carbonate horizons within 6 to 8 inches of the surface. The small-grain districts producing high yields have dark-brown to very dark-brown soils with friable weakly granular surface soil and lime carbonate horizons below a depth of 10 to 20 inches or more. The larger tracts of abandoned farm land lie almost wholly within the crop-producing sections where average yields are low—where the surface soil is shallow and light-colored and the subsoil usually differs little from the underlying geologic materials.

The soils of the area are grouped according to physical characteristics that determine their inherent maximum suitability for use. The three broad general groups are: (1) Farming soils, suitable especially for small grains and moderately suitable for hay and intertilled crops; (2) farming-grazing soils, commonly recognized as marginal and sub-marginal farming soils that have generally low productive capacity; and (3) grazing soils, suitable almost exclusively for grazing of livestock. Areas of unclassified soils and soil materials such as Alluvial soils, undifferentiated (light-colored); Rough mountainous land (timbered); and Badlands that do not fit well into any of these three groups are classed as (4) miscellaneous soils and land types.

The three major groups are subdivided on the basis of those soil characteristics (chiefly color and content of organic matter) that result primarily from the influence of climate and vegetation on the soils during formation. In great measure these groups reflect productive capacity. Each of the three groups is broken into three subgroups: (1) very dark brown (Chernozem and Prairie) soils; (2) dark brown (Chestnut) soils; and (3) brown (Brown) soils.

This correlation between soil development and crop yields is largely related to differences in climate and native vegetation. In seasons of favorable moisture and temperature, the brown soils suitable for farming will produce 15 to 25 bushels an acre of spring wheat on summer-fallowed land, and the dark-brown and very dark-brown soils 35 to 40 bushels or more. Droughts and insect damage are somewhat greater in the brown soil zone than in the dark-brown and very dark-brown zones; consequently, average crop yields are lower in the brown soil zone than is indicated by the productive capacity of those soils in favorable seasons. The deep and moderately deep tillable brown soils covering the more marginal farming districts are suitable for spring wheat and will produce fair yields on nonirrigated land in seasons of favorable moisture and temperature. Moisture rather than soil fertility is the chief factor limiting crop production on these soils. Where irrigation is practiced, the effects of differences in soil fertility are noticed within a few years.

Most of the better drained, more friable, and homogeneous soils in the irrigated districts have a wide adaptability to crops, and their use depends largely upon their acreage and location and the water available for irrigation. Soils with dense clay subsoils or cemented gravelly hardpans, as well as the more stony, gravelly, and poorly drained types, have limited agricultural value and are used mainly for wild and tame grasses that are pastured or cut for hay.

The soil map (cover page 3) has been prepared to show by color the recommended use for land in the Central Montana area. The indi-

vidual soil units are outlined on the map and designated by symbols in the background. The map, therefore, shows the location and extent of each soil unit and into which of the three principal groups of agriculture it falls. Irrigated land is not indicated separately on the soil map. Irrigation is practiced on soils of suitable physical properties, regardless of soil zones, wherever water is available and projects have been developed.

FARMING SOILS

The farming soils occupy tablelands, plateaus, and glaciated plains, chiefly north and west of the mountain ranges, but also occur locally in the foothills and higher stream valleys. Most of them are suitable for winter and spring wheat and other small grains. Tracts shown as farming soils include a moderate percentage of nontillable land in areas too small and scattered to be delineated on a reconnaissance map of this scale. Most of the tillable land on the plateaus, tablelands, and glaciated plains is under cultivation. Isolated areas suitable for farming but used for grazing occur on the mountain slopes and in the foothills.

VERY DARK-BROWN FARMING SOILS

The very dark-brown farming soils (Goshen, Judith, Sipple, and Teton series) occur largely on the higher tablelands, plateaus, and in the mountain foothills of Cascade, Judith Basin, and Fergus Counties, and to some extent in other counties. They lie chiefly on the northern and western slopes of the different mountain ranges at elevations of 4,000 to 5,500 feet and in many places form fairly continuous belts 3 to 10 miles wide.

These soils have developed in colluvial-alluvial deposits at the foot of slopes and on alluvial fans washed out of the mountains and in residual materials derived from sandstone, shale, limestone, and other rocks. The soils formed in residual material have developed under a tall-grass vegetation and the rest under short and tall grasses. The soils formed under a precipitation of 16 to 20 inches, comparatively low summer temperatures, and a relatively short growing season of 95 to 100 days. These soils are moderately deep to deep and have mulchlike or imperfectly granular structure, very dark-brown to almost black surface soil, heavy upper subsoil, and calcium carbonate horizons that lie relatively deep as a rule. Most of them have slightly acid surface soil, with a range in pH from 6.0 to 6.5.

Elevations are somewhat high for general or diversified farming, and the soils are planted largely to winter and spring wheat. The content of organic matter, lime, and essential plant nutrients is good. The productive capacity of the soils is high. The wheat grown is of excellent quality, in most seasons grading on the market as hard red winter or hard red spring. Data show that the yield of spring wheat on summer-fallowed land averages between 16 and 22 bushels an acre on the deeper and less stony soils.

Strong winds cause some drifting of soil on land summer-fallowed in large blocks. Winds strong enough to cause soil drifting or soil blowing are more frequent late in winter and in spring, and on many farms either strip cropping or stubble-mulch fallow is practiced to hold the snow on the fields and to prevent soil blowing and damage to early spring seeded small grains. The small areas of irrigated land in this

group are chiefly in alfalfa hay at the lower elevations and timothy and clover hay at the higher. Numerous areas too stony and broken for cultivation are included in the group of very dark-brown grazing soils.

Most of the very dark-brown farming soils are relatively uniform in distribution and are mapped as separate units, but some have complex distribution, and two or more types are therefore combined in one mapping unit. Owing to the comparatively wide interval at which the soils were examined and the small scale of the map, small areas of similar soils and soils of widely different character may be included with some of the mapping units.

DARK-BROWN FARMING SOILS

Dark-brown farming soils (one or more types of the Belt, Danvers, Doughty, Farland, Fergus, Morton, Darret, Regent, Savage, Orman, Scobey, and Wade soil series) occupy high gently sloping tablelands, undulating to gently rolling plateau remnants and glaciated plains, and nearly level stream terraces in Cascade, Judith Basin, and Fergus Counties, as well as local areas in other counties. They lie chiefly north and west of the different mountain ranges, below the very dark-brown farming soils, at elevations of 3,300 to 4,000 feet. The mountain ranges locally influence climate, and in some of the intermountain basins and on the southern and eastern slopes of the mountains these soils are found at elevations above 4,500 feet.

These soils have formed in alluvial-fan deposits, on the tablelands on stream terraces, on glacial till, and in the rolling uplands on residual material derived largely from sandstone and sandy shale. The residual soils of the upland have developed under short grass. Those of the tablelands and till areas and terraces developed under mixed short and tall grasses. The soils formed under a rainfall of 13 to 16 inches, a comparatively low average summer temperature, and a growing season of 100 to 135 days. These farming soils are characterized by fair depth of development, a dark-brown friable surface soil, a brown subsoil with prismatic or blocky structure, and well-developed horizons of lime carbonate accumulation within 8 to 15 inches of the surface. The surface soils range from slightly acid to neutral, or in PH value, from 6.5 to 7.0.

Two closely related soils are included in several of the mapping units because the individual areas of each kind were not large enough to be shown separately at the scale used or because the soils were so intricately associated that they could not be separated conveniently. The soils mapped together have similar origin and the same general color, depth or thickness, structure, and content of organic matter. They differ mainly in surface soil texture and in the quantity of gravel or rock fragments they contain.

In central Montana the dark-brown farming soils occur where the summer temperatures are comparatively low and the length of the growing season is too uncertain for production of many kinds of crops. The main crops are spring and winter wheat, oats, and barley. Spring wheat yields 12 to 15 bushels an acre on most soils of this group. Nearly all the small grains grown by dry-land farming are on land summer-fallowed every other year to conserve moisture. Winds are strong late in winter and early in spring, and on

most farms strip cropping and stumble-mulch fallow are practiced to control soil drifting and to prevent damage to small grain seeded early in spring. Much of the region occupied by dark-brown soils is too broken for farming and is included in the dark-brown grazing soils group.

BROWN FARMING SOILS

The brown farming soils are members of the Brown great soils group, which is represented in most of the intermountain basins and on the tablelands and plateaus in the western, southern, and eastern parts of the survey area lying east of the Continental Divide. Nearly all the light-colored soils of the Brown great soils group are classified as farming-grazing soils and grazing soils; only a few areas are separated as brown farming soils.

Most of the brown farming soils (Amsterdam, Midway, and Manvel) occur in basins that receive supplemental water from the higher levels or lie on high tablelands and plateaus where conditions approach those under which the dark-brown farming soils developed. Elevations range from 2,800 feet in the eastern part of the area to over 4,000 feet in the intermountain basins and on the high tablelands and plateaus south and east of the different mountain ranges.

The brown farming soils have formed over colluvial-alluvial material at the foot of slopes and from residual material derived from sandstone, shale, and other rocks. They have developed under a short-grass cover, and in most sections under a rainfall of 11 to 13 inches, a comparatively low summer temperature, and a growing season of 125 to 140 days.

Two types of Amsterdam soil—Amsterdam loam and Amsterdam silt loam—were mapped as a single unit because of close similarity and the small scale of the map. The Manvel and Midway soils, uniformly silt loam in texture and occurring in complex association in most places, were also mapped as a complex. Separation of the Manvel and Midway soils could not be accomplished readily even in a fairly detailed survey.

The brown farming soils have fair depth, brown surface soil, distinct prismatic structure in the upper subsoil, and well-developed horizons of lime carbonate accumulation 6 to 10 inches below the surface. Some of the intermountain basins, tablelands, and plateaus lie at a comparatively high elevation and have low summer temperature and a normal precipitation of over 13 inches. The soils in the intermountain basins, and locally those on the tablelands and plateaus, are much lighter in color than might be expected in a grassland area having a rainfall as high as this. In addition, the soils are neutral to calcareous in their surface layers, having a pH range of 7.0 to 8.5. The effect of precipitation and low summer temperature on formation of soil in these areas is probably modified by the seasonal distribution of moisture and by winds—the chinook winds of low humidity coming during winter, and the warm winds during summer.

The brown farming soils produce on summer-fallowed land an average yield of less than 10 bushels an acre of spring wheat, the main cash crop. In many of the intermountain basins and on the tablelands and plateaus the average summer temperature is too low for production of such crops as corn; but in protected basins and

stream valleys in the southeastern part of the area, corn and similar crops are grown successfully. Winter wheat winterkills too frequently to be depended upon. Nearly all the small grain grown by dry-land farming is produced on land summer-fallowed every other year to conserve moisture. Most of the area is subject to strong winds late in winter and in spring, and the land under cultivation requires strip cropping to control soil drifting and to prevent damage to small grains seeded early in spring. Full utilization of floodwaters and the perennial flow of streams is needed for the production of irrigated feed and forage crops.

FARMING-GRAZING SOILS

The farming-grazing group is a broad one. Some of the soils have favorable texture, structure, and consistence, and smooth relief; others are shallow to bedrock, excessively sandy, gravelly, and stony, or steep or broken. All have low productive capacity for crops; their agricultural suitability is on the borderline between farming and grazing. A wide range of climate and greatly differing elevations modify their suitability for use. For example, some of the soils otherwise suited to cultivation occur at high elevations in a cool climate where the growing season is so short that only quick-maturing hay crops can be grown. Other soils, from the standpoint of their physical properties, are suited to cultivation but occur where precipitation is low and produce profitable yields only in seasons of above-average rainfall.

Farming-grazing soils fall into three general groups on the basis of surface soil color. The groups correspond closely to climatic belts or zones, which, to a great degree, are determined by elevation and, to a less degree, by the influence of the mountains on air currents and precipitation. The darkest soils (very dark-brown farming-grazing soils) are usually in areas of highest precipitation or in areas where precipitation is more effective; the lightest soils (brown farming-grazing soils) are in areas of lowest precipitation or where precipitation is least effective. The third group (dark-brown farming-grazing soils) includes those soils intermediate in color and other properties between the light-colored and dark-colored groups.

Aside from color of surface soil, each group of farming-grazing soils differs markedly from the other groups in chemical and physical properties and in content of organic matter. The differences among the soils within each group are due largely to differences in the character and composition of the material from which the soils have formed.

VERY DARK-BROWN FARMING-GRAZING SOILS

The very dark-brown farming-grazing soils are associated with the very dark-brown farming soils on the high tablelands and plateaus and in the mountain foothills. They occur principally in Cascade, Judith Basin, and Fergus Counties, but limited areas are in other counties. Only a few of the very dark-brown soils of the Chernozem soil zone are in the very dark-brown farming-grazing group; most soils of that zone are classified either as grazing or farming soils.

The very dark-brown farming-grazing soils have formed in alluvial-fan deposits and residual material similar to those of the dark-

brown farming soils, have developed under the same general climate, and have soil profiles much the same. The group includes complexes of moderately deep and shallow soils. The Boyd and Castle soils have developed on heavy shale; the Skaggs and Duncom, on limestone; the Teton and Cheadle, on sandstone and sandy shale; and the Utica and Judith, on alluvial-fan deposits of the gravel-capped benches.

Use of these soils for either farming or grazing depends upon location, general relief, or accessibility. Most of the ranchers, however, produce both livestock and grain. A fair part of the cultivated land is used for feed and forage crops. The deeper and less gravelly and stony soils have a productivity approaching that of the very dark-brown farming soils. In large part, however, soils of this group are too stony or gravelly, too steep or broken, or too shallow over bedrock to be well suited to cultivation.

DARK-BROWN FARMING-GRAZING SOILS

The dark-brown farming-grazing soils are of the Cheyenne, Beaverton, Darret, Fairfield, Hilger, Regent, Vebar, and Winifred series. Some of them are mapped as complexes. The soils are on tablelands, divides, and rolling plains in Lewis and Clark, Cascade, Judith Basin, and Fergus Counties, and locally in other counties. The more extensive areas are north and west of each of the different mountain ranges and on the high divides and mountain slopes in the south-central part of the survey. Elevations range from 3,300 to more than 4,000 feet. Some of the soils have parent materials somewhat similar to those of the dark-brown farming group, have developed under similar climate, and have some of the same general profile features.

The dark-brown farming-grazing soils are used for stock raising, or stock raising combined with grain growing. A number of features affect their agricultural suitability. Many of the soils are stony; some have a loose gravelly sandy subsoil and substratum; others are sandy throughout; yet others have heavy compact layers; and some are shallow or only moderately deep over bedrock. Because of these unfavorable features the soils have limited ability to absorb, hold, or deliver moisture to plants. They are, therefore, either nonarable or less suitable for cultivation than soils of the dark-brown farming group with which they are associated in many places. Small to fairly large areas are too steep for farming. The stony soils, which in other respects may be suited to crops, do not lend themselves readily to tillage and harvesting.

BROWN FARMING-GRAZING SOILS

The brown farming-grazing soils (Cushman, Flasher, Maginnis, Manhattan, Martinsdale, Bainville, Musselshell, Crago, Orman, Patent, Rocky Ford, Travessilla, Two Dot, Ulm, and Winnet) occur chiefly in the intermountain basins and on tablelands, plateaus, and divides in the western, southern, and eastern parts of the area. They lie at elevations ranging from 2,800 feet in Petroleum and Musselshell Counties to over 4,500 feet in some of the intermountain basins and on the higher divides and mountain slopes.

The brown farming-grazing soils have developed under the same climate as the brown farming soils, and in part over similar material.

They are much the same as the brown farming soils in arrangement and thickness of the layers in the upper part of the profile, in color of the surface soil, and in depth to the lime carbonate horizon. Nevertheless, they developed on a wider variety of parent materials that came from more varied sources, have a greater range in elevation, and occupy more varied topography. Furthermore, they have much greater range in ability to absorb and hold water and in productivity of farm crops and native vegetation. Stock raising and growing of small grain in combination with stock raising are the chief enterprises. Only a few farmers grow grain exclusively.

GRAZING SOILS

Most of the grazing soils are not suitable for farming because they are shallow to bedrock, stony or gravelly, and rough. Also included are soils at elevations above 5,000 feet, heavy soils in the drier sections, saline soils, and soils having claypans and other features unfavorable for cultivated crops. In this survey a large percentage of the soils outside the mountain areas are grazing soils, but because of the small scale used in mapping and the broad soil groupings, some soils suitable for farming may be included in areas mapped as grazing soils.

The grazing soils are subdivided and described according to color groups, or soil-color zones. Differences in color are generally due to differences in climate. There may be regional differences in climate, as well as differences caused by elevation or the effects of mountain masses on the frequency of storms and the direction of their movement. Within each color zone the grazing soils have developed under much the same climate as the farming and the farming-grazing soils associated with them. The black soils of the mountain grassland areas are grouped with the very dark-brown grazing soils.

Some areas of grazing soils are irrigated and used mainly for the feed and forage crops needed in the livestock industry. The stock ranches in grazing areas have 5 to 15 sections of land, and large tracts of the better grazing land on these are fenced. State grazing districts have been organized in some of the poor grazing sections to protect and restore the vegetation. Dams and dugouts have been made in many drier sections to hold surface water for livestock.

VERY DARK-BROWN GRAZING SOILS

The very dark-brown grazing soils (Adel, Teton, Barnes, Boyd, Spring Creek, Bridger, Castner, Morton, Cheadle, Hanson, Utica, and Williams series) occur mainly on or near the mountains, on high slopes and benches in narrow valleys, and on the high rolling to broken foothills and high tablelands extending out from the mountains. Some of the soils otherwise suitable for farming are at elevations above 5,000 feet where the growing season is too short or summer temperatures are too low for maturing crops other than grass hay. In large part, however, the soils are too steep and broken, too stony or gravelly, or too shallow over bedrock to be suitable for cultivation under ordinary tillage practices.

The small scale of the soil map makes it impossible to show small areas separately. A number of the mapping units therefore include two soil types either of the same or of different series. Though some of the mapping units are made up of soils of two series having markedly different parent rock materials, the association of soils in these mapping units may be just as close as in those units consisting of soils from the same series. At least one of the soil types in these units, usually the one of minor area, has physical properties and slopes suitable for farming. For example, Adel loam, included in the mapping unit Adel stony loam and loam, undifferentiated, is free of large stones, deep, dark-colored, permeable and friable, easily cultivated, high in available essential plant nutrients, and very productive of crops adapted to the climate. Adel loam, however, makes up only a small part of the mapping unit; it occurs as small areas within generally large areas of Adel stony loam, a soil suited only for grazing.

DARK-BROWN GRAZING SOILS

The dark-brown grazing soils are members of the Ashuelot, Beaverton, Gilcrest, Castner, Fairfield, Lihen, Moline, Arvada, Regent, Rhoades, and Scobey series. They occur on the middle and lower parts of the high alluvial fans and tablelands that extend out from the Rocky Mountain front; north of the outlying mountainous areas; and on the rolling uplands, stream terraces, and valley slopes below fans. South and east of the outlying mountains they occur in the lower part of the foothills, on the tablelands near the mountains, and at the apexes of the fans lying at the foot of the mountains. In places some of the lighter colored (brown) soils are interfingered with these dark-brown soils.

The dark-brown grazing soils have developed on materials much the same as those on which the very dark-brown grazing soils have formed, but they occur in areas of lower rainfall, higher average annual temperatures, and mostly at lower elevations. They are in the same general regions as the dark-brown farming soils and dark-brown farming-grazing soils, but are not suited to cultivated crops because of one or more unfavorable factors such as rolling and broken relief, high stone or gravel content, hardpan and claypan subsoil, extreme sandiness, or relatively high concentration of alkali salts.

Where there is no other land suitable for farming, some of the less stony grazing soils are used for forage crops if the relief permits use of farm machinery. Some of the soils ordinarily too droughty for dry-land farming produce fair to good yields of feed grains and forage crops when irrigated.

BROWN GRAZING SOILS

In its drier eastern and northeastern parts and in the dry intermountain valleys, central Montana is occupied mainly by brown grazing soils. These soils are of the Arvada, Wade, Avalanche, Bainville, Travessilla, Flasher, Berthoud, Larimer, Billings, Crago, Delpine, Gilcrest, Gilt Edge, Laporte, Lismas, McKenzie, Midway, Patent, Pierre, Ringling, Roy, Sage, Spring Creek, Terry, and Winifred series.

For the most part the brown grazing soils occupy rolling to strongly rolling, hilly, or broken areas too steep for cultivation. Some, however, occupy relatively smooth uplands, benches, and terraces, and from the standpoint of slope alone, could be farmed. Much of this smooth land, however, is too stony or gravelly for tillage, too shallow over bedrock, and too droughty for profitable production of most crops. Some of the soils are so salty that crops cannot grow or do not develop normally.

Small areas of medium-textured friable soils generally free of stone and relatively deep are included with the brown grazing soils because of the small scale used in mapping. These included soils are suitable for farming but on most of them successful production of crops will require rigid practice of summer fallowing and strip cropping to prevent soil blowing and drifting.

Some of the soils otherwise not suited to farming produce fair to good yields of nearly all crops adapted to the region if a well-managed system of irrigation is practiced. Where water is available, irrigation of the native grasslands greatly increases the yield of hay or pasture.

MISCELLANEOUS SOILS AND LAND TYPES

Except for two general classes of undifferentiated alluvial soils, the miscellaneous soils and land types have few characteristics in common. The alluvial soils have, in general, a common origin; that is, they have been washed from upland soils underlain by similar kinds of rocks, and they occupy similar positions along streams. They differ chiefly in the color of their surface soils, or in the color of the alluvium itself, and are classified as (1) Alluvial soils, undifferentiated (light-colored) and (2) Alluvial soils, undifferentiated (dark-colored). Most areas of the first are in the more easterly and northerly semiarid parts of the survey at some distance from the mountains; areas of the second are in the humid, subhumid, and semiarid parts, mainly within and near the mountains.

The soils of the extensive rough mountainous areas, mainly within national forests, were not classified and mapped at the same level of detail as the rest of the area. Instead, they were grouped under a general classification and divided into subgroups based on the prevailing dominant types of natural vegetation. The subgroups are (1) Rough mountainous land (timbered) and (2) Rough mountainous land (thin shrub and grass).

Other land types were mapped to show outstanding topographic or physiographic character and areas of widely differing kinds of soil materials either without soils or in which soils are still in the first stages of formation. These land types are Badlands, Bouldery and gravelly outwash, Riverwash, and Rock outcrop.

DESCRIPTION OF SOIL UNITS

The soils of the country, each identified by the same symbol as is used on the soil map (cover page 3) are described in detail in the following pages, and their agricultural relations are discussed. The acreage and proportionate extent for each soil are given in table 6.

TABLE 6.—*Acreage and proportionate extent of the soils mapped in central Montana*

Soil	Acres	Percent
Adel and Teton loams and stony loams, undifferentiated	240, 677	1. 7
Adel stony loam and loam, undifferentiated	65, 887	. 5
Alluvial soils, undifferentiated (dark-colored)	581, 063	4. 1
Alluvial soils, undifferentiated (light-colored)	356, 844	2. 5
Amsterdam loam and silt loam, undifferentiated	72, 640	. 5
Arvada and Wade loams and clay loams, undifferentiated	16, 514	. 1
Arvada clay loam and clay, undifferentiated	9, 534	. 1
Ashuelot loam and gravelly loam, undifferentiated	38, 590	. 3
Avalanche loam and gravelly loam, undifferentiated	31, 326	. 2
Badlands	389, 986	2. 8
Bainville, Travessilla, and Flasher loams and stony loams, undifferentiated	1, 141, 987	8. 1
Barnes stony loam and loam, undifferentiated	22, 530	. 2
Beaverton and Gilcrest loams and gravelly loams, undifferentiated	7, 037	(¹)
Beaverton gravelly loam	48, 408	. 3
Belt clay loam and clay, undifferentiated	78, 542	. 6
Berthoud and Larimer loams and gravelly loams, undifferentiated	28, 262	. 2
Berthoud loam and stony loam, undifferentiated	78, 429	. 6
Billings-Arvada clay loams	191, 077	1. 4
Bouldery and gravelly outwash	1, 589	(¹)
Boyd and Spring Creek clay loams and stony clay loams, undifferentiated	17, 309	. 1
Boyd clay loam	8, 399	. 1
Bridger stony loam	26, 900	. 2
Castle clay and clay loam, undifferentiated	11, 180	. 1
Castner-Morton loams and stony loams	85, 409	. 6
Castner stony loam	225, 525	1. 6
Cheadle stony loam	227, 908	1. 6
Cheyenne-Beaverton gravelly loams	19, 325	. 1
Cheyenne loam and gravelly loam, undifferentiated	27, 921	. 2
Crago gravelly loam	252, 878	1. 8
Cushman-Bainville loams and silt loams	113, 103	. 8
Cushman loam	223, 992	1. 6
Danvers silty clay loam	80, 755	. 6
Darret loam and stony loam, undifferentiated	6, 186	(¹)
Delpine shaly loam	28, 716	. 2
Doughty and Utica loams and gravelly loams, undifferentiated	38, 193	. 3
Fairfield loam and gravelly loam, undifferentiated	82, 969	. 6
Fairfield stony loam	16, 685	. 1
Farland and Fergus loams, undifferentiated	19, 409	. 1
Flasher-Cushman fine sandy loams	43, 414	. 3
Flasher-Terry fine sandy loams	11, 407	. 1
Gilcrest loam and gravelly loam, undifferentiated	28, 375	. 2
Gilt Edge clay loam and gravelly clay loam, undifferentiated	83, 763	. 6
Goshen loam	3, 519	(¹)
Hanson stony loam	109, 244	. 8
Hilger loam and stony loam, undifferentiated	221, 893	1. 6
Judith-Utica loams and gravelly loams	174, 677	1. 2
Laporte silt loam and stony loam, undifferentiated	16, 741	. 1
Larimer gravelly loam	67, 306	. 5
Larimer stony loam	60, 836	. 4
Lihen sandy loam	31, 042	. 2
Lismas clay	972, 695	6. 9
McKenzie clay	7, 264	. 1
Maginnis clay loam	61, 971	. 4

See footnote at end of table.

TABLE 6.—*Acres and proportionate extent of the soils mapped in central Montana—Continued*

Soil	Acres	Percent
Manhattan sandy loam.....	26, 162	. 2
Manvel-Midway loams.....	14, 415	. 1
Martinsdale loam and gravelly loam, undifferentiated.....	165, 370	1. 2
Midway-Bainville-Cushman loams and stony loams.....	124, 283	. 9
Midway-Patent clay loams.....	82, 515	. 6
Moline and Arvada loams and clay loams, undifferentiated.....	72, 300	. 5
Morton-Darret loams and clay loams.....	52, 778	. 4
Morton fine sandy loam.....	21, 565	. 2
Morton silt loam.....	206, 059	1. 5
Musselshell-Crago loams and gravelly loams.....	350, 375	2. 5
Orman clay and clay loam, undifferentiated.....	40, 860	. 3
Patent clay loam.....	119, 743	. 8
Pierre clay.....	414, 843	2. 9
Regent clay loam.....	14, 301	. 1
Regent-Rhoades clay loams.....	38, 420	. 3
Regent stony loam-clay loam.....	90, 516	. 6
Ringling loam-shaly loam.....	20, 487	. 1
Riverwash.....	2, 781	(¹)
Rock outcrop.....	60, 950	. 4
Rocky Ford silt loam.....	40, 293	. 3
Rough mountainous land (thin shrub and grass).....	200, 214	1. 4
Rough mountainous land (timbered).....	3, 892, 000	27. 6
Roy stony loam.....	61, 177	. 4
Sage-Arvada clay loams and clays.....	35, 355	. 3
Savage and Orman clays and clay loams, undifferentiated.....	11, 974	. 1
Scobey loam and clay loam, undifferentiated.....	45, 173	. 3
Scobey stony loam.....	37, 796	. 3
Sipple loam.....	73, 889	. 5
Skaggs and Duncom loams and stony loams, undifferentiated.....	150, 331	1. 1
Spring Creek stony loam.....	48, 238	. 3
Teton-Cheadle loams and stony loams.....	128, 028	. 9
Teton loam.....	83, 650	. 6
Travessilla-Cushman loams and stony loams.....	43, 187	. 3
Travessilla stony loam.....	25, 424	. 2
Two Dot loam and gravelly loam, undifferentiated.....	5, 789	(¹)
Ulm fine sandy loam.....	21, 565	. 2
Utica gravelly loam.....	60, 950	. 4
Utica-Judith gravelly loams.....	91, 027	. 6
Vebar sandy loam.....	21, 452	. 2
Wade clay loam.....	1, 986	(¹)
Williams stony loam.....	43, 471	. 3
Winifred clay loam.....	122, 240	. 9
Winifred-Pierre clay loams and clays.....	111, 627	. 8
Winnett silt loam.....	13, 223	. 1
Total.....	14, 096, 640	100. 0

¹ Less than 0.1 percent.

Adel and Teton loams and stony loams, undifferentiated (A_A).— Areas of these soils occur on higher and more broken foothills in Cascade, Judith Basin, Fergus, Meagher, and other mountainous counties at elevations of 5,000 to 6,000 feet, chiefly north of the Big Belt, Little Belt, and Big Snowy Mountains. Teton soils occupy the ridges; the Adel, the colluvial-alluvial slopes.

The Teton soils of this mapping unit are mainly dark-colored stony loams underlain at comparatively shallow depth by fine-grained sandstone or quartzite of Jurassic or older age. They are not so representative of their series as Teton soils developed on the indurated sandstone of the Kootenai formation in the lower foothills and on the high plateaus in Cascade and Judith Basin Counties. The Teton surface soil on the ridges, below a shallow layer of dark plant residue, is friable almost black imperfectly granular stony loam or stony silt loam. There is then a thin transitional layer grading into slightly altered fine-grained sandstone or quartzite at a depth of 6 to 15 inches. Many of the Teton soils, however, are 2 feet or more deep over bedrock and have a blocky dark-brown clay loam or silty clay loam subsoil comparatively free of rock fragments. The Teton soils are noncalcareous, though in some places the parent material will effervesce if dilute hydrochloric acid is applied. Rock outcrops occur on most of the area.

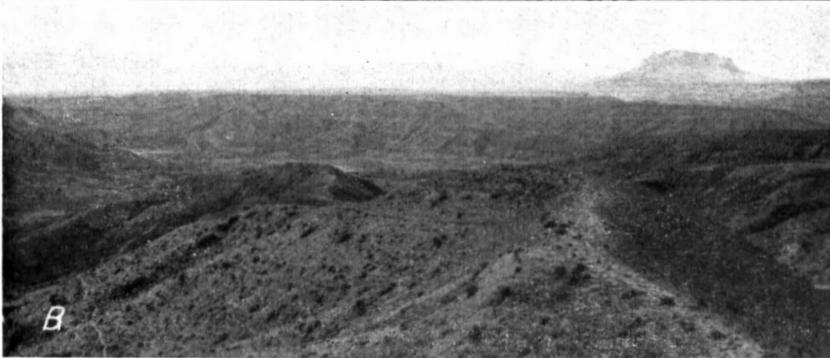
The profiles of Adel loam and stony loam do not differ greatly from that of Adel stony loam and loam, undifferentiated. At higher elevations, however, the surface soil is nearly black granular loam 15 to 20 inches thick that grades into lighter colored material, which rests on bedrock at a depth usually exceeding 3 feet.

The survey of the higher and more broken foothills and mountains was general, and this Adel-Teton mapping unit includes small areas of other soils that would have been separated in a more detailed survey. Cheadle stony loam on the narrow ridge crests and steep breaks is the chief inclusion; soils developed in glacial outwash, till, and hard limestone are minor inclusions.

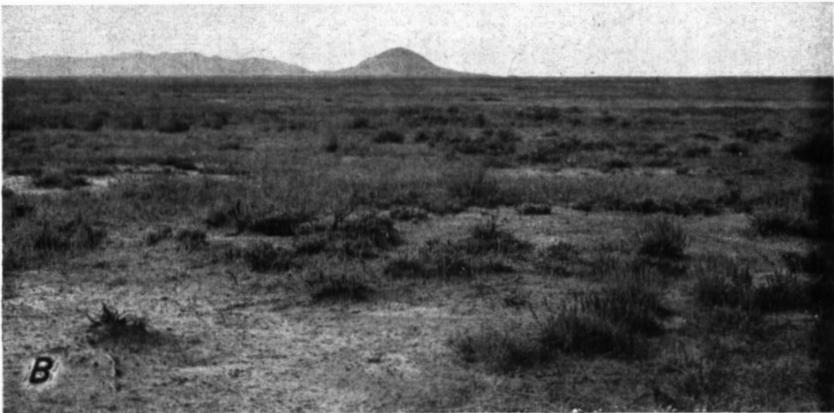
Use and management.—Most areas of Adel and Teton loams and stony loams, undifferentiated, are too stony, too broken, or lie at elevations too high for maturing most of the common small grains. Local stone-free areas in the foothills are used for growing timothy, clover, and small grains harvested in the dough stage for hay. Wild hay is cut on many of the smoother and less stony slopes. Some hayland is irrigated to increase the yield. The soils are well drained and productive, but surface runoff is high on steep slopes where natural vegetation has been destroyed. Numerous shrubs, upland sedges, and grasses such as mountain timothy and redtop densely cover most areas. The livestock carrying capacity is usually high during the 5 or 6 months the higher foothills are free from snow. Scrub timber grows on the higher ridges, and clumps of brush on the slopes. Both cattle and sheep are ranged on these soils, but the vegetation is somewhat more palatable to sheep than to cattle.

Adel stony loam and loam, undifferentiated (AB).—Most areas of these soils occur on smooth but steep relief in the foothills and on sloping park lands in the mountains at elevations above 4,800 feet. They are chiefly in Cascade and Fergus Counties but occur to limited extent in other counties. They have developed over colluvium consisting mainly of silty and loamy material mixed with angular and subangular stone fragments.

The surface soil is friable almost black imperfectly granular loam or silt loam 8 to 15 inches thick. Below a thin transitional layer is a friable grayish-brown to dark grayish-brown loam or silt loam subsoil containing many stone fragments. The noncalcareous colluvium is underlain by metamorphosed or crystalline sedimentary rocks at



- A**, Subirrigated valley in Helena Basin with Alluvial soils, undifferentiated (dark-colored), traversed by braided stream channel and indicated by clumps of trees; Avalanche loam and gravelly loam, undifferentiated, in foreground and Rough mountainous land (timbered) in far background.
- B**, Scattered sagebrush and grass on Badlands, 2 miles south of Arrow Creek in Judith Basin County.
- C**, Looking northward along valley of Wolf Creek: Rough mountainous land (thin shrub and grass) in background, which includes some areas of Ringling loam-shaly loam; Alluvial soils, undifferentiated (dark-colored), between road and foot of mountains; Berthoud loam and stony loam, undifferentiated, to right of road.



A. Profile of Judith loam (Judith-Utica loams and gravelly loams mapping unit), 2 miles west of Moccasin in Judith Basin County, showing limestone gravel.

B. Dry semiarid plains southeast of Judith Mountains in Fergus County showing vegetation on saline areas of Sage clay (Sage-Arvada clay loams and clays mapping unit) in foreground; Pierre clay on low ridge in middle distance; Judith Mountains in far background.

a depth of 3 feet or more. The quantity of stone fragments on the surface and in the soil varies from one area to another and even within short distances in the same area. In some places the surface is relatively free of large stones.

Use and management.—Areas of Adel stony loam and loam, undifferentiated, are usually too stony and steep for cultivation and are used for grazing. An area in Cascade County relatively free of large stone is used for early maturing small grains and such forage crops as timothy and clover. The soils are well drained and highly productive of adapted crops and native grasses. The surface acre-foot contains 5,000 to 8,000 pounds of nitrogen and 2,000 to 2,400 pounds of phosphorus. The cover of tall grasses, upland sedges, and shrubs is dense, and the carrying capacity for livestock is high during the 6 to 7 months the areas are free from snow.

Alluvial soils, undifferentiated (dark-colored) (Ac).—These dark alluvial soils occupy flood plains and high bottoms in stream valleys, chiefly in the mountains and foothills (pl. 1, A). The flood plains are largely stony riverwash, for most of the mountain streams flow through deep canyons. Wet bottoms occur along many of the streams. The high bottom lands are confined largely to the valleys of the larger streams below the mountains. The soils vary greatly in texture, and most of them are poorly drained but comparatively free of soluble salts.

The flood plains of most of the streams are covered with groves of native cottonwood and dense thickets of willow, chokecherry, service-berry, alder, and other brush. Western yellow pine grows on the gravelly soils in the Big Blackfoot Basin; other conifers grow on some of the soils in the higher mountain valleys; and wiregrass, sedges, and various shrubs are the chief cover on the wet bottom lands.

Use and management.—On the flood plains along the streams these soils are in places cleared of brush. Most of this cleared land, as well as the wet bottom land, is used for wild hay. The wet bottom lands have a high carrying capacity for livestock during the 6 to 9 months they are not covered with snow. The high bottom lands are in irrigated and nonirrigated crops grown for feed and forage.

Alluvial soils, undifferentiated (light-colored) (Ad).—These soils occur chiefly on flood plains and high bottom lands in the stream valleys of the north-central and eastern parts of the area. In the narrow valleys it was not possible to separate those alluvial strips along the streams and subject to flooding from similar strips of soils developed on older and higher terrace deposits, sloping alluvial fans, and colluvial deposits at the foot of slopes. All were therefore combined as one unit and shown on the map as continuous or disconnected areas along the streams.

The range in texture is wide, and the content of lime carbonate and soluble salts varies greatly. Surface and internal drainage differ widely depending on slope, texture, and position or elevation of the soils in relation to stream channels. Most areas of this mapping unit occur in a region of low rainfall where soils of the uplands and higher benches are light-colored; consequently, the alluvium washed from them and redeposited along the streams was originally light-colored. The alluvium of this mapping unit has mostly remained light-colored,

except in places where favorable moisture has caused an above-average growth of vegetation and darkening of the soil through its decay.

Use and management.—These light-colored alluvial soils generally are cultivated only where they are subirrigated or where water is diverted to them for irrigation. The less saline and lighter textured soils on the high bottoms are suited to a wide range of crops under irrigation and produce good yields of small grains and forage. The subirrigated bottom land soils support groves of cottonwood and dense thickets of willow, alder, and other brush. Under virgin conditions the high bottoms have a fair cover of short grasses. The heavy soils on the colluvial slopes below the shaly breaks of the Musselshell and Missouri Rivers in Musselshell, Petroleum, and Fergus Counties are covered chiefly with stunted black sage. Buffaloberries and other alkali-tolerant shrubs and grasses thinly cover the more saline soils. The livestock carrying capacity of these soils varies widely with location and soil material but is generally low.

Amsterdam loam and silt loam, undifferentiated (A_F).—Tablelands in the Helena and Townsend Basins and the Smith River Valley, as well as local high benches along the Missouri River Valley in eastern Lewis and Clark and northeastern Cascade Counties, are the sites of this unit. The soils have developed in silty aeolian, or loesslike, deposits, which in most of the intermountain basins overlie stratified weakly consolidated Tertiary lake sediments at comparatively shallow depth. The tablelands—dissected by deep coulees and in places separated by deep intervening stream valleys—range from 3,300 feet elevation in Cascade County to over 5,300 feet in the Smith River Basin in Meagher County. Most of the tablelands have smooth single slopes (gradients of 40 to 80 feet to the mile), but in the Helena and Townsend Basins they occupy different erosional levels or different stages of deposition—the materials at each level coinciding with different levels of the ancient lakes in which they were laid down. The higher levels are undulating to gently rolling and usually have a lag of gravel on the ridges and slopes.

Gravelly outwash or alluvial-fan material from the mountains and foothills mantle the lake sediments in many of the intermountain basins from a depth of 3 feet to many feet. Soils developed over this material are chiefly those of the Larimer and Berthoud series. In a more detailed survey isolated areas of Amsterdam loam, silt loam, and gravelly loam would be mapped in the upper Smith River Valley and in some other places, but these minor soils are in this survey mapped as one unit.

The surface soil in most areas is grayish-brown loam or silt loam, 4 to 6 inches thick and of fine crumb structure. The subsoil is calcareous soft blocky grayish-brown silt loam, which at depths of 12 to 20 inches is replaced by a massive grayish-brown silt loam or silty very fine sandy loam streaked with lime carbonate. Below 3 feet or more are lake sediments consisting mainly of partly weathered stratified silt, very fine sand, gray volcanic ash, and, in places, layers of clay and gravel. The lake sediments have been reworked locally by the wind. In some places the surface soil is slightly sandy and grades downward into fine sandy loam. On some of the ridges and slopes enough gravel occurs in the surface soil to form small areas of Amsterdam gravelly loam.

Use and management.—Most areas of these undifferentiated soils occurring in Lewis and Clark, Cascade, and northern Broadwater Counties are under cultivation, largely to spring wheat grown on summer-fallowed land. Areas in southern Broadwater and in Meagher Counties were cultivated before the droughts of 1918 to 1921, but these have been abandoned and only a small acreage is now farmed. During the past 20 years farms on Amsterdam soils have been slowly consolidated into large operating units.

The soils of this mapping unit that occur on the lower levels of the tablelands in the Helena Basin are irrigated and among the soils most productive of small grains and truck crops in that basin. They have a high water-holding capacity and good surface and internal drainage and are easily tilled under a wide range of moisture conditions. The surface acre-foot of soil contains 3,000 to 4,500 pounds of nitrogen and 1,500 to 2,000 pounds of phosphorus. The average yield of spring wheat on summer-fallowed land is 10 bushels an acre, though yields are much higher in seasons of favorable moisture.

If irrigated, these soils need to be built up by adding organic matter and mineral fertilizer. Their loose consistence and fine structure and texture favor accelerated wind and water erosion. In large fields it is nearly impossible to prevent heavy loss of soil through severe drifting unless the land is farmed in strips or a stubble mulch is kept on it during summer fallowing.

A small percentage of the Amsterdam soils occupy strongly rolling to hilly relief and are suitable mainly or entirely for grazing. Most of the steeper areas are shown on the soil map by hachure lines, which are used to differentiate soils suited mainly to cultivation from those suited chiefly to pasture.

Arvada and Wade loams and clay loams, undifferentiated (AF).—Several small basins below shale escarpments in northern Cascade County are occupied by this complex. The soils are marked with bare spots and have the scabby appearance characteristic of Wade and Arvada soils.

The Wade soils occupy the lower parts of basins where runoff from the higher slopes collects and promotes a more luxuriant growth of grasses, the accumulation of more organic matter, and darker colored soils than are on the slopes of the basins. The Wade surface soil is friable dark brownish-gray loam or clay loam, 5 to 7 inches thick. It grades quickly into the heavy upper subsoil, a dense, compact, brown to dark grayish-brown clay of pronounced columnar structure. A massive highly calcareous light-gray silty clay loam spotted white with salt accumulation occurs 8 to 12 inches below the surface and continues to a depth of 3 feet or more.

The Arvada soils are light-colored and do not differ greatly from Arvada clay loam and clay, undifferentiated.

Use and management.—This complex of Arvada and Wade loams and clay loams is used only for grazing. The soils are so slowly permeable that some water runs off the upper slopes and collects in the lower part of the basins, where it eventually enters the ground or evaporates. Except in the bare spots where the claypan subsoil is exposed, the cover of tall and short grasses is fair. The forage on 25 to 30 acres will feed one steer through a 10-month grazing season.

Arvada clay loam and clay, undifferentiated (Ag).—This unit occurs on terracelike alluvial fans or low benches lying below areas of heavy soils in many of the stream valleys in the eastern part of the surveyed area. The larger tracts are in the north-central part of Fergus County along Armells Creek. Many small areas and long narrow strips also occur in narrow stream valleys but cannot be shown at the scale of mapping used and are therefore included with Alluvial soils, undifferentiated (light-colored). Numerous slick spots (exposed claypan subsoil) and some puff spots (salty soils of fine granular structure) give the surface of the otherwise smooth benches a slightly hummocky microrelief.

The surface soil to a depth of 4 or 5 inches is mostly a friable laminated gray or light-gray heavy clay loam or silty clay. Underlying this is a layer of grayish-brown columnar clay, 3 to 5 inches thick. The subsoil below the columnar claypan is chiefly stratified to massive silty clay or clay containing slight accumulations of carbonate of lime, gypsum, and other salts. The southern part of the large tract west of Armells Creek is underlain by gravel at depths of 2 to 4 feet. In the extreme southern part the soils grade to gravelly silty clay loam with claypan subsoil and are fairly typical of Gilt Edge soils.

Use and management.—Arvada clay loam and clay, undifferentiated, is not dry farmed and is used chiefly for grazing. Thin stands of big sage and western wheatgrass are the bulk of the vegetation. Greasewood occurs on the included saline spots. The carrying capacity for livestock is low. The small areas along Armells Creek under irrigation are planted chiefly to wild hay and alfalfa.

Ashuelot loam and gravelly loam, undifferentiated (Ax).—A layer of rounded gravel cemented by lime to a hard concretelike mass is characteristic of the Ashuelot soils. The hard layer is not continuous over large areas and gives way to less consolidated subsoil or to gravel weakly cemented with lime. The soils occupy benchlands in the northwestern part of Cascade County and isolated areas on tableland in Judith Basin County. In a more detailed survey isolated areas of these soils on the tablelands in northwestern Musselshell and northern Golden Valley and Wheatland Counties would be mapped separately, but in this survey they are mapped as inclusions in the Doughty and Utica soils. In Cascade County the benches are capped chiefly with the rounded quartzite and argillite gravel deposits typical of the Ashuelot series, but in Judith Basin County the gravel is chiefly rounded fragments of limestone.

In most places the surface soil is 4 to 10 inches of friable dark grayish-brown loam or silt loam containing little to abundant gravel. It usually rests directly upon a hard 3- to 5-inch layer of cemented gravel. Below the hard layer the interstices between the gravel are filled with almost white limy clay material. Stratified loose quartzite and argillite gravel and sand lie at a depth of 2 to 3 feet.

In Judith Basin County the dominant surface soil is very dark grayish-brown gravelly loam or silt loam underlain at 6 to 10 inches by calcareous grayish-brown gravelly loam. At a depth of 9 to 18 inches is a hardpan layer, which grades downward into the less consolidated, firm, or weakly cemented gravelly limy lower subsoil, which at a depth of 30 to 40 inches grades into the loose gravelly and sandy substrata. Large angular fragments of the concretelike material,

locally termed "Belgian blocks", occur on the surface where the hardpan lies near the top of the ground and has been turned up by tillage.

Use and management.—Ashuelot loam and gravelly loam, undifferentiated, has been placed under cultivation in Judith Basin County but the acreage cropped has been slowly declining because of low yields. Spring and winter wheat are the chief crops. Recently the canals of the Sun River irrigation project have been extended into areas on the bench in Cascade County, and on these alfalfa and feed crops are grown. The hardpan in these soils appears impervious, but irrigation water moves readily through it, and the soils are well drained and fair in water-holding capacity. The surface acre-foot of soil on the bench in Cascade County contains 3,200 to 3,500 pounds of nitrogen and 2,000 to 2,500 pounds of phosphorus; in Judith Basin County it contains 1,000 to 1,500 pounds more of nitrogen and about the same quantity of phosphorus. The yields of irrigated alfalfa are fair. These soils had a good grass cover and a fair livestock carrying capacity before they were cultivated. Native grasses are slowly coming back on the abandoned areas, and some of these have been seeded to crested wheatgrass.

Avalanche loam and gravelly loam, undifferentiated (AL).—Occurring as interspersed gravelly and nongravelly areas on benchlands in the Townsend Basin in northern Broadwater and southeastern Lewis and Clark Counties, these soils have developed over relatively thick beds of water-worn gravel derived from metamorphic and igneous rocks. The upper part of the gravel is mixed with loamy fine earth material and is in places mantled with up to a foot or more of silty loesslike material. The benchlands have smooth gentle slopes but are dissected by narrow deeply entrenched stream valleys. Some large angular and subangular rocks occur locally on the higher parts of the slopes near the mountains.

The 4- to 6-inch surface soil is chiefly a friable calcareous light grayish-brown loam or gravelly loam of soft crumb structure. The subsoil—a highly calcareous ill-defined soft blocky silt loam or gravelly silt loam—grades into loose water-worn gravel at 10 to 12 inches. The gravel, consisting largely of argillite and quartzite, is coated with lime 2 or 3 feet below the surface. A moderately large percentage of the gravel on some of the benches is from limestone.

These soils are similar to the Larimer, also brown grazing soils, but have a lighter colored surface soil, lack the accumulation of silty lime in their subsoil and in the upper part of the gravel, and have a thinner solum over the gravel.

Use and management.—These undifferentiated soils are used mainly for grazing. The areas are largely open range land, in many places overgrazed. Grama grass predominates in the thin cover of native grasses. The forage on 30 to 35 acres or more is required to carry a steer through a 10-month grazing season. The perennial flow and floodwaters of mountain streams are in places diverted to the benchlands to increase yields of alfalfa, small grains grown for hay, and other forage crops. These soils have 3,500 to 4,500 pounds of nitrogen and 2,200 pounds of phosphorus in the surface acre-foot. Alfalfa produces fair yields on the deeper less gravelly soils.

Badlands (BA).—Areas designated as Badlands are chiefly breaks of streams, escarpments of tablelands, and local upland exposures of

eroding shale and sandstone. Along the Missouri and Musselshell Rivers in the eastern and northern parts of the surveyed area are two general types of badlands—the shale and the sandstone. The shaly badlands consist of gullied clay—shale hills, ridges, and buttes separated by deep coulees with steep barren shale slopes. In Fergus County the higher ridges and buttes are locally capped with sandstone. The sandstone badlands are chiefly broken sandstone ridges with barren cliffs and steep escarpments. The shale formations exposed in these areas are often undercut; the sandstone forms shelves and “mushroom” rocks, and the shale buttes and pinnacles are capped with sandstone.

Use and management.—Badlands of the shaly type are partly vegetated with thin stands of Western yellow pine, juniper, big sage, and bluebunch wheatgrass (pl. 1, *B*); those of the sandstone type support an open stand or scattered individual trees of Western yellow pine, with thin stands of grama grass and western wheatgrass on the broader ridges. Most isolated areas in the uplands are devoid of vegetation, but a few juniper and Western yellow pine and scattered patches of grass occur in places. Badland areas have a low carrying capacity for livestock and are usually grazed with other range lands that support better stands of grasses of higher grazing value.

Bainville, Travessilla, and Flasher loams and stony loams, undifferentiated (Bn).—These soils occupy gently rolling to strongly rolling and broken uplands, mainly in the southeastern and eastern parts of the area. They have developed on fairly soft and hard sandstone and silty or only slightly clayey shale, which are chiefly of the Fort Union Formation and of Tertiary age. In large part these are the soils on the Bull Mountains Upland of Musselshell and Golden Valley Counties. They also occupy relatively large discontinuous areas along the breaks of the Musselshell and Missouri Rivers in Fergus and Petroleum Counties, and isolated small and large areas in all of the counties above mentioned. Each soil in the mapping unit has distinct properties that would permit mapping it separately in a detailed soil survey, but all have many properties in common and about the same suitability for grazing. The soils absorb water readily but have a low total water-holding capacity because they are shallow to bedrock. Runoff is high on the steeper slopes and where the soils are only a few inches thick over bedrock.

A number of minor soil types were included, particularly in the Bull Mountains. Chief among these inclusions are small areas of sandy Terry and Vebar soils, which are moderately deep and deep, respectively. The Terry and Vebar soils are on the broader less sloping ridges in association with the shallow and very shallow Flasher soils that developed from relatively soft sandstone. Other included soils not otherwise mapped in the area are Wibaux loams and stony loam, which developed from red shale, incorrectly known as “scoria”, that was hardened and reddened by burning of former coal beds. These soils are associated with the Bainville soils, which developed from light-colored shale of medium or silty texture. Also included are narrow strips of alluvial soils lying along the small intermittent streams and soils developed in colluvial material on the lower slopes of the narrow valleys.

The shallow and very shallow Travessilla soils of this mapping unit have developed over and around outcrops of hard noncalcareous or only slightly calcareous sandstone. They differ from the Flasher soils chiefly in having a less limy subsoil and a substratum of hard relatively impervious sandstone rather than one of soft sandstone that absorbs water readily.

The Travessilla soils occupy relatively steep and broken areas. They have a light-brown, grayish-brown, or light grayish-brown commonly slightly calcareous loam or sandy loam surface soil, 2 to 6 inches thick and of ill-defined soft crumb structure. Underlying this is light grayish-brown or pale-brown mildly calcareous fine sandy loam or loamy fine sand with little or no structure and about the same thickness as the layer above. Next in profile is the little altered hard light-brown sandstone. Numerous small and large fragments of the hard sandstone are on the surface and embedded in the soil. Rock outcrops, including continuous ledges and escarpments around the rims of the valleys, are common.

The Bainville soils have a 4- to 5-inch surface layer consisting chiefly of friable calcareous grayish-brown loam or silt loam of soft crumb structure. The subsoil—a massive, friable, calcareous, yellowish-brown silt loam or silty clay loam—grades at a depth of 8 inches into a massive, friable, light yellowish-brown silt loam or silty clay loam. The silty clay loam continues down to the partly weathered stratified parent shale, which is at depths of 12 to 15 inches in most places. Outcrops of soft shale and firm stratified silt occur on the steep slopes and breaks or lie only a few inches below the surface in most areas.

The Flasher soils have a grayish-brown fine sandy loam and sandy loam surface soil 4 to 5 inches thick. Next occurs a transitional layer of calcareous grayish-brown loamy fine sand or fine sand, which at a depth of 8 to 12 inches is underlain by partly decomposed soft calcareous sandstone. The soft sandstone outcrops on some of the steep slopes and ridge crests, and lenses of hard rock contribute a few sandstone fragments to the surface soil.

Use and management.—Bainville, Travessilla, and Flasher loams and stony loams, undifferentiated, are not cultivated but are used for grazing. The Bull Mountains Upland and breaks from the upland down to the streams support an open to moderately thick stand of Western yellow pine. Over much of the mountains, however, the trees are confined to the more sandy soils. Most of the remaining area, being only lightly covered with grama, threadleaf sedge, and the tall grasses, has a comparatively low livestock carrying capacity. Some of the deeper soils on the higher grass-covered colluvial slopes in the Bull Mountains Upland have a good carrying capacity.

Some of the included deeper and darker soils are used for feed crops, and where they occur with areas of farming soils they are used partly for growing wheat and other small grains. Grain yields, however, are low.

Barnes stony loam and loam, undifferentiated (Bc).—Areas of this unit, most of them very hummocky and stony, occur in the higher glaciated foothills and on the mountain slopes south of the Sun River in northern Lewis and Clark County and on the slopes of the Big Blackfoot Basin west of the Continental Divide in the same county.

The boulders and rock on the surface consist mainly of argillite, quartzite, and limestone. The surface soil is somewhat darker than the typical Barnes soil in other States.

The surface soil below a shallow mat of dark plant residue is an imperfectly granular almost black stony loam or silt loam 6 to 9 inches thick. The subsoil is a firm dark grayish-brown stony clay loam that grades into a highly calcareous light grayish-brown stony clay loam at 24 to 30 inches. Below 40 inches is the parent till, a light olive-brown calcareous stony clay loam. In places the slopes of the Big Blackfoot Basin are comparatively free from boulders and stone. On these slopes the surface soil is a dark silt loam and the subsoil is a mottled iron-stained heavy clay containing some stone and gravel.

Use and management.—Most of this land lies too high for small grains to mature and is too stony and hummocky for cultivation. It is used almost exclusively for summer grazing. A few small basins on the moraines are suitable for those forage crops that can withstand the light frosts coming every month in most years. The surface acre-foot of soil contains 6,000 to 7,000 pounds of nitrogen and 2,000 to 2,500 pounds of phosphorus. The soils are very productive of the native grasses, and during the 5 or 6 snow-free months the park land type of vegetation (mixed tall grasses, upland sedges, and shrubs) forms a dense cover of high livestock carrying capacity. Some brush and small trees grow in most areas.

Beaverton and Gilcrest loams and gravelly loams, undifferentiated (B_D).—These gravelly soils of the Beaverton and Gilcrest series occupy low stream terraces or benches along the Sun River in the northwestern part of Cascade County. They have developed in water-transported material and differ chiefly in color and thickness of surface soil.

Beaverton gravelly loam occupies higher and older terraces and the higher parts of low terraces. The surface soil below a fine sandy surface mulch is dark grayish-brown gravelly loam. Underlying, at a depth of 5 or 6 inches, is calcareous brown prismatic or blocky gravelly loam. Stratified sand and gravel are at a depth of 12 to 15 inches.

The Gilcrest soils, occurring on the lower parts of the benches, are of both gravelly loam and gravelly sandy loam types. The 5- or 6-inch surface soil, a grayish-brown loam containing varying quantities of gravel, overlies a calcareous light grayish-brown gravelly loam or gravelly sandy loam subsoil. Stratified sand, silt, and gravel are at a depth of 10 to 18 inches.

Use and management.—These undifferentiated soils are irrigated. The cultivated land is used chiefly for alfalfa and small grains. Internal drainage is excessive, and frequent irrigation is required for maximum crop production. The surface acre-foot of soil contains 3,500 pounds of nitrogen and 2,500 pounds of phosphorus. Under good management, yields of irrigated alfalfa and small grains are fair. Where not irrigated, the soils are suitable only for grazing because they are shallow to gravel and low in water-holding capacity.

Beaverton gravelly loam (B_E).—Parts of high terraces or low benches in the valleys of many of the larger streams are occupied by this soil. These benches lie 15 to 75 feet above stream level, and where

drains from the uplands cross the terraces, they are locally dissected by narrow deeply entrenched valleys or coulees. The largest areas are along the South Fork of the Sun River in northern Lewis and Clark County. The soil has developed in water-transported gravelly material and is usually associated with Cheyenne soils.

To a depth of 1 to 2 inches the soil along the South Fork of the Sun River is loose mulchlike grayish-brown silt loam in which some quartzite gravel is embedded. Below this mulch lies a friable dark grayish-brown gravelly loam 4 to 5 inches thick and of soft crumb structure. The subsoil—a grayish-brown blocky gravelly loam—is calcareous in the lower part and is underlain by loose stratified sand and gravel at a depth of 10 to 15 inches. On the terraces near the mountains gravel and larger stones are on the surface and at all depths in the soil. On the benches the loose gravel and sand do not lie at a uniform depth, and in places this soil grades into Cheyenne gravelly loam, which is an associated dark-brown soil developed from similar materials but 18 to 36 inches thick over the loose gravel.

Use and management.—Beaverton gravelly loam is too droughty for dry-land farming and where not irrigated is used only for grazing. The lower part of the bench along the South Fork of the Sun River is under irrigation, and the cultivated land is used chiefly for alfalfa and small grains. Subsurface drainage is excessive, so crops require frequent light irrigations for maximum yields. The surface acre-foot of soil contains 4,500 to 5,000 pounds of nitrogen and 1,500 pounds of phosphorus. Grass, threadleaf sedge, and pricklypear are the chief native cover, and 30 acres or more are required to support a steer during the 10-month grazing season.

Belt clay loam and clay, undifferentiated (Br).—The clay loam soil of this mapping unit occurs on nearly level to undulating glacial-lake terraces in the northeastern part of Cascade County; the clay soil, in basins or slightly depressed areas in the terraces. Both have developed in fine-textured material deposited in former glacial lakes. They are characterized by well-developed claypans, which are locally exposed and form bare or slick spots on the surface. In cultivated fields the slick spots have a distinct light grayish color.

The surface soil on most areas is dark grayish-brown heavy clay loam, 8 to 12 inches thick and of fine crumb structure. The surface soil is underlain by a thin, platy, light grayish-brown or gray leached silt layer, which at a depth of 9 to 16 inches rests directly on a very dark-brown claypan of columnar or pronounced prismatic structure. This columnar claypan, 6 to 12 inches thick, grades to a massive or indistinctly blocky highly calcareous clay that becomes lighter textured and more friable with depth. The parent material at depths of 30 inches or more is massive calcareous light grayish-brown clay loam. A small quantity of glacial gravel occurs on the surface and through the soil in nearly all places. The leached gray silt layer is indistinct in places, and the claypan not well enough developed to be readily recognized.

The clay soils in the shallow depressions or basins differ from the clay loam soils in the better drained positions chiefly in having a heavier texture throughout, thinner surface and subsoil layers, and, in addition to calcium carbonate, an accumulation of gypsum and other salts at 30 to 40 inches.

Use and management.—These undifferentiated Belt soils are almost entirely under cultivation and are among the better winter wheat producing soils of the area. Some of the largest wheat farms cover 6 sections or more. The average rainfall during the growing season is 7 to 9 inches, most of which comes during May and June.

The land is usually prepared for summer fallowing with one-way disk plows early in spring, and north of the Missouri River it is strip-cropped. The soils of undulating relief have good surface drainage and slow but adequate internal drainage. Soils in the low places lack surface drainage, and water ponds temporarily because moisture moves downward through the heavy subsoil very slowly in wet seasons. The surface acre-foot of soil contains 4,000 to 5,000 pounds of nitrogen and 2,500 to 3,000 pounds of phosphorus. Yields of winter wheat are remarkable, considering the heavy texture and claypan subsoil. They are between 18 and 22 bushels an acre on well-prepared summer-fallowed land.

Berthoud and Larimer loams and gravelly loams, undifferentiated (Bg).—The soils of this mapping unit occupy colluvial slopes and coalescing alluvial fans in basinlike valleys between argillite and quartzite ridges and isolated, eroding, gravel-capped ridges and slopes in Lewis and Clark County. The Berthoud soils occur chiefly on the lower colluvial slopes, and the Larimer on the high parts of the fans and on the ridge crests. Most of the gravel in the soils consists of fragments of red and green argillite and quartzite.

The Berthoud surface soil is 3 to 5 inches of friable brown loam or gravelly loam. The subsoil is highly calcareous grayish-brown clay loam containing varying quantities of gravel at a depth of 20 inches or more. Below 20 inches it grades into material less limy and more gravelly. Bedrock is at various depths, usually below 5 feet.

The Larimer surface soil is usually friable brown loam of fine crumb structure that contains much gravel. The subsoil at a depth of 6 to 10 inches is calcareous brown to grayish-brown compact gravelly clay loam. At 30 inches or more the subsoil grades into lime-coated gravel or into calcareous light-colored very gravelly loam.

The boundary between the Berthoud and Larimer soils is not very well defined, but on a detailed soil survey it would be possible to show the soils separately on the basis of topography and slight differences in profile development.

Use and management.—These undifferentiated soils are used chiefly for grazing. Floodwaters and the perennial flow of some mountain streams are diverted onto valley slopes to grow alfalfa and other forage crops. The soils are well drained as a rule, but runoff is rapid on some of the steeper slopes. Small areas of naturally seeped land occur on some valley slopes. Most irrigated tracts produce fair yields of alfalfa, and some wild hay is cut on the wet lands. The surface acre-foot of soil contains 3,500 to 4,000 pounds of nitrogen and 1,500 to 2,000 pounds of phosphorus. Blue grama grass, blue-bunch wheatgrass, big sage, and rabbitbrush form the chief cover. The forage on about 35 acres is required to support a steer during a 10-month grazing season.

Berthoud loam and stony loam, undifferentiated (Bx).—Areas of this unit occur in Broadwater, Lewis and Clark, and Meagher Counties. They are on colluvial-alluvial slopes and fans below lime-

stone ridges and gravel-capped tablelands and also below limestone escarpments in the Townsend and Helena Basins and the Smith River Valley. Most tracts are smooth and gently sloping, but in places slopes are dissected by deep coulees and the land is sharply rolling.

The surface 2 to 3 inches is mostly grayish-brown loam or stony loam of crumb structure. Below this is the subsoil—a friable calcareous grayish-brown heavy loam, stony loam, or stony clay loam of ill-defined weak blocky structure. At a depth of 10 to 15 inches the subsoil grades to friable massive light grayish-brown heavy clay loam containing stone and gravel. This clay loam continues to a depth of 20 inches, where it gives way to the little altered parent material, a very light grayish-brown clay loam containing various proportions of rock fragments.

In a gently sloping basin between the limestone ridges in the southwestern part of Broadwater County and at the higher elevations east of Toston the surface soil is moderately dark grayish-brown clay loam and the upper subsoil is slightly heavier textured than elsewhere. The soils in the lower part of this basin contain a small quantity of limestone gravel. In the northern and western parts of the Helena Basin, these soils have developed in colluvium consisting largely of fragments of red and green argillite. In these areas they are very light-colored, do not show as strong development as in most areas, and vary from place to place in quantity of stone on the surface and in the soil.

Use and Management.—Grazing is the chief use of Berthoud loam and stony loam, undifferentiated. The moderately dark colored soils in Broadwater County are locally cultivated, largely to rye and other small grains for hay. Surface drainage is good, permeability is moderate, and the water-holding capacity is fair to good. Fair yields of alfalfa and small grains are obtained on the small acreage under irrigation in the Helena basin. The surface acre-foot of soil contains 3,000 to 3,500 pounds of nitrogen and 1,500 to 2,000 pounds of phosphorus. These soils support an open stand of short grasses. In many of the lower areas 30 to 35 acres is required to carry a steer through a 10-month grazing season.

Billings-Arvada clay loams (BL).—This complex occupies low terraces or high bottoms along many of the larger stream valleys in the eastern part of the area. The Arvada soils differ from the Billings chiefly in having a well-developed claypan 3 to 5 inches below the surface.

The surface 1 to 2 inches of the Billings soil is calcareous light-gray clay loam of mulchlike or flaky structure. The surface soil below the mulch is calcareous light-gray to gray clay loam of massive or ill-defined blocky structure. At a depth of 8 to 10 inches the surface soil grades into slightly stratified or massive, calcareous, light-gray heavy clay loam, which continues to a depth of 3 feet or more. Saline puff spots occur on the surface, and gypsum crystals are abundant in the lower subsoil.

The Arvada clay loam of this unit is much the same as the Arvada soil in the mapping unit Arvada clay loam and clay, undifferentiated.

Use and management.—Billings-Arvada clay loams are not dry farmed. The floodwaters of streams are in places diverted to the

terraces for irrigating forage crops, chiefly wild grasses. Some of the land is nearly level and under irrigation tends to become ponded because of slow permeability. Where the land has fair surface drainage and is not too saline, alfalfa and other crops produce fair yields. The surface acre-foot is comparatively low in nitrogen but contains a fair supply of phosphorus. The less saline spots support a light stand of blue grama grass and wheatgrass; the more saline soils, greasewood, shadscale, and winterfat. The grazing value is low.

Bouldery and gravelly outwash (B_M).—Two areas of this outwash occur on a high alluvial fan in Lewis and Clark County where the Sun River emerges from the mountains. They consist of subangular and rounded pebbles and cobblestones and large boulders derived from a wide variety of rocks, quartzite predominating. There is little evidence of soil formation. This land is too coarse and open for any growth except scattering shrubs and has no value for grazing.

Boyd and Spring Creek clay loams and stony clay loams, undifferentiated (B_N).—The soils of this unit occur in the foothills of the Rocky Mountains in northern Lewis and Clark County. They are characterized by low igneous ridges or dikes between which are small rolling basins or depressions. The Boyd soils have developed on dark-colored shales lying between the ridges; the Spring Creek, on the igneous and metamorphic andesitic rocks that form the ridges.

The Boyd soils have a profile much the same as that of Boyd clay loam. Some igneous rock fragments occur on the surface of those slopes near outcrops of igneous rock.

The Spring Creek soils on the igneous ridges consist of grayish-brown stony loam of crumblike structure overlying bedrock at 3 to 8 inches. The parent rock is exposed in many places.

Use and management.—These soils are used mainly in support of stock raising. Part of the Boyd soils are under cultivation, chiefly to feed and forage crops. The stony Spring Creek soil supports a thin stand of bunchgrasses and has a low carrying capacity for livestock. Virgin areas of the Boyd soils support good stands of tall grass, and the forage on 15 acres of native sod will carry a steer through a 7- to 8-month grazing season.

Boyd clay loam (B_O).—Basinlike valleys and gentle slopes in the foothills and mountains of Broadwater, Lewis and Clark, and Fergus Counties are occupied by this soil, which has developed over dark, hard, slaty and soft clayey shale and lies at relatively high elevations. In central Montana it has somewhat darker surface soil than is typical of the series.

The 8- to 10-inch surface soil is very dark grayish-brown to almost black clay loam of massive to crumb structure. The subsoil, a dense massive olive-brown clay, grades to calcareous olive-brown clay or to disintegrated shale at 18 to 36 inches. In some places the lower part contains many shale fragments.

Use and management.—In Lewis and Clark and Fergus Counties most of Boyd clay loam is cultivated, but in Broadwater County it lies at elevations above 4,500 feet and is used chiefly for grazing because of cool climate and danger of frost damage to crops. Stock raising is the chief enterprise on most farms and ranches on this soil, and much of the land under cultivation is in feed and forage crops. Be-

cause the soil is very sticky and plastic when wet and very hard and tough when dry, careful management is required to maintain good tilth. Surface drainage is usually good, but permeability is very slow and considerable water is lost through runoff during heavy rains.

Local areas in Lewis and Clark County are under irrigation. Some of the irrigated land has become seeped and is used for pasture and wild hay. The surface acre-foot of soil contains an average of 6,300 pounds of nitrogen and 2,100 pounds of phosphorus. Yields are good under proper management.

In Fergus County the average yield of spring wheat on summer-fallowed land is over 15 bushels an acre. In Broadwater County this soil has a dense cover of the tall grasses and a high carrying capacity for livestock during the 6 to 7 months it is open for grazing.

Bridger stony loam (Br).—Most areas of this steep grassland soil occur on mountain slopes at elevations of 5,000 to 6,000 feet, chiefly in Broadwater County. This soil has developed in colluvial material consisting of a heterogeneous mixture of silt, clay, and angular and subangular igneous, sedimentary, and metamorphic stones.

The 6- to 10-inch surface soil in representative areas is friable nearly black imperfectly granular loam containing a few to many loose stones. The subsoil, a grayish-brown to brown stony silty clay loam of medium blocky structure, grades into grayish-brown friable non-calcareous stony or very stony silty clay loam and loam (the parent material) at 20 to 30 inches. The surface soil on the large area north of Confederate Creek in Broadwater County is friable almost black stony loam 8 to 10 inches thick. The subsoil in this area is very stony and gravelly clay loam, grading into noncalcareous stone and fine gravel mixed with a small quantity of fine earth. Large boulders occur on the surface.

Use and management.—Because it is too stony for cultivation and lies too high for the production of most of the small grains and forage crops of the area, this soil is used mainly for grazing. Tall grasses, upland sedges, and shrubs predominate, and the carrying capacity for livestock is high during the 5 to 6 months the soil is open for grazing. Birch, quaking aspen, and willow occur along the streams and in small seep spots.

Castle clay and clay loam, undifferentiated (CA).—These soils occur on the McDonald Divide between the Big Snowy and Judith Mountains and on the north slopes of the Little Snowy Mountains in Fergus County. They have developed over dark calcareous clay shale and occupy undulating to rolling areas at elevations of 4,400 feet or more.

The surface soil is mostly friable, calcareous, imperfectly granular, nearly black heavy clay, 8 to 12 inches thick. In small areas the texture is clay loam. The subsoil—a massive, calcareous, dark grayish-brown clay—grades at depths of 18 to 24 inches into nearly black clay shale that is streaked and spotted with lime. In places the subsoil contains a small quantity of shaly limestone fragments, and some soft lime segregations occur in the lower part.

Approximately half of this unit is strongly rolling to hilly. On the steep slopes the soils, as a whole, are thinner over bedrock, averaging probably less than 18 inches deep to the disintegrated and partly

weathered shale. In places where the slopes break abruptly, the partly weathered shale is at or only a few inches below the surface.

The rolling to steep areas are shown on the soil map by hachure lines so that they can be distinguished from soils on slopes of low and moderately low gradient that are suitable for cultivation. The strongly rolling to hilly areas are the grazing soils of this unit. The soils shown on the map without hachure lines are those, from the standpoint of a slope alone, that are suitable mainly for farming.

Use and management.—The smoother and more gently rolling areas of Castle clay and clay loam, undifferentiated, are used chiefly for winter wheat and oats, which are grown on land summer-fallowed occasionally to control weeds. Stock raising and grain growing are combined on most farms. Surface drainage is good to excessive, and surface runoff is high on the steeper areas. The soils are slowly permeable but absorb a large porportion of the precipitation, which comes chiefly in the form of light rains. The surfaces acre-foot contains 6,000 to 8,000 pounds of nitrogen and 1,500 to 2,000 pounds of phosphorus. On the average, winter wheat on summer-fallowed land yields 20 bushels or more an acre. The pasture land has a cover of tall grass and a high carrying capacity for livestock during the 7 to 8 snow-free months.

Even where the Castle soils are thin over bedrock they support a fair to good cover of grasses, shrubs, and forbs and have a higher carrying capacity for livestock than normally would be expected for soils as shallow and of as heavy texture.

Castner-Morton loams and stony loams (C_B).—Several large areas west of the Smith River in central Cascade County and smaller local areas associated with Castner stony loam in other counties make up this unit. In most areas the soils have developed on metamorphosed sandstone of the Colorado formation and are underlain by this parent sandstone at comparatively shallow depths. Nearly all the areas are undulating to gently rolling, with the Castner stony loam on the low ridges and the nonstony soils on gentle slopes and in well-drained depressions.

The profile of the Morton loam in this unit differs chiefly from that of Morton silt loam in having many fragments of sandstone in the lower part of the subsoil.

The Castner surface soil on the low ridges is friable dark grayish-brown stony loam, 4 to 7 inches thick and of fine crumb structure. It is underlain by friable light-brown calcareous loam or clay loam containing varying quantities of hard sandstone fragments. Little-altered sandstone is at a depth of 8 to 15 inches, and in places the surface soil rests directly on bedrock.

In different areas and to some degree in the same area the soils of this mapping unit vary chiefly in depth to the partly weathered metamorphosed sandstone.

Use and management.—Most areas of these soils in Cascade County were placed under cultivation during the homesteading period between 1906 and 1910, but after the droughts of 1918 to 1921 much of the farm land was abandoned. Now about 30 percent of the acreage is cultivated. The soils are well drained for the most part. The surface acre-foot contains 3,500 to 4,000 pounds of nitrogen and 2,500 to 3,000 pounds of phosphorus. The yield of spring wheat on summer-fal-

lowed land varies with the depth of the soil, but on most of the land it ranges between 10 and 12 bushels an acre. The short grasses predominate in the native sod, and 25 acres or more are required to support a steer for the 10-month snow-free grazing period.

A few areas occur on relatively steep slopes and are suitable only for grazing. Such areas large enough to be shown at the scale of mapping used are designated on the soil map by hachure lines. The largest area of steeper soils occurs in the vicinity of Lennep in Meagher County.

Castner stony loam (Cc).—This survey maps Castner stony loam only in Cascade, Meagher, Fergus, and Wheatland Counties, but in a more detailed survey small areas in northern part of Lewis and Clark County would be shown separately. The soil has developed on hard sandstone of the Kootenai formation in Cascade and Fergus Counties and on older metamorphosed sandstone in other counties. Relief is undulating to sharply rolling. Included are small areas of Morton loam and silt loam, soils developed on colluvium at the foot of steep slopes in the narrow valleys, and wasteland consisting of steep-sandstone escarpments along some of the valleys.

The surface soil on most areas is 4 to 7 inches of friable dark grayish-brown stony loam. Next follows light-brown to light grayish-brown friable calcareous stony loam or stony clay loam, which rests on partly weathered stratified sandstone 8 to 15 inches below the surface. The soil is not calcareous, but the sandstone fragments in the partly weathered material are coated with lime carbonate. The quantity of sandstone slabs and fragments on the surface and in the soil varies with the locality. The soil is chiefly shallow and stony, but small fairly deep tracts with heavy subsoil occupy slight depressions in some areas.

Use and management—The smoother and less stony tracts of Castner stony loam in Cascade County, as well as parts of some areas in other counties, were once cultivated, but most of them have been abandoned because of low crop yields. In many places the included small areas of Morton soils are cultivated, chiefly for feed crops.

The water-holding capacity is not high, because the Castner subsoil is stony and shallow to bedrock. The surface acre-foot of soil in Cascade County contains 3,500 to 4,000 pounds of nitrogen and 2,500 to 3,000 pounds of phosphorus. In virgin areas the soil supports a fair to good cover of mixed tall and short grasses, but 25 to 30 acres is needed to carry a steer through the 9- to 10-month grazing season.

Cheadle stony loam (Cb).—Most of this soil occurs on the high divides between the different mountain ranges and on remnants of a former high gently sloping plateau in Cascade, Judith Basin, and Fergus Counties. It has developed on moderately hard sandstone of the Kootenai formation. Many of the individual areas are separated by deep coulees or narrow steep-sided valleys. Included with this soil are many small areas of Teton loam, an associated deeper soil on the smooth uplands, and of Adel loam, a soil developed on colluvium on the steep slopes.

The surface soil is mostly dark grayish-brown or nearly black loamy fine sand, in most places resting directly on the light-brown or yellow moderately hard sandstone at a depth of 8 to 12 inches. A thin tran-

sitional layer of loam or sandy loam overlies the slightly altered sandstone in some places. The soil is noncalcareous, but the sandstone fragments above the bedrock may be partly coated with carbonate of lime.

Use and management.—This soil is too stony and shallow for farming and is used for grazing. The included small areas of Teton loam are in places planted to feed and forage crops. The land is well-drained, and runoff is high on the steeper areas. The carrying capacity for livestock is fair during the 6 to 7 months the land is free from snow. The higher areas locally support thin to thick stands of Western yellow pine. In the more heavily timbered areas the soil is light-colored and has a relatively low carrying capacity for livestock because most of the grass has been shaded out by the trees.

Cheyenne-Beaverton gravelly loams (CE).—Although many areas of this complex occur on terraces or low benches along many of the streams in the higher intermountain basins, they are too small and narrow to be shown on the map. The larger areas along the Judith River, Ross Fork, and Ross Creek in Judith Basin and Fergus Counties are shown. The soils have developed on gravelly alluvial deposits and differ chiefly in depth to underlying stratified loose sand and gravel. The Cheyenne soils have 15 to 40 inches of fine earth over gravel; the Beaverton, less than 15 inches of fine earth over similar gravel. Beaverton soils generally occur in small areas, which are as a rule intricately associated with larger areas of Cheyenne soils. The two grade into each other without a definite change in surface contour. Even in a detailed survey it would be difficult to separate the two series. In places the benches are dissected by deep coulees.

Beneath a 1- to 2-inch dark grayish-brown loose, loamy surface mulch, the Cheyenne soils have a surface soil 6 to 8 inches thick of dark grayish-brown to very dark grayish-brown loam of coarse prismatic structure. The subsoil is brown prismatic loam or gravelly loam. At 15 to 18 inches or more is stratified loose gravel and sand. The upper part of the gravel bed is highly calcareous, and the pebbles may be incrustated with lime. On most areas gravel occurs on the surface and throughout the profile. The Cheyenne surface soil is chiefly of loam texture as described above, but some included areas of Cheyenne soils have a texture no heavier than a sandy loam.

The shallow Beaverton soils, chiefly gravelly loams, occur mainly along the borders of the terraces above the steep slopes of the stream valleys and immediately adjacent to the drainage courses. The Beaverton surface soil, below a thin, loose silty to sandy surface mulch, is dark grayish-brown gravelly loam of fine crumb structure. It is underlain at 5 to 7 inches by friable brown blocky gravelly loam that grades into stratified, loose, calcareous gravel and sand at 8 to 12 inches. The upper part of the gravel bed is in places slightly cemented with lime carbonate. In some places the surface 6 to 10 inches is comparatively free of gravel.

Use and management.—Along the Judith River, Ross Fork, and Ross Creek in Judith Basin and Fergus Counties these soils are cultivated. Continuous cropping to spring wheat was generally practiced until the droughts in the 1930's, when winds caused considerable soil drifting and made strip cropping of many fields necessary. Since

that time a fairly high percentage of the cultivated land has been used for winter wheat grown on summer-fallowed land under a practice of strip cropping. Nevertheless, soils of this complex do not have a high water-holding capacity, because they are relatively shallow to loose gravel. Summer fallowing does not greatly increase crop yields except on the deeper inclusions of Cheyenne soils. The surface acre-foot contains 4,000 to 5,000 pounds of nitrogen and 1,800 to 2,000 pounds of phosphorus. The yield of spring wheat on continuously cropped land generally ranges between 8 and 10 bushels an acre, but for some of the higher lying darkest colored soils 12 bushels or more an acre are reported. A fairly large part of the land abandoned during the dry years has been seeded to crested wheatgrass, which prevents soil blowing and provides pasture and hay.

Cheyenne loam and gravelly loam, undifferentiated (C_F).—Areas of this unit occupy the low benchlands or terraces along the larger streams in Cascade, Judith Basin, Fergus, and Meagher Counties, and locally in other counties in the dark-brown (Chestnut) soil zone. The fine earth material above the loose sand and gravel averages between 18 and 24 inches thick, but in places the gravel layer lies near the surface and the soils grade into those of the Beaverton series. Included are some areas having a silt loam surface soil comparatively free of gravel to a depth of 3 or 4 feet and a moderately heavy subsoil. Inclusions of this kind are representative of Farland silt loam, which is mapped in the unit Farland and Fergus loams, undifferentiated.

The general profile is much the same as that of the Cheyenne soils in the mapping unit Cheyenne-Beaverton gravelly loams. On the bench along the Judith River south of Hobson, Cheyenne soils have only a sprinkling of gravel, are chiefly of loam texture though a few areas of sandy loam occur, and have stratified loose gravel and sand at depths of 15 to 40 inches. The soils on the low bench in the valley of Wolf Creek northwest of Stanford have loam to clay-loam texture and contain varying but usually small quantities of gravel. In this valley the gravel strata are of mixed limestone and quartzite gravel and lie at a depth of 18 to 24 inches. Gravelly loam of about the same depth as that on the low bench predominates on benches along Wolf Creek, northwest of Denton. West of White Sulphur Springs on the low gently sloping bench north and east of the Smith River the soils are also of about the same texture, but their gravel strata are of mixed origin and lie only 12 to 15 inches below the surface.

Use and management.—Most nonirrigated areas of these soils are farmed to spring and winter wheat, largely on land strip-cropped to control soil drifting. The area south of Hobson in Judith Basin County and the areas west of White Sulphur Springs in Meagher County are irrigated. The irrigation project south of Hobson is supervised by the State Water Conservation Board, which also provides supplemental water for the irrigated lands on the bench west of White Sulphur Springs. The area south of Hobson has been irrigated only a few years and is used almost entirely for cash crops such as spring wheat. The areas in Meagher County are in stock-producing sections, and nearly all the well-drained irrigated land on the bench is used for alfalfa and oats, barley, or other feed crops. Much of this bench has become seeped and is suitable only for pasture and wild hay.

Frequent light irrigations are required for maximum production of crops and to prevent loss of water. The water-holding capacity is high in the fine earth above the gravel, but the water drains away rapidly in the gravel of the lower part of the subsoil and substratum. The surface acre-foot averages somewhat higher in nitrogen than that of Cheyenne-Beaverton gravelly loams and has about the same content of phosphorus. On the average, dry-farmed small grains yield a few bushels more an acre than on that complex.

Crago gravelly loam (Cg).—Areas of this soil occur chiefly on the points and tongues of the high limestone- and gravel-capped tablelands in Meagher, Wheatland, Golden Valley, Petroleum, and Fergus Counties. Some areas, however, are on the higher and more gravelly parts of the tablelands near the mountains, and others are at lower erosional levels. The borders of the tablelands along the narrow valleys are indented by many short deeply entrenched drains, and the steep slopes along the valleys and at the heads of the drains are usually very gravelly. A thin layer of silty loesslike, or aeolian, material overlies the gravel on most of the smoother and less sloping areas, but gravel is mixed with this fine material and the soil is nearly everywhere gravelly. The gravel deposit on the tongues or narrow ridgelike points of the tablelands is underlain by sandstone and shale bedrock at relatively shallow depths, and in a more detailed survey these areas shallow to bedrock would be mapped as types of other soil series. At higher elevations, close to the mountains, this Crago soil grades to Utica soils, which have darker colored surface soil.

The Crago surface soil is calcareous light grayish-brown gravelly loam, 3 to 5 inches thick and of crumb structure. The subsoil is light-gray or very pale-brown calcareous friable gravelly clay loam that grades into the substratum at 4 to 10 inches. To a depth of 3 or 4 feet the substratum consists of gravel embedded in light-gray, light yellowish-gray, or nearly white limy clayey material. Below the highly calcareous layer the gravel is open and loose but includes thin seams of sand and silt. The lower erosional levels and the areas near the mountains are locally cobbly and stony.

Use and management.—Most areas of Crago gravelly loam are too shallow and gravelly for farming and are used for grazing. A small acreage is included in an irrigation project west of Harlowton in Wheatland County, but it is on slopes too steep for cultivation and even where irrigated is used for pasture. The content of nitrogen and phosphorus in the surface acre-foot of soil averages lower than in the associated Musselshell soils. The short grasses predominate, and 30 acres or more are required to carry a steer through a 10-month grazing season. Tracts on the slopes of the stream valleys near the mountains and on some of the gravelly fans at the mouths of the canyons are partly timbered with an open stand of Western yellow pine.

Cushman-Bainville loams and silt loams (C_H).—Chiefly on rolling divides and slopes in southern Wheatland and Golden Valley and southeastern Musselshell Counties, the soils of this complex have developed over silty to moderately clayey shale of Cretaceous age. The two series—Cushman and Bainville—differ mainly in depth over the bedded shale and in stage of soil development attained. The Cushman soils are much the same as Cushman loam (see p. 67). The Bainville

are Lithosols, or immature soils, and occur largely on ridges and slopes where geologic erosion keeps them shallow. Included, however, are small areas of moderately heavy soils typical of the Midway series and similar to the small areas of moderately heavy soils included with the Cushman loam mapping unit. Hachure lines on the soil map differentiate sharply rolling areas suitable only for grazing from areas in part suitable for cultivation.

The Bainville soils are chiefly friable grayish-brown loams and silt loams, 3 to 5 inches thick and of crumb structure. Their subsoil varies from friable soft blocky calcareous yellowish-brown silt loam to friable massive calcareous light yellowish-brown heavy clay loam. The subsoil becomes lighter in color and more stratified with depth and grades into relatively unweathered shale at 10 to 16 inches. Exposures of the partly weathered parent shale material occur on the steeper ridges and slope breaks. The Bainville and Cushman soils grade into one another, and in many places the partly weathered parent shale lies 18 to 24 inches below the surface.

Use and management.—These are marginal farming soils. The cultivated land—approximately 10 percent of the total acreage—consists of scattered deeper and more uniform areas where soil material has accumulated on foot slopes. Stock raising and grain growing are combined on most of the ranches on which the soils occur. Forage crops, feed grains, and cash wheat are grown. In Golden Valley and Musselshell Counties some corn is produced for feed and roughage. The surface acre-foot contains 3,500 to 4,500 pounds of nitrogen and 1,600 to 2,200 pounds of phosphorus. The yield of spring wheat, grown chiefly on summer-fallowed land, averages less than 10 bushels an acre, but occasionally 15 to 20 bushels an acre are harvested in seasons of favorable moisture and temperature. Strip cropping is needed to control soil drifting. Grama grass and western wheatgrass are the chief plant cover. The forage on 25 to 30 acres of native sod will carry a steer through the usual 10-month grazing season.

Cushman loam (Ck).—Undulating to rolling areas of this soil occur in southern Wheatland and Golden Valley Counties and in northern Fergus County. Isolated areas are also in Petroleum and Musselshell Counties. The soil has developed on moderately clayey to silty or slightly sandy shale of Cretaceous age. Included with it are small areas of Bainville loam and Midway clay loam. In Wheatland County the soil of some of the areas is similar to Maginnis clay loam, a soil having many fragments of hard shale in its subsoil and underlain by hard thin platy shale. Minor inclusions are small areas of Patent soils on the colluvial-alluvial slopes, and of Billings and Arvada soils on the narrow terraces along the intermittent streams. Some small and several relatively large areas with sharply rolling relief are shown on the soil map by hachure lines so that they may be distinguished as strictly grazing lands, not farming-grazing lands.

The surface soil is typically friable crumb-structured grayish-brown loam or heavy loam, 5 to 7 inches thick. The subsoil—a friable prismatic grayish-brown loam or clay loam—grades into somewhat blocky or stratified calcareous light grayish-brown loam or clay loam at a depth of 10 to 18 inches. This clay loam continues down to about 3 feet, where it merges with the friable stratified calcareous light-gray loam or silty clay loam material of the partly weathered shale.

The soil on areas south of Harlowton in Wheatland County has developed on hard shale, fragments of which appear on the surface and form a large part of the subsoil.

Use and management.—Before 1937 most of Cushman loam was cultivated, but because of droughts and wind drifting a large part of it was abandoned. Recently, however, some of the abandoned land has again been placed under cultivation. The largest cultivated areas are in southern Golden Valley County near Belmont and in northern Fergus County around Winifred. Spring wheat grown on summer-fallowed land is the chief cash crop; oats and barley harvested for hay, crested wheatgrass, sweetclover, and alfalfa are the main forage crops. The average yield of spring wheat on summer-fallowed land is less than 10 bushels an acre near Winifred and between 10 and 12 bushels an acre on the divides and valleys in southern Golden Valley County. Cushman loam in the other counties is chiefly in stock-raising sections and is used for grazing.

The quantity of nitrogen in the surface acre-foot of soil ranges from 3,500 pounds in some of the lower areas to 5,000 pounds on the high divides. The phosphorus content varies from 1,600 to 2,200 pounds. The soil has adequate surface and internal drainage and good water-holding capacity. In seasons of favorable rainfall it produces excellent yields of small grains and forage crops. The areas in native sod have a good cover of grama grass and western wheatgrass; 25 to 30 acres will carry a steer through a 10-month grazing season. The abandoned farm lands not brought back into cultivation are being seeded to crested wheatgrass.

Danvers silty clay loam (D_A).—This soil occupies high tablelands along Arrow Creek and the Judith River in the northwestern part of Fergus County and isolated benches along Antelope and Buffalo Creeks and Ross Fork in southern Judith Basin County. The tablelands—smooth and level to undulating with slopes of 40 to 60 feet to the mile—have an elevation of 3,600 or more feet and are capped by 3 feet or more of a moderately clayey aeolian (wind-laid) deposit that overlies a bed of water-worn limestone gravel. The bench west of the Judith River in the vicinity of Danvers occupies several erosional levels, the lower of which is gravelly. The tablelands along Arrow Creek and the Judith River lie 200 to 300 feet above the levels of these streams, and in many places their slopes are steep shale and sandstone escarpments. The borders of these tablelands are indented with deep coulees. Wind-blown material from the shaly breaks along Arrow Creek form low dunes at the heads of coulees on the western part of the high bench east of Arrow Creek.

The aeolian deposit on the tablelands along Arrow Creek and the Judith River is largely of local origin, and its texture varies with the nature of the geologic material exposed on the breaks of these streams. Included in the general area of Danvers soil are soils developed on thin loamy to sandy aeolian deposits laid down over limestone gravel benches. These inclusions are classified as Doughty and Utica loams and gravelly loams, undifferentiated. Local small areas of included soils are solonized or have claypan development, and the soil profile above the gravel bed is similar to that of Belt clay loam and clay, undifferentiated. These claypan inclusions usually occupy shallow depressions or sags and flats where surface drainage is not well established.

The surface soil of Danvers silty clay loam is a friable dark grayish-brown silty clay loam, 8 to 12 inches thick and of crumb structure. The subsurface layer is prismatic or blocky grayish-brown heavy silty clay loam containing some limestone gravel. At 15 to 20 inches this layer overlies massive to blocky calcareous light grayish-brown heavy clay loam containing some limestone gravel. The bed of limestone gravel is 2 to 3 feet or more below the surface. The spaces between the pebbles in the upper several feet of this gravel bed are filled with almost white limy clayey material. The wind-formed deposit on the western border of the high benches along Arrow Creek and on the bench east of the Judith River is locally 5 to 10 feet thick and is comparatively free of gravel.

Use and management.—This productive soil, used for winter wheat, lies where 7 to 8 inches of rain falls during the growing season, almost one-half of it coming in June. Nearly all the tillable land is in large grain farms, each of which covers one or more sections. In most places the soil is deep enough over the gravel bed to hold nearly all the moisture that falls in years of average precipitation. The soil is plastic when wet and hard and difficult to manage when dry. It is very mellow in spring, and unless strip cropping is practiced the wind will cause some soil drifting on summer-fallow land. The land is usually first tilled for summer fallow early in spring with one-way disk plows. This is done immediately after the spring seeding of small grains is completed. If tillage of the fallow land is delayed until late in June or in July only a small part of the summer moisture is conserved.

This soil is moderately well supplied with organic matter and nitrogen and other essential plant nutrients. The surface acre-foot contains 4,500 to 5,000 pounds of nitrogen and 1,500 to 2,400 pounds of phosphorus. On properly prepared summer-fallow land, winter wheat averages 20 bushels an acre and in favorable seasons occasionally yields 35 to 40 bushels. The winter wheat produced on the high tablelands is of high quality in most seasons.

A small part of this soil on the benches along Buffalo Creek and on the bench east of the Judith River in Fergus County is irrigated. The soil on these benches has good surface and subsurface drainage where the gravel bed lies within 2 to 3 feet of the surface, but where the gravel bed is at a depth greater than 3 feet, subsurface drainage is deficient because the subsoil is heavy-textured and slowly permeable. When irrigated this soil is suitable for a variety of crops—small grains, sugar beets, and alfalfa. Most of the irrigated land is on stock ranches and is used to produce alfalfa hay and such feed grains as oats and barley.

Darret loam and stony loam, undifferentiated (DB).—Soils of this mapping unit occupy the lower part of an undulating to rolling plateau lying north of the Little Belt Mountains along Sand Coulee in Cascade County. They have developed on the red shale and sandstone of the Kootenai formation.

The surface soil on most areas is reddish-brown friable crumb-structure heavy loam or clay loam, 6 to 10 inches thick. The subsoil, a reddish clay loam of fine nut structure, grades into red massive calcareous moderately friable clay loam at a depth of 12 to 15 inches. Partly weathered red shale and sandstone underlies the soil nearly everywhere at 2 to 3 feet. The soils are shallow and stony along the

coulee slopes and on the crests of ridges where their surface soil has been thinned by erosion or where the more resistant sandstone lies near the surface.

Much of the Darret stony loam occurs on strongly rolling to steep slopes. Hachure lines on the soil map distinguish these steeply sloping areas suitable only for pasture from those on milder slopes that are suitable for cultivation.

Use and management.—In large part the less stony areas of Darret loam and stony loam, undifferentiated, are cultivated, chiefly to winter and spring wheat grown on land summer-fallowed every second or third year. Most grain farms on these soils cover one or more sections. The cultivated soils are well drained, well supplied with most of the essential plant nutrients, and relatively high in productive capacity. The surface acre-foot contains 5,000 to 6,000 pounds of nitrogen and 2,000 to 3,000 pounds of phosphorus. Spring wheat on summer-fallowed land yields 12 to 15 bushels an acre.

Delpine shaly loam (Dc).—Areas of this shaly loam occur on foot-hill ridges bordering a basin between the Castle and the Little Belt Mountains in Meagher County. The parent material is highly metamorphosed slaty shale of Pennsylvanian or pre-Pennsylvanian age. In places the soil is associated with Ringling loam-shaly loam. Delpine soil occurs in much of the area mapped as rough mountainous land. Only the smoother areas of it are mapped separately. Included in the mapping are small areas and strips of deeper and darker soils on colluvial slopes and in small stream valleys.

The surface soil is friable grayish-brown loam containing many shale fragments. It rests directly upon slightly altered gray phyllitic (thinly laminated) slaty shale at a depth of 4 to 10 inches. For the most part the soil is not limy, but below a depth of about 20 inches a thin coating of lime carbonate adheres to the lower sides of the shale fragments.

Use and management.—Delpine shaly loam is used exclusively for grazing. It supports only an open stand of wheatgrasses and bunchgrasses and has a low livestock carrying capacity.

Doughty and Utica loams and gravelly loams, undifferentiated (Dd).—These soils occupy the lower tablelands in the northern part of the Judith Basin in Judith Basin and Fergus Counties and local benches or tablelands in western Fergus and northern Wheatland Counties. The smooth gently sloping tablelands in Fergus and Judith Basin Counties have elevations of less than 3,800 feet and are capped with a shallow loamy to silty aeolian, or loesslike, deposit which overlies limestone gravel. The benches lie several hundred feet above the level of the streams, and the slopes from them to the streams are steep shale escarpments in most places. The tableland in northern Wheatland County, capped with similar material, lies at an elevation generally above 4,500 feet, and its surface is rolling in the vicinity of Judith Gap.

Doughty and Utica soils are closely associated and occupy contiguous areas on most tablelands. They differ chiefly in depth to the underlying gravel bed and would have been shown separately in a more detailed survey. Where the gravel horizon lies below 15 and not deeper than 30 inches, the soils are representative of the Doughty series; where the gravel horizon is within 15 inches of the surface,

the soils are representative of the Utica series. Utica soils occur chiefly on the borders of the benchlands, on the crests of narrow drainage divides, and on low ridges that rise as gravel bars above the surrounding nearly level Doughty soils.

Doughty loam and gravelly loam are the dominant soil types in this mapping unit, though small areas having a silt loam or heavier texture are included in places. The surface 6 to 9 inches of Doughty loam is friable crumb-structured dark grayish-brown loam or silt loam that contains a sprinkling of limestone gravel in most areas. Beneath a shallow transitional layer, the upper subsoil is soft blocky calcareous friable clay loam or gravelly clay loam. It grades into cloddy highly calcareous friable grayish-brown gravelly clay loam at a depth of 12 to 20 inches. This highly calcareous layer rests abruptly on a bed of water-worn limestone gravel at 15 to 25 inches. The voids in the upper part of the gravel bed are filled with almost white limy clayey material to a depth of several feet. In places the aeolian deposit is of silty to clayey texture, and in these the surface soil is friable clay loam, usually containing some scattered limestone gravel.

The Utica soils have a friable dark grayish-brown gravelly loam surface soil 4 to 10 inches thick, a thin transitional layer, and then gravel similar to that of Doughty loam.

Use and management.—Doughty and Utica loams and gravelly loams, undifferentiated, are cultivated in most places, chiefly to spring and winter wheat. Most of these soils are on large grain farms, but near the borders of the tablelands and on the more remote benches they are on a few combination grain and livestock farms. Summer fallowing does not greatly increase crop yields because the water-holding capacity of the gravelly subsoil is low. Yields are stabilized somewhat, however, when wheat is grown on land summer-fallowed in strips less than 20 rods wide. The strip farming and summer fallow control soil drifting, keep down weeds, and hold snow on the land. The yield of spring wheat on summer-fallowed land varies with the location of the tablelands. Yields are between 10 and 15 bushels an acre on the benches south and east of the main mountain range and somewhat above 15 bushels on the larger tableland north and northeast of Denton (Fergus County). The surface acre-foot of soil contains 4,500 to 5,000 pounds of nitrogen and 1,500 to 2,400 pounds of phosphorus.

Fairfield loam and gravelly loam, undifferentiated (F_A).—Soils of the Fairfield series have developed on gravel-capped tablelands in most of the mountainous counties. In most places these tablelands lie several hundred feet above the level of the streams and have about the same gradients as the stream valleys. They are dissected by deep coulees, and their borders are indented by short steep-sided draws. The parent material consists of rounded gravel, cobblestones, and fine earth material brought down from the mountains and spread out to form high alluvial fans and outwash plains. Most of these soils have a gravelly to stony surface layer and are suitable only for grazing. The cobblestones and gravel are largely of quartzite and argillite. On a few of the tablelands in Cascade and Lewis and Clark Counties the soils are dominantly loam and gravelly loam, contain only a few large stones, and are suitable for farming.

The 1- to 2-inch surface soil on the tablelands is loose grayish-brown sandy to loamy mulch. Below the mulch is dark grayish-brown loam containing some gravel. The subsoil is prismatic calcareous grayish-brown loam or gravelly loam. It grades into nearly white highly calcareous gravelly clay loam at a depth of 15 to 20 inches, and, in turn, the clay loam grades into the parent material of stratified silt, sand, and gravel at depths of 3 to 4 feet.

The principal variation in these soils is the inclusion of small areas of Fairfield stony loam. Rolling to steep areas of Fairfield soil are dominantly stony and are mapped as Fairfield stony loam.

Use and management.—During the period of early settlement much of Fairfield loam and gravelly loam, undifferentiated, was cultivated, but during the droughts of 1918 to 1921 most of the shallower and more gravelly soils were abandoned. In Cascade County most of these soils lie adjacent to but above the irrigation canals of the Sun River Irrigation Project. They are, therefore, farmed mainly to spring wheat grown largely under a system of strip cropping and summer fallow.

Drainage and water-holding capacity above the loose gravel are good. In seasons of well-distributed rainfall, these are among the more productive soils in the dark-brown (Chestnut) soil zone. The surface acre-foot contains 5,000 to 6,000 pounds of nitrogen and 2,100 to 2,400 pounds of phosphorus. Spring wheat on summer-fallowed deeper soils produces 10 to 12 bushels an acre.

Grama grass and western wheatgrass are the chief part of the native sod; 15 to 20 acres are needed to carry a steer through a 10-month grazing season. The indented gravelly borders of the tablelands are more lightly grassed, and a few more acres are required to carry a steer through the same grazing season. Overgrazing and subsequent wind erosion have greatly reduced the stand of grass on the isolated areas in northern Lewis and Clark County, and in these places 30 acres or more are required to carry one animal through the grazing season.

Fairfield stony loam (F_B).—Alluvial fans on high tablelands or remnants of a dissected peneplain below the mountains in Lewis and Clark, Wheatland, and Meagher Counties are occupied by this soil. The parent material is chiefly stony outwash, which consists for the most part of angular and subangular igneous and metamorphosed sedimentary stones and gravel. In the upper part of the outwash deposit fine earth material fills the voids between the rock fragments. This soil lies at somewhat higher elevations than Fairfield loam and gravelly loam, undifferentiated, which have developed mainly in quartzite and argillite gravel deposits. The tablelands have smooth surfaces, gentle slopes, and lie several hundred feet above the level of the present streams that dissect the old land surface. The higher areas in Wheatland and Meagher Counties have a very dark grayish-brown to almost black surface layer, darker than that of typical Fairfield soils, and in a detailed survey would be mapped as soil types of a different series.

The 6- to 10-inch surface soil is typically a friable dark grayish-brown to very dark grayish-brown stony loam or stony clay loam. The subsoil is brown, slightly tinged with red, stony clay loam of firm irregular medium blocky structure. It grades into gray or brownish-gray calcareous stony clay loam at 15 to 20 inches. This grayish ma-

terial becomes more stony and sandy with depth, and at 3 or 4 feet passes into loose cobblestones, sand, and gravel. The areas in slight swales are comparatively free of stone to depths of a foot or more. Blue and green argillite compose a large part of the angular stone on the benches west of the Smith River in Meagher County, and the lower subsoil of these benches is largely calcareous yellowish-gray stony silty clay loam. The surface soil on the eroding tablelands north of American Fork Creek in Wheatland County is very stony and thin.

The inclusions of darker colored soils on the high tablelands at the mouths of American Fork and Elk Creeks in Wheatland County and on the benches near the head of Butte Creek in Meagher County are chiefly friable imperfectly granular almost black stony loam or stony silt loam. Their subsoil, a compact brown to yellowish-brown stony loam grading into very stony clay loam, is in places leached free of carbonate of lime to a depth of 28 to 30 inches.

Use and management.—Fairfield stony loam is not dry farmed but it is grazed. In Meagher and Lewis and Clark Counties it is irrigated, chiefly for alfalfa. Surface and internal drainage are good, and the water-holding capacity fair. The supply of nitrogen and phosphorus in the surface acre-foot varies with location and the character of the parent material. On the tableland on the western slopes of the Big Belt Mountains a surface acre-foot contains 3,500 to 5,800 pounds of nitrogen and 1,800 to 2,000 pounds of phosphorus; and on the higher tablelands north of the Crazy Mountains, 4,500 to 7,000 pounds of nitrogen and 2,000 to 2,900 pounds of phosphorus. The average yield of alfalfa on the irrigated land is between 2 and 3 tons from two cuttings. The tall grasses predominate on these soils; 10 to 15 acres on the higher tablelands is sufficient to carry a steer through a 7- to 8-month grazing season.

Farland and Fergus loams, undifferentiated (F₀).—Soils of these two series occupy well-drained terraces in some of the stream valleys in central Cascade and Fergus Counties. They have developed in alluvium derived chiefly from Kootenai sandstone and shale. Except for the reddish color and slightly heavier texture of the Fergus, the profiles of the two soils are similar. In some valleys these soils are in complex association; in others separate areas of one type or the other occur.

The Farland surface soil is friable dark grayish-brown loam, 5 to 7 inches thick. The subsoil, a prismatic dark grayish-brown heavy silt loam, grades into massive or weak blocky grayish-brown heavy silt loam at 15 inches or more. In the lower part the blocky layer is calcareous. The parent material, at depths of 24 to 30 inches, is calcareous friable heavy clay loam or silty clay loam. In places, however, the parent material grades into stratified silty and slightly sandy material at depths below 3 or 4 feet. On some of the small benches in the vicinity of Roy in Fergus County, a small quantity of stone is scattered over the surface and through the soils.

The Fergus soils are chiefly heavy loam, silt loam, and clay loam types. The 7- to 12-inch surface soil is crumb-structured dark reddish-brown loam, silt loam, or clay loam. The upper subsoil is reddish-brown heavy clay loam of fine blocky or nut structure. At 15 to 20 inches it is underlain by a massive or indistinctly blocky red or reddish-

brown heavy clay loam. The material at depths of 20 to 25 inches is calcareous and in places has a variegated red, gray, and brown color. A small quantity of gravel may be scattered throughout the soil profile.

Use and management.—Farland and Fergus loams, undifferentiated, are productive soils well suited to a variety of small grains and forage crops. They receive 7 to 9 inches of rainfall during the growing season, most of it in May and June. Nearly all the acreage is used for winter and spring wheat, which is grown on land summer-fallowed occasionally to control weeds. Surface and subsurface drainage are adequate in most seasons. The surface acre-foot of soil has a good nitrogen and phosphorus content, and the average yield of winter wheat on summer-fallowed land is slightly over 20 bushels an acre. Other small grains and forage crops give good yields.

Flasher-Cushman fine sandy loams (Fd).—This complex occurs chiefly on undulating to rolling uplands in Petroleum and Musselshell Counties, but small areas are in other counties. The soils have developed over moderately hard gray and brown Cretaceous sandstone, interbedded in places with sandy shale. Included are small areas of Glendive fine sandy loam, a soil not separately mapped in this survey, which occurs on the alluvial fan slopes and in the bottoms of narrow draws.

The 5- to 6-inch surface soil of Cushman fine sandy loam is noncalcareous brown fine sandy loam of soft crumb structure. The subsoil, a fairly coherent calcareous light-brown fine sandy loam or loam of medium soft, blocky structure, grades into calcareous very light-brown fine sandy loam or partly weathered fine-grained sandstone at 15 to 30 inches. The surface soil on a few areas along the valley of the Musselshell River in Musselshell County is shallow, calcareous, very light-brown fine sandy loam underlain by a moderately coherent massive fine sandy loam subsoil.

Flasher fine sandy loam occurs chiefly on the ridges where geological erosion has nearly kept pace with rock weathering and soil formation. It has a surface layer of single-grained light-brown fine sandy loam 4 to 6 inches thick, and then 2 to 4 inches of similar but lighter colored fine sandy loam that rests on partly weathered parent sandstone.

Use and management.—Although cultivated at one time, Flasher-Cushman fine sandy loams have been abandoned because of soil blowing and low crop yields. A few small areas in Musselshell and Petroleum Counties are used to grow feed crops for livestock. The soils have good surface drainage, moderate to rapid permeability, and moderate water-holding capacity. The surface acre-foot of soil contains about the same quantity of nitrogen and phosphorus as Ulm fine sandy loam, with which this unit is associated in some sections. The carrying capacity for livestock is fair.

Flasher-Terry fine sandy loams (Fe).—The areas of this complex mapped are largely in the Bull Mountains Upland in Musselshell County. Other areas are widely distributed in central Montana, but most of them are too small to be shown on the soil map and are included in the mapping unit Bainville, Travessilla, and Flasher loams and stony loams, undifferentiated. These Flasher-Terry soils have developed over soft calcareous sandstone and sandy shale, but pre-

dominantly on sandstone. Most of them are shallow to bedrock and belong to the Flasher series, but nearly all areas include some moderately deep soils typical of the Terry.

The 5-inch Flasher surface soil is predominantly calcareous grayish-brown fine sandy loam of soft crumb structure. The subsoil is calcareous pale-brown or light grayish-brown loamy fine sand or fine sand underlain at a depth of 8 to 15 inches by partly disintegrated calcareous sandstone or sandy shale. In places the parent rocks include thin lenses of hard sandstone, and fragments and flaggy slabs of sandstone occur on the surface.

The deeper Terry soils have beneath their thin surface soil a mildly calcareous weak blocky brown or pale-brown fine sandy loam upper subsoil 4 to 8 inches thick. They have calcareous pale-brown or light grayish-brown loamy fine sand lower subsoil layers about the same as those in the Flasher. Moderately firm unweathered bedrock occurs at 20 to 30 inches, but in places several feet of loamy fine sand from the relatively unconsolidated parent rock underlies the Terry soils.

Use and management.—The larger areas of Flasher-Terry fine sandy loams were placed under cultivation during the period of early settlement, but nearly all have now been abandoned and are used exclusively for grazing. The smoother and less stony areas support a fair cover of grama grass, threadleaf sedge, and prairie sand reedgrass and have a fair livestock-carrying capacity. The areas more stony and broken are only sparsely vegetated and low in carrying capacity.

Gilcrest loam and gravelly loam, undifferentiated (GA).—These soils occupy gently sloping and sloping terraces and terracelike alluvial fans, chiefly in the northern part of the Helena Basin in Lewis and Clark County and along the Missouri River in the central part of Broadwater County. Many small areas occur on narrow terrace strips in the larger stream valleys in the mountainous counties, but most of these are too small to be shown on the map and are included with the undifferentiated alluvial soils. In the Helena Basin the parent material consists largely of small fragments of argillite and quartzite; in Broadwater County, of mixed gravel from a wide variety of rocks.

The surface soil in the Helena Basin is friable light grayish-brown to brown gravelly loam or silt loam of soft crumb structure and 5 to 6 inches thick. The subsoil is firm or moderately compact calcareous gray to reddish-gray gravelly clay loam, grading at 12 to 24 inches into a mass of small fragments of red and green argillite and quartzite that contains a small quantity of fine earth. Along the shallow drainage courses subject to flash floods, the soils are very gravelly.

The surface soil on the terraces in the vicinity of Townsend (Broadwater County) is chiefly gravelly and cobbly loam. The subsoil consists largely of gravel and stone mixed with a little highly calcareous gritty silty material. Loose gravel and stone occur below a depth of 12 to 15 inches. On the low terraces along Deep Creek the silty to loamy fine earth over the loose gravel varies from a few inches to several feet thick. The deeper areas are not typical of Gilcrest soils but are included because it was not possible to show them separately at the scale of mapping used.

Use and management.—Most areas of Gilcrest loam and gravelly loam, undifferentiated, are irrigated. The shallower soils in Broad-

water County are used for pasture and wild and tame hay; the deeper soils, for small grains. The soils are rapidly permeable below the surface and upper subsoil layers, and much water is lost if heavy applications are made. Frequent light irrigations are required to attain maximum production of crops and to prevent loss of water and plant nutrients through leaching. Barnyard manure and commercial fertilizer are applied to most fields in the Helena Basin to maintain fertility and increase crop yields. Under good soil and irrigation management fair yields of truck vegetables, potatoes, and other crops are obtained from the deeper soils. The surface acre-foot of soil contains 3,500 to 4,000 pounds of nitrogen and 1,500 pounds of phosphorus.

Dry-land areas are mostly lightly covered with bluebunch wheatgrass, big sage, rabbitbrush, and pricklypear and have a comparatively low carrying capacity for livestock. In Broadwater County, the water table rises during the irrigation season and the swales in the terraces become cattail marshes. A part of the irrigated land in the Helena Basin also has become seeped, and in places it is strongly saline.

Gilt Edge clay loam and gravelly clay loam, undifferentiated (GB).—High terraces or benchlands in Fergus, Petroleum, and Musselshell Counties are occupied by these soils. They have developed on wind- or water-deposited clayey material, which at 1 to 2 feet is underlain by thick gravel deposits. The subsoils are claypans. The upper part of the gravel is mixed with the overlying fine material, and the soils are gravelly in places. Where the wind has removed the friable surface soil many micro-depressions, bare spots, or slick spots occupy 10 to 20 percent of the surface and the claypan subsoil is at or near the top of the ground. In most areas the gravel deposits consist of rounded fragments of argillite and quartzite rocks mixed with sand and some finer materials, but in some the gravel is from limestone and other rocks. A few areas lie adjacent to and below areas of heavy soils. In these the clayey local wash from the heavy soils gives rise to small areas of Arvada and Billings clay loams, which are included with the Gilt Edge.

The surface soil on most areas is flaky or laminated friable grayish-brown clay loam, 2 to 7 inches thick and of fine crumb structure. This surface layer rests directly on a grayish-brown heavy compact clay loam or claypan of medium columnar structure. At a depth of 8 to 15 inches the clay loam or claypan grades into calcareous grayish-brown or light grayish-brown blocky heavy clay loam or clay. At 15 to 30 inches there is a further gradation into water-worn gravel the interstices between which are filled with highly calcareous light-gray clay loam or sandy clay loam merging with loose sand and gravel at 4 to 5 feet.

Use and management.—Grazing is the chief use of Gilt Edge clay loam and gravelly clay loam, undifferentiated. In a few places floodwaters of intermittent streams are diverted to irrigate pastures and land used for growing wild hay. The soils have slow surface drainage or no surface drainage whatever, and their subsoil is very slowly permeable. The soils are droughty, and the small areas once cultivated have been abandoned because of frequent crop failures and low average yields. Big sage, grama grass, and western wheatgrass are

the bulk of the natural vegetation. The forage on 35 acres or more is required to carry a steer through a 10-month grazing season.

Goshen loam (Gc).—The one large area of this loam lies in an undulating basin below the tablelands capped with limestone gravel that lie northeast of Denton in Fergus County. It has developed on alluvial fans and colluvial-alluvial deposits washed from the slopes of adjacent benches and uplands.

The surface soil in most of the basin is mellow friable very dark grayish-brown loam or silt loam, 8 to 10 inches thick. The subsoil—a dark-brown heavy clay loam of ill-defined prismatic structure—grades at 24 to 30 inches into a lime-splotched grayish-brown heavy clay loam without definite structure. In most places a small quantity of limestone gravel occurs in the subsoil.

Use and management.—Goshen loam is deep and has good water-holding capacity. It receives an annual precipitation of about 14 inches, 60 to 65 percent of which falls during the growing season. Under normal rainfall the soil is well drained, but in seasons of excessive rainfall drainage is locally deficient in lower lying areas because of low surface runoff and slow permeability. Nearly all the land is cultivated, the crops being spring and winter wheat. The farms are large. On most farms more than 300 acres are annually seeded to grain. Small grains are grown mainly on land summer-fallowed every other year. Spring wheat yields 20 bushels or more an acre on the better managed summer-fallowed land, but the average range is 12 to 15 bushels. The surface acre-foot of soil contains about 5,000 pounds of nitrogen and 2,000 pounds of phosphorus. Strip cropping is practiced on many farms to control wind erosion and drifting.

Hanson stony loam (HA).—This soil occurs in most of the mountainous counties, mainly on grass-covered mountain slopes and steeply sloping alluvial fans. There is, however, some on alluvial fans with smooth gentle slopes. The average elevation is generally less than 5,000 feet, or lower than that of Bridger stony loam. The soil differs from Bridger stony loam in having a well-developed horizon of lime carbonate accumulation beginning 15 to 20 inches below the surface. The parent alluvium and colluvium is a heterogeneous mixture of fine earth and stone containing abundant lime carbonate.

The surface soil on representative areas is imperfectly granular very dark grayish-brown loam, 6 to 8 inches thick. The upper part of the subsoil, a dark grayish-brown friable silty clay loam, has macro-prismatic primary structure and fine blocky breakage. This layer grades into calcareous grayish-brown stony silty clay loam at depths of 15 to 20 inches. Some angular and subangular stones and cobbles occur on the surface, and these become more numerous with depth. In places more than half of the lower subsoil is stone. On the lower parts of the fans in Broadwater County the stony colluvium overlies Tertiary lake-bed sediments, which are at depths of 3 feet or more.

Use and management.—Most areas are too steep, rolling, and stony for farming and are used for grazing. The areas less stony, particularly those in Broadwater County, are used for spring and winter wheat and such feed crops as oats and barley. The soil is permeable and well drained, but has high surface runoff on the steeper areas

where natural vegetation has been destroyed. The surface acre-foot of soil contains 4,000 to 5,000 pounds of nitrogen and 1,800 to 2,400 pounds of phosphorus. Spring wheat grown on summer-fallowed land produced 15 to 18 bushels an acre on the less stony and rolling areas. The natural cover consists chiefly of tall grasses and shrubs; 8 to 10 acres will carry a steer through the 6- to 7-month grazing season.

Hilger loam and stony loam, undifferentiated (H_B).—The soils of this unit occur in the foothills and on lower mountain slopes in Fergus, Cascade, Lewis and Clark, Broadwater, and Meagher Counties. They occupy moderately to steeply sloping alluvial fans composed largely of gravelly and stony outwash materials derived from igneous and metamorphic rocks. They lie at moderate to high elevations, and their topography is undulating to sharply rolling. Parts of the areas have long uniform slopes and benchlike relief. The quantity and relative proportion of angular and subangular limestone and igneous and metamorphic rock on the surface and in the soil vary with the locality.

These soils grade into Hanson stony loam at the higher elevations and into Roy stony loam at the lower. Small areas of included soils are developed on local alluvium at the foot of steep slopes and from residual material derived from local exposures of sedimentary rocks. The sharply rolling and more stony phases suitable principally or exclusively for grazing are shown on the soil map by hachure lines so they may be distinguished from areas suitable for cultivation.

Although the surface texture of most of these soils is loam or stony loam, in some places the soils are of clay loam texture. The surface soil on most areas suitable for farming is friable crumb-structured dark grayish-brown heavy loam or clay loam, 7 to 10 inches thick and containing stone and gravel. The subsoil is a brown, friable, prismatic, moderately stony clay loam. At a depth of 15 to 20 inches it grades into calcareous blocky light-brown stony clay loam that continues down to 3 or more feet. The stone content usually increases with depth, but in some places the surface 3 feet is comparatively stone-free.

Use and management.—Areas of these undifferentiated soils are mostly too rolling and stony for farming and are used chiefly for grazing. In Fergus County and locally in other counties, however, the less stony and smoother areas are nearly all cultivated, chiefly to winter and spring wheat. The more rolling areas are planted mainly to feed and forage crops. Farms on which these soils occur have one or more sections of land; the ranches, 5 to 10 sections. A small acreage in the foothills under irrigation is used chiefly for feed and forage crops. Drainage on both dry-farmed and irrigated lands is good, and surface runoff is high on the steeper cultivated areas. Fertility is moderate to high, and productivity is good. The surface acre-foot of soil contains 4,500 to 5,500 pounds of nitrogen and 1,800 to 2,100 pounds of phosphorus. Less stony and deeper areas of summer-fallowed land in Fergus County yield 12 to 15 bushels an acre of spring wheat. Grazing areas have a tall-bunchgrass cover and a high carrying capacity for livestock during the 7- to 8-month snow-free period.

Judith-Utica loams and gravelly loams (J_A).—This complex is on high tablelands along the Judith River. The tablelands have an elevation of 3,800 to 4,300 feet and a protective covering of limestone

gravel overlain by a thin mantle of loamy to silty aeolian, or loesslike, material, which is somewhat thicker in the more westerly areas of these soils. A small quantity of gravel is commonly mixed with the silty layer, and in places the soils are gravelly at the surface. The tablelands are separated by wide stream valleys and have smooth level to undulating surfaces and gradients of 40 to 60 feet to the mile. Their borders are locally indented by deep coulees, and abundant gravel usually occurs along the drainage courses.

Judith and Utica soils are in somewhat complex association on most tablelands, but in a more detailed soil survey they would be separated on the basis of depth to gravel. Where the gravel horizon lies below 15 inches and not deeper than 30 inches, the soils are representative of the Judith series; where the gravel is within 15 inches of the surface, the soils are representative of the Utica series. Utica soils occur chiefly at the border of the tablelands, on the crests of narrow drainage divides or on low ridges where erosion has thinned the surface soil.

The dominant soils on the tablelands are Judith loam and gravelly loam, but some soils of clay loam texture are included. The Judith surface soil is usually friable crumb-structured very dark grayish-brown heavy loam or clay loam containing a small quantity of limestone gravel. The subsurface layer, a friable very dark grayish-brown clay loam of ill-defined prismatic structure, also contains variable but usually not large quantities of gravel. Blocky calcareous grayish-brown gravelly clay loam is at 10 to 18 inches. Below this are water-worn limestone pebbles, the voids between which are filled with limy light-gray clayey material. This deposit grades into loose stratified iron-stained limestone gravel and sand at 3 or 4 feet (pl. 2, A).

The Utica soils in this mapping unit are chiefly gravelly loams. The surface soil of Utica gravelly loam is 4 to 10 inches thick, dark grayish brown to very dark grayish brown, and of well-developed crumb structure. Beneath the surface soil and overlying the gravel bed is a thin highly calcareous grayish-brown transitional layer of gravelly clay loam. The spaces between the pebbles in the upper part of the bed are filled with limy light yellowish-gray clayey material. Loose stratified iron-stained limestone gravel and sand occur below 3 feet.

In depth, the soils of this complex vary with location, slope, and topography. The more shallow soils are on the tongues of the tablelands; the deeper ones, above the western escarpments and on the eastern slopes of the large tableland west of the Judith River in Judith Basin County. The color of the surface soil is influenced by differences in elevation and distance from the mountains. The gravel bed does not lie at a uniform depth and in places is exposed. Locally, the upper 2 to 3 inches of the gravel bed is firmly cemented with lime.

Small areas of Sipple soil (with thicker gravel-free horizons than Judith and Utica soils), some dark heavy soils of the small depressions, and some soils with cemented hardpan subsoil are included with this mapping unit. Where the areas of Sipple soil were large enough to be shown separately, as in the slightly depressed area just east of Benchland, they were mapped as Sipple loam.

Use and management.—Judith-Utica loams and gravelly loams are the most extensive dry-land farming soils in the Judith Basin. They

were placed under cultivation soon after a railway was constructed through the basin in 1907. Nearly all the tillable land is under cultivation; it is used for winter and spring wheat. Most grain farmers operate on one or more sections of land. Winter wheat was grown almost exclusively up to 1915, but several consecutive years of severe winterkilling followed and caused a change to spring wheat.

Formerly continuous cropping was practiced until the land became infested with weeds, but recently the weed problem has been partly solved by summer fallowing every second or third year. Summer fallowing does not greatly increase crop yields because the water-holding capacity of the gravelly subsoil is low and the normal rainfall of 7 to 9 inches during the growing season is sufficient to insure paying yields in most years. Yields of spring wheat on summer-fallowed land average between 12 and 15 bushels an acre on the deeper and less gravelly soils, though occasional yields of 30 bushels or more an acre are obtained in favorable seasons. The surface acre-foot of soil contains 5,000 to 6,000 pounds of nitrogen and 1,500 to 2,400 pounds of phosphorus.

During the droughts of 1930 to 1937, strong winds caused considerable soil drifting on land summer-fallowed or seeded to winter wheat. On many farms strip cropping has been adopted to control soil drifting and to hold the snow on fields seeded to winter wheat.

Laporte silt loam and stony loam, undifferentiated (L_A).—The Laporte soils occur largely on undulating to rolling ridge tops and on gentle slopes in areas of limestone bedrock in Meagher County. They have developed in material weathered from the limestone. Isolated areas occur in many of the mountainous tracts in other counties but are mapped with surrounding soils because of their small size. The included undifferentiated soils are chiefly darker colored, shallow members of the Duncom series on the higher areas and deeper soils developed in colluvium at the base of and on the slopes.

The surface soil in representative areas is friable granular dark grayish-brown silt loam or stony loam, 4 to 7 inches thick. Underlying this is light grayish-brown or yellowish-brown silt loam or clay loam, which continues to the partly disintegrated parent limestone lying at a depth of 10 to 20 inches. In most places varying quantities of loose fragments, blocks, and slabs of limestone are on the surface and in the soil. Adjacent to intrusive igneous rocks, the limestone usually has a reddish color that is imparted to the soils. Outcrops of limestone bedrock are numerous in nearly all areas; exposed rock probably covers 15 to 25 percent of the land in places.

Use and management.—Areas of Laporte silt loam and stony loam, undifferentiated, are too stony and shallow for farming and are utilized chiefly for grazing. The included deep and less stony soils are locally dry-farmed and irrigated, largely for forage crops. Under irrigation the soils tend to become waterlogged and seepy, but where surface drainage is fair they produce good yields of all crops grown. The deeper soils have a good cover of bunchgrasses; 20 to 25 acres will carry a steer through an 8- or 9-month grazing season. The soils more shallow and stony have a light cover of bunchgrasses and scrubby cinquefoil and a low livestock carrying capacity.

Larimer gravelly loam (L_B).—This soil occurs on high gently sloping to rolling coalescing fans and benches on the slopes of the

Townsend Basin in Broadwater County and locally in other counties. It has developed over a mixture of silt, sand, and gravel of Tertiary age. The gravel is from a variety of crystalline and sedimentary rocks. These parent materials have been reworked by winds and water, and in places Larimer soil grades into Manhattan sandy loam. The crests of the hills, ridges, and coulee slopes are usually very gravelly and cobbly.

The 4- to 6-inch surface soil on most areas in Broadwater County is friable grayish-brown gravelly loam of soft crumb structure and calcareous in the lower part. The subsoil—a highly calcareous brownish-gray gravelly loam of ill-defined medium blocky structure—grades into light-gray gravelly sandy loam at 10 to 18 inches. West of the Missouri River the subsoil on the lower slopes consists chiefly of argillite gravel and sand. In many areas in Lewis and Clark County the upper part of the subsoil is blocky or prismatic gravelly clay loam, and at a depth of 15 to 18 inches the subsoil is underlain by stratified gravel and sand.

Use and management.—Most of Larimer gravelly loam is used for grazing. A small acreage is irrigated in Broadwater County, largely for small grains and forage crops. Much of the irrigated acreage has high runoff because it is on 5- to 10-percent slopes. The soil is rapidly permeable below the upper subsoil layers. Under proper irrigation and management, however, fair crop yields are obtained. The surface acre-foot of soil contains 3,000 to 4,000 pounds of nitrogen and 1,400 to 1,800 pounds of phosphorus. The soil supports a fair stand of short grasses. If not overgrazed, 25 to 30 acres will carry a steer through the 10-month grazing season.

Larimer stony loam (Lc).—This soil developed under environment similar to that of Larimer gravelly loam; its parent materials were similar or more stony. At lower elevations 1 to 3 miles from the Missouri River the soil grades into Larimer gravelly loam. It occurs on coalescing fans on the steeper slopes of the Elkhorn Mountains in Broadwater County. The areas near the mountains occupy slopes of 10 percent or steeper and have many boulders and cobblestones from igneous and metamorphic rock scattered over the surface.

To a depth of 5 to 8 inches the surface soil on most areas is crumb-structured brown stony loam that has a slight reddish tinge in many places and is slightly calcareous in the lower part. The subsoil is highly calcareous brownish-gray or reddish-gray stony loam. It grades into loose stone and gravel at a depth of about 20 inches. A few depressions occur in areas north of Crow Creek, and the soils in these depressions are silty and relatively free of coarse material above the gravelly and cobbly substratum.

Use and management.—Most of this soil is too stony for cultivation and is used for grazing. Some local areas along Crow Creek are irrigated and used for pasture and wild hay. Pricklypear, rabbitbrush, and several species of bunchgrass form the chief vegetative cover. In nonirrigated areas the forage on 35 to 40 acres is required to carry a steer through the 10-month grazing season.

Lihen sandy loam (Ld).—Undulating to rolling upland areas along the Missouri River in Cascade County are occupied by this soil. The parent material probably was laid down in the Great Falls glacial

lake and later sorted by stream and wind action. The areas east and southeast of Great Falls have a low dunelike topography.

The 8- to 12-inch surface soil in areas south of the mouth of the Smith River is friable dark grayish-brown fine sandy loam or sandy loam. The subsoil is semicoherent grayish-brown loamy fine sand that grades into calcareous light grayish-brown fine sand at 20 or more inches. Areas above the mouth of the Smith River are locally underlain by gravel, and a sprinkling of gravel occurs at all depths in the soil section. The surface soil on the dunelike areas is loose medium- to coarse-textured sand underlain by incoherent sands, which are calcareous below 30 inches.

Use and management.—Areas of Lihen sandy loam west of the Smith River are cultivated. Spring and winter wheat are the chief crops. Many of the cultivated fields are strip cropped to control soil drifting. The soil absorbs nearly all the rainfall but is rapidly permeable and comparatively low in water-holding capacity. The surface acre-foot contains 3,000 to 4,500 pounds of nitrogen and 1,800 to 2,000 pounds of phosphorus. The average yield of spring wheat is low. The tall and short grasses adapted to sandy soils predominate in grazing areas. About 25 acres of native sod will carry a steer through a 10-month grazing season. The dunelike areas near Great Falls have a thin grass cover and low carrying capacity for livestock.

Lismas clay (L_E).—This clay occupies large areas widely distributed over rolling to hilly and broken areas of clay shale uplands in Fergus, Petroleum, Musselshell, Golden Valley, and Wheatland Counties, as well as isolated relatively small areas in other counties. It has developed largely on Bear Paw and associated shales of Cretaceous age. Included are many small areas of Pierre clay on the smoother ridge tops and slopes of relatively low gradient, and of Orman clay loam at the foot of slopes and in narrow valleys.

The upper 1 or 2 inches of surface soil in most areas is noncalcareous loose or flaky laminated grayish-brown silty to clayey mulch. Below this, the surface soil is dense, massive or irregularly blocky, olive-brown clay. At a depth of 6 inches the surface soil grades into dense olive-brown clay shale or partly decomposed shale. This soil is noncalcareous or only slightly calcareous, but free lime is usually present in the cracks and seams of the partly weathered shale.

Use and management.—Lismas clay is too shallow, too heavy and plastic, too droughty, and generally too steep for farming. Even where irrigated it is used exclusively for grazing. The soil supports only thin stands of dwarfed black sage, western wheatgrass, and numerous annual weeds. Many areas on the steep slopes are barren of vegetation. The carrying capacity is very low.

McKenzie clay (M_E).—In Cascade County and other counties farther to the east, most areas of this soil are in the bottoms of small basins or in the lower parts of relatively large enclosed basins and are too small to be shown separately on the map. The mapped areas occur chiefly in glaciated tracts, but many are scattered through the shale uplands.

Soil color and organic-matter content are influenced by the length of time accumulated water stands and by the depth to the water table. In many basins the water stands for only a few weeks in spring and the soils are much lighter colored than is typical of McKenzie soils. The

larger basins in western Cascade County lie within areas of Orman clay, and here, too, the soils are light colored.

The areas that remain moist or that are covered with water most of the year have a 4- to 6-inch surface soil of heavy clay, dark gray when dry, black or very dark gray when moist, and faintly mottled with gray and brown. The subsoil is calcareous dense dark-gray clay, grading to calcareous massive light-gray clay or clay loam at 12 to 24 inches. Crystals of gypsum and white streaks of other salts are common in the lower part of the subsoil.

The basins covered with water for only short periods in spring have a thin gray flaky mulch, below which lies the surface soil, a grayish-brown clay about 4 inches thick. Under this and continuing to a depth of 2 feet or more is calcareous dense massive light olive-brown clay. Many areas include alkali or saline spots.

Use and management.—McKenzie clay is not dry farmed; it is used chiefly for grazing. Surface drainage is not established, and the soil is very slowly permeable. On drying, the clayey material breaks into large intractable blocks and cracks penetrate to a depth of 2 to 3 feet. In places the darker colored areas support a fair stand of western wheatgrass, smartweed, and povertyweed; the light-colored areas, foxtail barley and plants tolerant of saline conditions. Many of the light-colored areas are barren of vegetation. Several storage reservoirs are located in the large basins in the western part of Cascade County, and part of one basin is under irrigation. The irrigated land is used largely for growing wild hay. The carrying capacity for livestock is very low on most of this soil.

Maginnis clay loam (M_A).—Gently sloping to rolling areas dissected by deep coulees in the east-central part of Fergus County are occupied by this soil, which has developed on metamorphosed clay shale of the Colorado formation. Included with it in mapping are numerous small areas developed on local alluvium lying at the foot of slopes or in strips in the narrow valleys of small intermittent streams. In many places on the valley slopes the included soils are very shallow and have bare shale outcrops. Hachure lines on the soil map separate the sharply rolling areas suitable only for grazing from those partly suitable for farming.

In most places the surface 6 to 10 inches is friable crumb-structured grayish-brown to dark grayish-brown clay loam containing many fragments of platy shale. A shallow transitional layer composed chiefly of dark grayish-brown partly disintegrated shale overlies the hard platy dark-brown shale lying at a depth of 10 to 15 inches. The shale has not been greatly altered by weathering. The soil is non-calcareous, but below a depth of about 20 inches the lower sides of the shale fragments are coated with lime carbonate.

Use and management.—Most rolling areas of Maginnis clay loam north of McDonald Creek have been cultivated one time or another, but low crop yields have caused abandonment. South of this stream the more gently sloping areas are now cultivated, largely to spring wheat. The soil has moderate to high runoff and moderate permeability but is droughty because of its generally shallow depth and low water-holding capacity. Water passes freely through the cracks and seams in the underlying shale. The surface acre-foot of soil contains 3,500 to 4,000 pounds of nitrogen and 1,500 to 2,000 pounds of

phosphorus. The yield of spring wheat on land summer-fallowed in strips is between 8 and 10 bushels an acre. Native grass lands have a fair cover of blue grama and western wheatgrass. The carrying capacity is one steer to 25 to 30 acres for a 10-month grazing season. The abandoned cropland now has a fair covering of western wheatgrass, and other native grasses are gradually coming in.

Manhattan sandy loam (M_B).—Areas of this undulating to gently rolling soil occur in the southern and northern parts of the Townsend Basin in Broadwater County. It is a sandy loam developed on Tertiary lake deposits that have been reworked and sorted by wind. On many intermountain tablelands it is associated with Amsterdam silt loam. In the southern part of the county, limestone underlies the old lake sediments and locally crops out on the slopes.

The surface soil is usually 6 to 10 inches of firm grayish-brown sandy loam or very fine sandy loam of macro-prismatic or coarse blocky structure. The upper part of the subsoil, a friable calcareous very light grayish-brown or nearly white silt loam of medium irregularly blocky structure, grades at a depth of 10 to 15 inches into coherent calcareous light grayish-brown very fine sandy loam or moderately firm massive loamy very fine sand. This massive layer continues to about 30 inches, where the lower part of the subsoil contains lenses of coarse sand and in places thin gravelly layers. The soil at the higher levels is much the same in the upper part of the profile but grades into coarse sands with depth and has an incoherent coarse sandy subsoil. The soil on the steeper slopes has some gravel on the surface and, near limestone outcrops, some limestone rock fragments.

Use and management.—A large part of this soil was once cultivated, but nearly all the cropland not irrigated was abandoned after the droughts of 1918 to 1921. The surface acre-foot of soil contains 3,000 to 4,000 pounds of nitrogen and 1,400 to 1,600 pounds of phosphorus. Surface and internal drainage are good. Good yields of small grains and alfalfa are obtained under irrigation. Short grasses predominate on unplowed areas; about 30 acres of native sod will carry a steer through a 10-month grazing season. The abandoned cropland now has a fair cover of western wheatgrass and needle-and-thread grass.

Manvel-Midway loams (M_c).—This complex occupies a level to gently sloping basinlike valley almost entirely enclosed by high sandstone rimrocks that lies south of Ryegate in Golden Valley County. The Manvel soils are on the colluvial-alluvial slopes below the rimrocks and on small alluvial fans formed where side draws enter the valley. The Midway soils occupy the undulating floor of the valley and the higher valley slopes where the shale is near the surface. Included with these soils on the map are narrow strips of bottom land soils formed from recent alluvium along Big Coulee Creek and some of its tributaries.

In cultivated fields the soil on the colluvial-alluvial slopes is crumb-structured friable calcareous light grayish-brown silt loam, which is relatively uniform in structure, consistence, and texture to a depth of 3 or more feet. In virgin areas, however, the surface 3 or 4 inches is slightly darker than the underlying material.

The surface soil on the floor of the basin is friable heavy grayish-brown silt loam, 4 to 6 inches thick. The subsoil is friable calcareous slightly prismatic light grayish-brown clay loam. It grades into friable calcareous very light grayish-brown clay loam or silty clay loam below a depth of 8 to 15 inches. This very light colored layer extends down to partly weathered interbedded fine-grained sandstone and silty and clayey shale, which are generally 3 feet or more below the surface.

Use and management.—Nearly all of this land is in small grains, corn, and forage crops. The small grains are grown in rotation with a clean summer fallow or with an intertilled crop such as corn. In the protected parts of the valley soil drifting is not so severe as it is in the uplands, and a fair acreage of winter wheat is grown. Much of the wheat is seeded on disked corn land. Spring wheat yields 8 to 10 bushels an acre, and occasionally 20 bushels or more in seasons of favorable moisture. Winter wheat usually yields a few more bushels an acre than spring wheat on summer-fallowed land. Complete crop failures rarely occur in the valley. Along the creeks the land is locally subirrigated, and the type of farming is more diversified and includes the growing of considerable alfalfa hay.

The soils are readily permeable and absorb nearly all the rainfall. Dashing showers, however, result in some runoff and cause some sheet erosion on the steeper valley slopes. The surface acre-foot contains from 3,000 to 3,500 pounds of nitrogen and from 1,600 to 1,800 pounds of phosphorus.

Martinsdale loam and gravelly loam, undifferentiated (M_D).—Areas of this unit lie on smooth gently sloping benchlands along many of the streams in the intermountain basins. The larger areas are in Wheatland, Meagher, Broadwater, and Lewis and Clark Counties. The soils have developed in a mantle of fine earth material 10 to 24 inches thick that is underlain by thick deposits of quartzite and argillitic gravel and cobblestones. Included because they occupy areas too small to map separately are Martinsdale stony or cobbly loams and soils developing on colluvial-alluvial material on steep slopes or on alluvial material in the narrow stream valleys. Some of the benches deeply dissected and strongly rolling to steep are shown on the soil map by hachure lines to indicate that they are suitable only for grazing.

Below a thin gray surface mulch, the 5- to 7-inch surface soil on most of the benches is friable brown or grayish-brown loam of fine crumb structure. It contains varying quantities of cobblestones and gravel. Below this layer lies the subsoil, a compact blocky grayish-brown cobbly loam or gravelly loam that grades to massive highly calcareous grayish-brown gravelly or cobbly loam at 8 to 20 inches. The interstices between the stones and gravel in the lower part of this layer are filled with almost white limy clayey material to a depth of about 3 feet. Below 3 feet lies the substratum, chiefly a mixture of rounded and subangular large pebbles and cobblestones and fine gravel and sand. The surface soil and upper part of the subsoil have a perceptible reddish tinge where the parent material is largely igneous rock material.

The areas along Camas Creek in Meagher County and Prickly Pear Creek in the Helena Basin are stony, and the loose gravelly substrata

are at a comparatively shallow depth. On many of the longer benches the range is from stony loam at the higher levels to gravelly loam or gravelly sandy loam at the lower.

Use and management.—In most places these soils have too much stone on or near the surface to permit farming with ordinary tillage implements. They are therefore used chiefly for grazing. On most of the benches, however, there is some land under cultivation. The less stony areas are used for alfalfa and small grains; the more stony, for irrigated pasture and wild hay. The soils have good surface and internal drainage and are highly productive if irrigated. The surface acre-foot of soil contains 3,000 to 6,000 pounds of nitrogen and 1,500 to 2,200 pounds of phosphorus. The yield of alfalfa on irrigated land is 2 to 3 tons an acre from the two cuttings usually obtained in this part of central Montana. Mixed tall and short grasses form a good sod on most of the benches; 20 to 25 acres will support a steer during a 10-month grazing season. Areas in the Helena Basin support an open stand of bluebunch wheatgrass, and 35 acres or more will carry a steer through the same grazing period.

Midway-Bainville-Cushman loams and stony loams (Mf).—Undulating to gently rolling areas north of the Musselshell River in eastern Golden Valley and western Musselshell Counties are occupied by this soil, as are local areas in western Petroleum County. The Bainville and Cushman soils of this complex have developed on the yellow silty members of the Fort Union formation; the Midway soils, on the moderately clayey members of both the Fort Union and the Lance formations. The Cushman soils of this unit differ from the Bainville chiefly in having a thicker and darker colored surface soil, a thicker and better developed solum, and a more pronounced horizon of lime carbonate accumulation.

The individual types of Bainville and Cushman soils included in this complex differ little from those of Cushman-Bainville loams and silt loams. Sandstone outcrops locally on the low ridges and on the slopes of coulees, and in a more detailed survey small areas of Flasher stony loam included in this unit would be shown separately on the soil map.

Midway and Bainville loams and stony loams make up the greater part of the complex. The surface soil of Bainville loam—a friable calcareous grayish-brown loam or silt loam about 3 or 4 inches thick—is underlain by the partly weathered yellowish-brown silt loam of the parent shale. In places this parent shale contains thin stratified lignite and brown carbonaceous shale of silty clay loam texture. The included Midway soils differ from the Bainville chiefly in having a heavier subsoil and a more clayey substratum. Thin lenses of sandstone interbedded with shale are the source of the hard sandstone fragments and slabs occurring on and in these Midway soils from place to place.

The Cushman loam covers only a small part of the total area mapped in this complex. It has a 4- to 7-inch surface soil of friable grayish-brown loam or silt loam of soft crumb structure. The subsoil is friable medium soft blocky calcareous light-brown silt loam in the upper part, but it grades to massive calcareous yellowish-brown silt loam in the lower part and continues down to the stratified silty or only slightly clayey shale, which is at a depth of 24 to 36 inches.

Use and management.—Most of the smoother stone-free areas of this mapping unit were placed under cultivation after the main line of the Milwaukee Road was built through the Musselshell River basin. Most of these areas, however, were abandoned because yields were unprofitably low. The land now cultivated is largely that on smoother slopes of stream valleys, where the soils are deepest and receive some supplemental moisture from drifting snow and from runoff from the higher ridges. Soils on the lower slopes usually have good drainage and are moderately well supplied with essential plant nutrients. The surface acre-foot of soil contains an average of 3,400 pounds of nitrogen and 1,600 pounds of phosphorus.

Most cultivated land is in feed crops and small grains harvested for hay. The yield of spring wheat on summer-fallowed land is less than 10 bushels an acre. A small part of the cultivated land is irrigated by floodwater diverted directly from the streams. Good yields of alfalfa and small grains are obtained if a good volume of irrigation water is available. These soils are readily eroded by wind and water when farmed in large blocks, and strip cropping is necessary to control soil blowing and to minimize sheet erosion.

About 40 acres of range land is required for each animal unit for the 10-month grazing season, a lower carrying capacity than that of Cushman-Bainville loams and silt loams.

Midway-Patent clay loams (Mg).—These complexly associated Midway and Patent clay loams occupy gently rolling uplands in areas where there is moderately heavy shale of Cretaceous age. They occur chiefly in the northeastern part of Lewis and Clark County. The Midway soils comprising the larger part of the complex occur chiefly on the low rounded hills and ridges and are relatively shallow to bedrock. The Patent soils, on the lower parts of the slopes, have developed on material washed from the higher areas and are 3 feet or more deep over shale. A number of small areas of other soils also are included in the complex—Travessilla stony loam on the sandstone-capped ridges, and Arvada clay loam on the alluvial deposits along the intermittent streams. In places the Patent soils grade to and join with areas of Moline clay loam, which occurs on the lower colluvial slopes and sloping terraces in the wider valleys.

Beneath a 1- or 2-inch flaky or platy light grayish-brown clay loam mulch, the surface soil of Midway clay loam is blocky or prismatic grayish-brown clay loam, 4 to 7 inches thick. It is slightly calcareous in the lower part. The subsoil is an olive-brown clay loam of ill-defined blocky structure. It is somewhat stained or mottled with brown, contains white streaks and splotches of segregated carbonate of lime, and continues down to a depth of 24 to 30 inches, or to the partly weathered parent shale. In some areas the lower part of the subsoil is massive calcareous gray to greenish-gray clay, stained with brown iron oxide and containing some iron concretions. In such places the subsoil is underlain by stratified greenish-gray and yellowish-gray shale at about 3 feet. On the tops of the hills and ridges, fragments of gray and olive shale usually occur through the entire soil section, and in places the subsoil is composed largely of soft fragments of shale.

The 4- to 6-inch surface soil of Patent clay loam is mainly friable grayish-brown clay loam containing enough free lime carbonate to

effervesce freely when dilute hydrochloric acid is applied. The subsoil is moderately plastic calcareous light grayish-brown clay loam of medium blocky structure. It grades at depths of 15 to 20 inches into lime-flecked brownish-gray clay loam, which continues down to the underlying slightly altered shale. The shale is at varying depths, usually in excess of 3 to 4 feet. On the lower parts of the slopes Patent soils contain enough alkali, or salts, to prevent or retard the growth of most plants.

Use and management.—Midway-Patent clay loams are used chiefly for grazing. A small acreage was once cultivated, but low crop yields and frequent crop failures forced abandonment of most areas. Surface runoff is low. Subsoils are only moderately to slowly permeable, but drainage is adequate for the rainfall received. The surface acre-foot of soil contains 4,500 to 5,000 pounds of nitrogen and 2,000 to 2,200 pounds of phosphorus. The greater part of the natural vegetation is short grasses. The forage on 30 acres is needed to carry a steer through a 10-month grazing season.

Moline and Arvada loams and clay loams, undifferentiated (M_H).—Moline and Arvada soils occupy saline basinlike valleys in the northern part of Fergus County and small local areas in Petroleum, Musselshell, and other counties. The larger areas occupy partly enclosed upland basins at the heads of drains and are surrounded by Pierre and Winifred soils. Moline soils occur on colluvial slopes; the Arvada soils, on the lower more level parts of basins. These soils have claypan subsoil. Slick spots show where the friable surface soil has been removed by wind and the heavy subsoil has been exposed; saline "puff spots" occur where the soils are very light-colored. The soils are characterized by a fine granular structure and an abundance of free lime carbonate and other salts. Included are some soils with a friable subsoil rather than one of claypan.

The surface soil on the colluvial slopes is gray or light-gray clay loam or silty clay loam, 2 to 4 inches thick. It rests directly upon the claypan subsoil. The claypan is a columnar heavy grayish-brown clay loam, 6 to 10 inches thick. The subsoil below the claypan is calcareous massive light grayish-brown silty clay loam continuing to a depth of 3 feet or more.

In the lower positions the surface soil is 3 to 4 inches of gray or light-gray clay loam or silty clay loam of flaky or soft crumb structure. It is underlain by 4 to 6 inches of tough grayish-brown silty clay of strongly developed columnar structure. Below 7 to 10 inches the subsoil and substrata consist chiefly of stratified gray silt and clay. Some accumulation of lime carbonate occurs immediately below the claypan, and gypsum and other salts are present at slightly greater depths.

Use and management.—Moline and Arvada loams and clay loams, undifferentiated, are used for grazing. They have low surface runoff, and their heavy subsoil is very slowly permeable. They support only a light stand of grama grass, big sage, and greasewood and have a low carrying capacity for livestock. Most saline "puff spots" and heavy clay spots support no vegetation.

Morton-Darret loams and clay loams (M_K).—The soils of this unit occur on undulating to rolling plateaus in northern Cascade County and in local high areas in Judith Basin and Fergus Counties.

They have developed over interbedded gray, brown, and red shaly sandstone and silty shale of the Kootenai formation. Soils of the two series are in complex association in most places. They differ chiefly in color, the differences in color resulting from differences in parent material.

The Darret soils have developed largely over red silty shale; the Morton soils, over gray and brown shale and sandstone. Included with this unit because of the small scale of mapping used are small areas of Castner stony loam on the ridges, of Goshen loam and silt loam on the alluvial-fan slopes, and of Fergus clay loam on the sloping terraces.

Morton loam and silt loam are dominant in most areas. The surface 1 to 2 inches is flaky or very thin platy dark grayish-brown loamy to silty mulch. Below this is the surface soil, a friable dark grayish-brown loam or silt loam, 5 to 7 inches thick. The subsoil is firm well-developed clay loam of prismatic structure; it grades to massive or ill-defined blocky calcareous light grayish-brown clay loam at 12 to 18 inches. The parent material, at depths below 2 or 3 feet, is light grayish-brown or brownish-gray clay loam containing varying quantities of brown shaly sandstone or shale fragments. In places the soils rest directly upon partly weathered bedrock.

The Darret soils are chiefly clay loams but some are loams and silt loams. The surface 6 to 10 inches is friable crumb-structured reddish-brown clay loam. The subsoil is reddish-brown or dark-red clay loam of pronounced prismatic structure, grading into massive calcareous friable reddish-gray clay loam at 10 to 15 inches. The parent material, below 3 feet or more, consists of partly weathered and little altered weakly indurated red silty to clayey shale.

In southeastern Fergus County, these soils have somewhat lighter colored surface soils and thinner horizons and solums than elsewhere. These shallow stony soils developed over hard fine-grained sandstone of the Kootenai formation were mapped as Batterick stony loam, but because of limited extent, were included in this complex.

Use and management.—A large part of Morton-Darret loams and clay loams is cultivated in Cascade County, chiefly to spring and winter wheat produced on land summer-fallowed every second or third year. Farms growing grain exclusively have one or more sections of land. The soils are well supplied with organic matter and essential plant nutrients and have good drainage and relatively high productive capacity. The surface acre-foot of soil on the plateaus in Cascade County contains 5,500 to 6,500 pounds of nitrogen and 2,500 to 3,000 pounds of phosphorus. The yields of spring wheat on land summer-fallowed in strips to control soil drifting average 18 or more bushels an acre. The less stony and shallow soils of this complex in southeastern Fergus County contain 4,000 to 5,000 pounds of nitrogen and 2,000 to 2,500 pounds of phosphorus, and the yield of spring wheat on summer-fallowed land averages between 12 and 15 bushels an acre.

Morton fine sandy loam (Ml).—A relatively large rolling upland area of this soil lies west of the Missouri River in central Cascade County; similarly rolling but smaller areas are in eastern Fergus County. The upper part of the solum is derived from sandy material deposited by or locally reworked by wind; the lower part is from

residual materials weathered from stratified shaly sandstone of the Kootenai formation. Small areas of sandy soils derived from shaly sandstone and apparently unmodified by wind are included.

The surface 2 inches is dark grayish-brown mulch of loamy fine sand texture. Below the mulch is the surface soil, a dark grayish-brown sandy loam grading into grayish-brown loam at 9 to 12 inches. At 18 to 20 inches this grayish brown loam grades into massive calcareous brownish-gray clay loam, which at about 30 inches is underlain either by stratified light-gray or pale-brown sand and silt weathered from bedrock or by disintegrated shaly sandstone. Slabs and fragments of hard shaly sandstone occur on the surface in some areas of Fergus County and in the lower part of the soil in parts of Cascade County.

Use and management.—In Cascade County this soil is largely under cultivation. It is used chiefly for winter wheat and rye grown on land summer-fallowed in strips to control soil drifting. The soils have good surface and internal drainage and fair water-holding capacity but are relatively low in content of essential plant nutrients and organic matter. The surface acre-foot contains 3,000 to 4,000 pounds of nitrogen and 1,500 to 2,000 pounds of phosphorus. The yields of winter wheat on summer-fallowed land are comparatively low, or an average of less than 12 bushels an acre. The drifting of soils by wind late in winter and in spring damages fall-sown wheat considerably.

Morton silt loam (Mm).—This soil occurs in local undulating to rolling upland areas in most of the counties, but the larger tracts are in Cascade, Fergus, and Judith Basin Counties. The soil has developed largely over silty shale and shaly sandstone of Cretaceous age, but wind-blown material (thin loess) has contributed to the parent material in most places. In different localities this soil includes small areas of a number of different associated soils, as Castner stony loam, Regent clay loam, and various soils on colluvial slopes and alluvial-fan slopes. In northern Cascade County a thin mantle of glacial till covers parts of these soils, and in places in some of the other counties the subsoils are locally sandy. In a more detailed survey, soils with sandy subsoil would have been mapped separately as a type of the Vebar series. Morton silt loam occurs at lower elevations and in a lower rainfall belt than the Morton soils of the mapping unit Morton-Darret loams and clay loams.

The soil profile is very similar to that of the Morton soils of Morton-Darret loams and clay loams, but in most areas the several horizons, or layers, in the solum are somewhat thinner. The surface 5 to 7 inches is friable dark grayish-brown silt loam or loam. Next in profile is a grayish-brown clay loam of well-developed prismatic structure, which grades to a layer of fairly abundant lime carbonate accumulation at a depth of 8 to 15 inches. This limy layer, in turn, grades into stratified silty to clayey partly weathered shaly material at about 3 feet. Slabs and fragments of sandstone and sandy shale occur on the surface in some places, and in others a few stone fragments occur at all depths.

Use and management.—Most of the tillable acreage was cultivated at one time, but during the droughts of 1930 to 1937 a considerable part was abandoned. Approximately 60 percent of the soil is now

cultivated, largely for spring and winter wheat grown on land summer-fallowed every second year. A number of grain farms covering one or more sections of land are located on this soil, but on many farms grain growing and stock raising are combined. Surface and internal drainage are good, and the soil is fairly productive. The surface acre-foot contains, 3,500 to 5,000 pounds of nitrogen and 1,500 to 2,500 pounds of phosphorus. Yields vary with local differences in precipitation and temperature and in depth of the soil. In the drier areas or where erosion has thinned the soil and the calcareous subsoil is within 8 to 12 inches of the surface, spring wheat grown under a system of strip cropping and summer fallow produces 12 to 15 bushels an acre. Where the lime carbonate layer is at a depth greater than 12 inches (usually in the higher rainfall areas), yields are 15 bushels or more an acre.

Musselshell-Crago loams and gravelly loams (M_N).—Areas of this complex occupy tablelands north of the Musselshell River in eastern Meagher, Wheatland, Golden Valley, and Musselshell Counties and high benches north of Flat Willow Creek in Petroleum County. The tablelands range from 3,200 feet high in Petroleum County to more than 4,500 feet in Meagher County. They have a protective covering of limestone gravel mantled by a thin layer of silty aeolian, or loesslike, material. The tablelands occupy different erosional levels and have smooth level to undulating surfaces with gradients of 40 to 80 feet to the mile. In many places the edges of the benches are steep shale and sandstone escarpments.

Musselshell and Crago soils differ mainly in the thickness of the fine earth material over the gravel. Where the gravel bed lies at a depth between 15 to 30 inches, the soils are representative of the Musselshell series; where the gravel is within 15 inches of the surface, the soils are included with the Crago series. The two series are intricately associated in most areas and their separation would require a more detailed survey and larger map scale. Crago soils occur chiefly on the border and tongues of the tablelands, on the crests of narrow drainage divides, and on low mounds and ridges or gravel bars within large areas of otherwise nearly level Musselshell soils.

Small areas of Two Dot and Ashuelot soils were included in mapping. Two Dot soils have more than 3 feet of fine earth over the gravel. Ashuelot soils are characterized by a gravel subsoil cemented by lime carbonate. A more detailed survey would show on the borders and tongues of the tablelands other soils having gravel underlain at shallow depths by shale and sandstone.

Musselshell loam and gravelly loam make up the larger part of this complex. The 4- to 6-inch surface soil of Musselshell loam is friable crumb-structure grayish-brown loam containing at least a sprinkling of gravel in most places. The subsoil is a prismatic or blocky calcareous light grayish-brown clay loam or gravelly clay loam; it grades to massive very light grayish-brown or almost white gravelly clay loam at 8 to 15 inches. In the lower part of the subsoil the spaces between the water-worn limestone pebbles are filled with limy almost white clayey material to a depth of 3 or more feet. Below this depth lies stratified loose gravel, sand, and silt.

The Crago soils associated with the Musselshell soils are chiefly gravelly loam. The 4- to 10-inch surface soil is crumb-structured

grayish-brown gravelly loam. Beneath the surface soil lies a thin transitional layer of highly calcareous light grayish-brown gravelly loam that grades into a bed of pebbles, the interstices between which are filled with light-gray, light yellowish-gray, or almost white limy clayey material to a depth of 3 feet. Below this depth is stratified water-worn limestone gravel, sand, and silt similar to or the same as that underlying the Musselshell soils.

The depth of the soils varies with location, slope, and topography. The color of the surface soil is influenced by differences in elevation and distance from the mountains. The shallower and lighter colored soils are on the lower tongues of the benches, where the gravel deposit is underlain by shale and sandstone at relatively shallow depths. The gravel bed does not underlie the surface at a uniform depth, and in many places it outcrops as gravel bars. In places near the mountains the upper 2 or 3 inches of the gravel bed is firmly cemented with lime. The fine earth material and soil above the gravel in the Musselshell River Basin is of uniformly medium texture, but on some of the lower benches north of Flat Willow Creek it is derived largely from shale and the surface soils are clay loams with mottled lime-splotched gravelly silty clay subsoil.

In a few places alkali, or slick, spots occur on some of the benches where the soil material is closely underlain by shale containing free salts. The gently sloping tablelands forming the divides between the Musselshell River and Roberts and Careless Creeks in the east-central part of Wheatland County are characterized by deep depressions in which occur shallow intermittent lakes. In this part of the county, shale and sandstone underlie the soils and gravel deposits at shallow depths, and the soils are chiefly a complex of Musselshell and Cushman loams and clay loams.

Use and management.—Musselshell-Crago loams and gravelly loams were placed under cultivation in most of the counties between 1908 and 1915. Crop yields were fair until the drought of 1918 to 1921, but since then the cultivated area has steadily declined. Cultivated land is now confined largely to areas where the fine earth over gravel averages 20 inches or more thick. The larger farming areas are on the high benches southeast of Winnett in Petroleum County, in northwestern Golden Valley County, and in northeastern Wheatland County. Small areas are cultivated in northwestern Musselshell County and locally near the mountains in other counties. Stock raising and grain growing are combined on most farms; spring wheat is the main cash crop. Most areas are used for grazing livestock owned by ranchers located in the mountains and larger stream valleys. The surface acre-foot of soil contains 3,000 to 5,000 pounds of nitrogen and 1,500 to 1,700 pounds of phosphorus. Yields of spring wheat average less than 10 bushels an acre. Wind erosion has been severe, and on some abandoned fields near the mountains much of the surface soil has been removed and the calcareous gravelly subsoil is locally exposed. Strip farming to control soil drifting is becoming a general practice.

The State Water Conservation Board has constructed canals on several thousand acres west of Harlowton in Wheatland County. This acreage includes a high proportion of Musselshell and Crago soils, and the land is now being placed under irrigation. Feed and forage crops and cash crops such as wheat, flax, and peas are pro-

duced on land already irrigated. Small areas near the mountains are irrigated, chiefly to produce forage crops. Surface and internal drainage are good, but the water-holding capacity is only fair because of the relatively high gravel content and the rapid movement of water once it reaches the gravelly substrata. Under proper irrigation, fair to good yields of most crops are obtained. The land in native sod has a good cover of short grasses; 25 to 30 acres is sufficient to carry a steer through a 10-month grazing season. Abandoned land has only a thin cover of weeds, forbs, and unpalatable tall grasses. Crested wheatgrass or other adapted grasses would probably improve the quality of the forage and hasten the return of the abandoned land to full carrying capacity.

Orman clay and clay loam, undifferentiated (O_A).—This undifferentiated unit occupies low benches or terraces along the Sun River in Cascade County and along the Smith River in Meagher County. Similar soils in several glacial or preglacial stream valleys west of Augusta in Lewis and Clark County are included. Small areas of Orman soils occur in many of the larger stream valleys but are included with the undifferentiated light-colored or dark-colored alluvial soils. The parent materials consist of old alluvium, derived principally from Cretaceous shale and now occupying terraces well above flood levels. In Meagher County, however, the material is derived chiefly from the Belt formation of Algonkian age. In Cascade County the Orman soils are associated with Winifred and Pierre clays and include small areas of these soils.

The surface soil on representative areas is grayish-brown to dark grayish-brown blocky clay or clay loam, 4 to 8 inches thick. The subsoil, a light olive-brown clay of dense large blocky massive structure, overlies, at depths of 2 to 4 feet, chiefly stratified alluvium of varying but unusually heavy texture. The soils are calcareous at 8 to 15 inches, and spots and streaks of free carbonate of lime and, in places, soluble salts are in the lower part of the subsoil. The soils on the area west of the Smith River contain some fragments of slaty shale and near the river are underlain by Tertiary lake sediments. In the glacial stream valleys a few boulders occur on the surface and some small gravel is at all depths in the soil. Small gravelly fans formed by side draws along the edges of the valleys and shale outcrops along the terrace breaks are included in some areas of Orman soils.

Use and management.—The more friable clay loams of this mapping unit on the bench west of the Smith River were formerly cultivated but were in large part abandoned during the droughts of 1930 to 1937. The area south of the Sun River in Cascade County is irrigated, chiefly for alfalfa and small grains; most other areas are grazed. Surface drainage is slow but adequate. The soils are very slowly permeable because they have a heavy-textured surface soil of poorly developed structure and a dense massive clay subsoil. They are difficult to irrigate and to maintain in good tilth.

The surface acre-foot of soil contains 3,500 to 4,500 pounds of nitrogen and 1,500 to 1,700 pounds of phosphorus. On the average non-irrigated spring wheat on summer-fallowed land yields less than 10 bushels an acre. Under proper irrigation management, fair yields of alfalfa are obtained from fields with a satisfactory stand. Western wheatgrass, big sage, and rabbitbrush predominate on virgin areas; 30 to 35 acres of native sod will carry a steer through a 10-month graz-

ing season. Some wild hay is harvested in the glacial stream valleys in seasons when grass makes good growth.

Patent clay loam (PA).—Areas of Patent clay loam are widely distributed but are of sufficient size to be shown on the soil map only in northern Fergus and Petroleum Counties and a few places in other counties. The soil has developed in clayey colluvium locally deposited in narrow valleys and at the foot of slopes in broader valleys. Most of it is on smooth slopes of varying but usually low gradient. In places, however, the slopes are gullied by runoff from adjoining higher land. Areas on the lower parts of slopes are moderately saline in places. Small areas of Manvel silt loam are included with this soil where the parent material is partly from silty shale.

The surface 5 to 7 inches of Patent clay loam is friable calcareous light grayish-brown clay loam of fine crumb structure. The subsoil is medium blocky calcareous very light grayish-brown or pale-brown clay loam to a depth of 15 inches, below which it is calcareous massive heavy light-gray clay loam that changes little until the underlying shale or shaly sandstone is reached at 3 feet or more.

Use and management.—This soil occurs largely in stock-raising areas; a large part of it is used for grazing. Most of the cultivated land is used for feed and forage crops. A fair acreage of oats, barley, and wheat is harvested in the dough stage for hay. Some of the larger areas along Blood Creek and its branches in western Petroleum County are planted to spring wheat.

The State Water Conservation Board recently completed a dam on Blood Creek for storing floodwater. Patent clay loam, the chief soil below the dam, has adequate drainage for dry farming, but under irrigation tends to become waterlogged and to develop seep and saline spots unless adequate drainage is provided and it is not overirrigated. Fertility is moderate. The surface acre-foot of soil contains 2,400 to 3,000 pounds of nitrogen and 1,500 to 1,800 pounds of phosphorus. Under good management yields of small grains and alfalfa should be good. The yield of nonirrigated spring wheat on summer-fallowed land averages less than 10 bushels an acre. Grama grass and western wheatgrass are the chief vegetation; 30 acres will carry a steer through a 10-month grazing season.

Pierre clay (PB).—Relatively large, fairly continuous, undulating to sharply rolling upland areas of this soil are mapped in Fergus, Petroleum, and Musselshell Counties; isolated small and large areas occur in other counties. The soil has developed over Bear Paw and associated clay shale of Cretaceous age. The shale areas in northern parts of Fergus and Petroleum Counties have been glaciated and are characterized by low rounded to flat-topped ridges and shallow depressions. A few erratic boulders occur on the surface. Areas of Lismas clay loam, Orman clay loam, Billings clay loam, and Arvada clay loam too small to be shown separately on the map are included. Dark-colored shale locally crops out on steep slopes and breaks. In Meagher County several small areas of included soils have developed over hard slaty shale.

The 4- to 8-inch Pierre surface soil on most of the unglaciated areas is grayish-brown heavy clay of ill-defined crumblike structure. The subsoil is dense coarse blocky dark olive-brown clay grading into

olive-brown heavy clay or partly weathered platy-structured clay shale at 10 to 20 inches. The soil is commonly calcareous within 10 to 15 inches of the surface, and gypsum crystals and white streaks of other salts occur in the lower part of the subsoil and in the partly weathered shale material.

In places Pierre clay has developed on dark-colored calcareous shale-like clay only slightly hardened. The soil formed over this material is characterized by a calcareous fine granular mulchlike dark-gray surface soil and a blocky gray clay subsoil that contains free lime carbonate at all depths. The soil in glaciated areas differs from that in the unglaciated chiefly in having dense olive-brown clay subsoil that continues to a depth 3 or 4 feet in places and rests directly on partly weathered or stratified unweathered shale.

Use and management.—The deeper areas of Pierre clay were placed under cultivation between 1910 and 1915, but only the included dark-colored calcareous clays and a few of the other deep included soils are now cultivated. Pierre clay is very sticky and plastic when wet and hard and tough when dry. It is difficult to manage because it has a narrow range of moisture conditions under which it can be tilled. The surface acre-foot of soil contains 2,200 to 2,700 pounds of nitrogen and 1,200 to 1,500 pounds of phosphorus. The average yield of dry-farmed spring wheat on summer-fallowed land is less than 10 bushels an acre. A small acreage in Cascade and Lewis and Clark Counties is irrigated, but most of this has become seeped and is used only for pasture and wild hay. Big sage and western wheatgrass are the natural vegetation; 35 acres or more is required to carry a steer through the 10-month grazing season.

Regent clay loam (R_A).—Gently rolling upland areas in northeastern Lewis and Clark County and undulating areas along Skull Creek in western Fergus County are occupied by this soil developed on moderately clayey shale of Cretaceous age. As mapped, it includes small areas of Patent and Moline clay loams, which have developed in local alluvium at the foot of slopes, and some areas of moderately friable silty soils that are about typical of Morton silt loam.

The Regent surface soil is mostly crumb-structured dark grayish-brown clay loam, 5 to 7 inches thick. The subsoil is prismatic grayish-brown heavy clay loam or clay loam to a depth of 12 to 24 inches. The subsoil below this depth has about the same texture but is usually more friable, lighter colored, and calcareous and overlies disintegrated stratified clayey shale at 2 to 3 feet. The parent shale is usually calcareous and contains considerable other salts, principally gypsum.

Use and management.—Until the droughts of 1930 to 1937 most of Regent clay loam was cultivated, but then much of it was abandoned. On most farms grain growing and stock raising are combined, and much of the cultivated land is needed to produce feed and forage crops. Winter wheat, the chief cash crop, is grown largely on summer-fallowed land. Surface drainage is good, and runoff is medium to high in seasons of heavy rainfall. The subsoil is moderately to slowly permeable, but in most seasons the generally low precipitation is largely absorbed. The soil is well supplied with organic matter and the most essential plant nutrients. The surface acre-foot contains 4,000 to 5,000 pounds of nitrogen and 2,000 to 2,500 pounds of phosphorus. The yield of winter wheat on summer-fallowed land is between 12 and 15

bushels an acre, though yields of 35 to 40 bushels are occasionally obtained in seasons of favorable moisture and temperature.

Regent-Rhoades clay loams (Rb).—This complex association of soils occur chiefly in basins and on undulating uplands below the foothills and outlying buttes and dikes of igneous rocks of the Mission Range in northeastern Lewis and Clark and western Cascade Counties. The soils have developed in residual materials weathered from moderately clayey shale of Cretaceous age. Almost all areas have some depressed bare spots that give the surface a slight micro-relief. The bare spots are more numerous in the basins and on the more poorly drained slopes. Small areas of Moline and Arvada soils are included. They are largely on the colluvial-alluvial slopes and fans occurring in draws and narrow valleys.

The Regent soil of this complex differs from Regent clay loam chiefly in having a more compact and somewhat heavier textured sub-surface layer. The tendency toward claypan development, however, is not usually observed on the better drained slopes and low ridges.

The surface inch or more of Rhoades clay loam is laminated to plant mulchlike granular grayish-brown clay loam. Below this is the surface soil, 5 to 7 inches of friable dark grayish-brown clay loam. Next occurs compact dense clay of columnar structure and averaging 3 inches thick. The subsoil below the claypan is calcareous grayish-brown clay loam or heavy somewhat plastic clay loam of ill-defined prismatic or blocky structure. Usually it becomes lighter textured and more friable with depth. The parent material, at depths below 30 inches or more, consists of disintegrated stratified moderately clayey shale.

Use and management.—These soils occur largely in stock-raising sections; only a small acreage is cultivated. The land cultivated is used principally for feed and forage crops. Winter wheat grown on summer-fallowed land is the chief cash crop on the few small farms growing grain exclusively and on the combination grain and livestock farms. The content of nitrogen and phosphorus in the surface acre-foot of soil is similar to that in Regent clay loam. Yields of winter wheat are comparatively low. In normal seasons the grazing lands have a fair carrying capacity.

Regent stony loam-clay loam (Rc).—This complex occupies basinlike valleys, valley slopes, and foothill ridges capped with metamorphosed shaly sandstone and sandstone that occur chiefly in the northern and southern parts of Lewis and Clark County. In surface texture the soil varies from loam to clay loam within short distances. Included are a number of areas of other soils too small to be shown on the map. These included undifferentiated soils are Patent clay loam and Moline clay loam on the colluvial-alluvial slopes and Castner stony loam on the tops of ridges. Small areas of lighter colored somewhat shallower soils, as the Midway, occur where the surface soil has been thinned somewhat by erosion. Soils developed on several igneous dikes are also included. Sharply rolling areas on ridges or crests of ridges that are suitable only for grazing are shown on the soil map by hachure lines so they may be distinguished from soils on the smoother slopes that are suitable for cultivation.

Regent clay loam occurs chiefly in basinlike valleys, but locally on smoother valley slopes. Most of the smoother areas have a moderately

friable clay loam surface soil of soft crumb structure underlain by heavy clay loam containing shale or shaly sandstone fragments. The lower subsoil, that below 12 to 15 inches, consists largely of stratified disintegrated metamorphosed shale and shaly sandstone. The stony loam in the more broken sections is characterized by slabs and fragments of hard shale and shaly sandstone on the surface, and the subsoil is largely stratified disintegrated shale and shaly sandstone. In some places the slabs of loose rock occur largely on the surface and the subsoil is about the same as in the nonstony soils.

Use and management.—This complex occurs chiefly in stock-raising sections of Lewis and Clark County. Most of the land cultivated is used for feed and forage crops. The stock ranches usually cover 5 to 15 sections of land. The content of nitrogen and phosphorus in the surface acre-foot of soil compares favorably with that in Regent clay loam. The productivity of the less stony soils is fair. The natural vegetation consists of mixed tall and short grasses; the forage on about 25 acres is required to carry a steer through a 9- to 10-month grazing season. The density of the grass cover increases with increase in elevation, and on some of the higher ridges and on the north slopes the soils have somewhat greater carrying capacity.

Ringling loam-shaly loam (Rd).—These soils are on high ridges extending out from the Big Belt Mountains and on the lower slopes of the mountains in southwestern Meagher County. They have developed over red or brownish-red metamorphosed clayey shale of pre-Pennsylvanian age. They form a complex pattern of shallow soils containing an abundance of shale chips and fragments and soils relatively free of these materials.

These soils consist of 4 to 10 inches of reddish-brown loam or shaly loam resting directly upon or, at additional depths of 1 or 2 inches, grading into reddish-brown to red slaty shale not greatly altered by weathering. The soils and the underlying shale are noncalcareous as a rule, but at a depth of 10 to 12 inches the lower sides of the shale fragments are coated with carbonate of lime. Unaltered shale is exposed in many places on the steep slopes and sharp breaks. Included because it was not possible to show them separately at the scale of mapping used are many small areas and narrow strips of relatively deep reddish-brown soils developed on small alluvial fans and alluvial strips along the small stream valleys.

Use and management.—Ringling loam-shaly loam is suitable only for grazing. Thin stands of black (big) sage and several species of bunchgrass are the chief plant cover. The carrying capacity is comparatively low.

Riverwash (Rr).—Stony, gravelly, and sandy narrow alluvial strips along many streams and at the mouths of canyons are mapped as Riverwash where of sufficient size. Most areas, however, are too small or too narrow to be shown on the soil map. The largest area mapped, that along Big Elk Creek in Wheatland County, supports an open stand of cottonwood trees and is chiefly wasteland of no agricultural value. Most areas are barren of vegetation and are subject to additional accretion or removal of materials with successive overflows.

Rock outcrop (Rf).—Areas of Rock outcrop occur mainly within areas of pasture or farm land, mostly in the intermountain valleys.

The outcrop consists of barren rock slopes, escarpments of limestone and sandstone, and dikes, buttes, and relatively large areas of volcanic or other igneous rocks. This unit differs from larger more massive areas of similar rocks on rough mountainous land in that it occupies areas of low relief and is not part of any general mountain mass. No soils have formed on the outcrops, and no soil material has accumulated over the rocks except in the crevices and on projecting ledges. Rock outcrop supports only a few shrubs and grasses that grow in the soil material filling the crevices.

Many similar and larger areas of Rock outcrop occur throughout the mountains but are included with rough mountainous lands and not shown separately on the map.

Rocky Ford silt loam (Rg).—Low benches or terraces along the Missouri River and Crow Creek are occupied by this soil, and also a smooth gently sloping terrace near Canton in central Broadwater County. The soil has developed in silty alluvial deposits derived largely from Tertiary lake sediments. The silty alluvium is underlain by stratified gravel at varying depths, usually 4 or 5 feet in areas near the river. Small areas of other soils, chiefly Rocky Ford clay loam on the lower parts of some areas along the Missouri River, were included in mapping.

The 3- to 5-inch surface soil along the Missouri River and Crow Creek is friable soft granular or crumb-structured moderately calcareous brownish-gray loam or silt loam. The subsoil is massive or ill-defined fine blocky highly calcareous very light grayish-brown very fine sandy loam. At 12 to 24 inches it grades into massive calcareous very light grayish-brown loam or silt loam. The silt loam continues down to the little-altered parent material, chiefly calcareous floury silt lying at depths of 3 feet or more. In places the lime in the lower part of the subsoil is segregated as spots and scattered white specks. A small quantity of limestone and siliceous gravel is scattered over the surface and through the soil in most places. Most intermittent streams rising in the adjoining uplands deploy on the benches, and most of the small alluvial fans at the mouths of the coulees are somewhat gravelly and sandy. The shoulders of the benches have a sprinkling or a large quantity of gravel on and in the soil.

A representative profile near Canton has friable light grayish-brown silt loam of soft crumb structure to depths of 3 or 4 inches. This layer grades quickly to massive or soft blocky friable mildly calcareous silt loam that continues to 3 feet or more. In places at about this depth the silt loam contains strata of very fine sand. The soils on the alluvial fans at the mouths of the coulees in this general area are chiefly sandy loams and fine sandy loams with sandy subsoil. Some gravel and stone occur on the surface of the soils contiguous to areas of Larimer soils.

Use and management.—Rocky Ford silt loam in nonirrigated areas is used exclusively for grazing. East of the Missouri River it is irrigated and used for such crops as wheat, oats, barley, sugar beets, and alfalfa. Surface and internal drainage and water-holding ability are good, but the soil is low in nitrogen and phosphorus. Additions of organic matter and phosphorus are needed to maintain high average yields. Alfalfa yields 2 to 3 tons an acre under irrigation; sugar

beets, between 10 and 15 tons. Sugar beets have been grown for only a few years, but results on similar soils in other areas indicate it is entirely possible that higher yields can be obtained with good practices of soil management and irrigation. Some swales on the lower parts of the benches have become seeped and saline, a condition likely to become aggravated unless proper drainage is established. Grama grass predominates on the grazing areas, and if the land is not overgrazed 30 to 35 acres will carry a steer through a 10-month grazing period.

Rough mountainous land (thin shrub and grass) (R_H).—Rough mountainous areas supporting mainly shrubs and grasses occur on lower drier mountain slopes, high broken foothills, and secondary ridges between the main mountain ranges (pl. 1, C). On southern and eastern exposures the grass extends much higher on the mountainsides than on the northern and western slopes. Some grasslands, however, are high in the mountains where conditions favor growth of trees, though trees have not yet invaded. In some of the intermountain basins local rough and broken areas consisting of igneous or volcanic rock outcrops and buttes and old dissected volcanic cones are included with mountainous grasslands.

These soils are generally dark-colored, and, in this respect, like the grassland soils in the lower foothills where most of the land is included in farms and ranches. The soils, however, are usually thinner, on more broken topography, and include many rock outcrops, barren rock slopes, and ridge tops. Nearly all mountainous grassland accessible to livestock is used as summer range for sheep and cattle.

Rough mountainous land (timbered) (R_K).—This land type occurs mainly within the higher more humid parts of the mountains and on the north- and west-facing slopes of the mountains at lower elevations in the prevailing path of rainstorms. Timbered areas of mountainous land (suitable mainly for forestry) are shown separately on the soil map to distinguish them from grassland areas (suitable mainly for grazing). The line separating the forest lands and the grasslands coincides with the line separating two major soil provinces: (1) The generally light-colored soils of the forests and (2) the generally dark-colored or nearly black soils of the grasslands.

The soils in the timbered mountains are as varied and have as distinctive physical and morphological features as the soils of the grasslands. As the present survey is primarily for making an inventory of farm and range lands, the soils of the forested mountains were not mapped, except to show their general distribution in relation to other soils.

A moderately large part of the land included in this mapping unit consists of rock outcrops, rock slides, steep rock-walled canyons, and extremely stony or barren mountain peaks on which few large trees and little grass grow.

Use and management.—Rough mountainous land (timbered) is mainly within the national forests, and areas are used for forest production, recreation, and wildlife. They also serve as reservoir areas for the storage of a great volume of water, which is released through melting snow, seepage, and springs, and helps maintain the perennial flow of streams from which irrigation water is drawn for use on dry areas below the mountains and on the plains.

Park land areas (open timber and grass areas) within generally forested areas are extensively used as summer range for livestock, principally sheep.

Roy stony loam (RL).—Areas of this soil occupy outwash fans and aprons on the lower mountain slopes in the drier parts of the mountainous counties. The largest areas are in Fergus, Meagher, and Lewis and Clark Counties. The parent materials consist largely of a heterogeneous mixture of fine earth and subangular rounded stone and gravel washed out of the mountains. Some of the included soils occur on the slopes of outlying dikes and igneous rocks, and a few outcrops of igneous or intrusive volcanic rocks occur in some areas. Relief is chiefly undulating to rolling, but some areas are nearly level and others are broken and hilly.

The surface soil consists chiefly of friable grayish-brown stony loam of medium crumb structure and 6 to 8 inches thick. The brown or pale-brown stony clay loam subsoil of ill-defined prismatic structure grades into very cobbly and gravelly massive friable highly calcareous light grayish-brown clay loam at 12 to 16 inches. This is underlain by similarly cobbly and gravelly but sandy material at 30 to 40 inches. The content of stone on the surface and in the soil and the size of the stones commonly decrease with increased distance from the mountains, and on edges of some of the fans no large stones are present. In a few places the stone consists of large fragments of coarse-grained igneous rock weathering into fine gravel and coarse sand.

Use and management.—In most areas this soil is too stony for farming and is used for grazing. It is well drained, but runoff is high on the more sloping and rolling areas. Short grasses form a fair to good sod between the stones on nearly all areas, but the forage on 25 to 30 acres is needed to carry a steer through a 10-month grazing season if the soil is not to be overgrazed.

Sage-Arvada clay loams and clays (SA).—These soils occupy saline upland basins and basinlike valleys or alkali flats in several counties in the eastern part of the area. They are in a region of generally heavy soils that developed from clayey shale that contains a relatively high percentage of free salts. Lower parts of the enclosed basins are covered with water in spring and wet seasons. When the basins are dry, the soils are in considerable part covered with a salt crust, and many slick spots and "puff spots" appear on much of the total area. Small areas of other soils, chiefly McKenzie clay in the lowest parts of the basins, are included with these soils in the mapping. Sage and Arvada soils also occur on narrow low terraces in some of the stream valleys, but in these valleys they are included with Alluvial soils, undifferentiated (light-colored).

On the higher and better drained parts of the basins soils of the Sage-Arvada complex have profiles much the same as those of Arvada clay loam and clay. Sage soils in the lower and more saline parts of the basins have a gray, glazed, silty clay crust at the surface. Under the crust lies gray porous or vesicular silty clay, which at 2 or 3 inches grades into stratified to massive light olive-brown clay loam or clay, high in soluble salts.

Included in the Sage-Arvada complex is an association of soils in a basinlike valley near Nihill in the northeastern part of Wheatland

County. The gravelly alluvial deposit in the valley is underlain at relatively shallow depths by residual material derived from Bear Paw shale. Soils similar to the Crago occupy chiefly the low swells or remnants of an old terrace, and the Arvada soils, derived mainly from alluvium from the shale, occupy the flats below the gravel areas. Many bare spots of exposed clay subsoil and saline spots characterize these Arvada soils. Included narrow strips of soils along the shallow drainage courses in the valley are high in soluble salts.

Use and management.—Sage-Arvada clay loams and clays are suitable for grazing. They support only a light cover of greasewood, shadscale, and salt-sage in the saline areas (pl. 2, *B*) and a thin stand of grasses having low carrying capacity where the salts are leached below the surface.

Savage and Orman clays and clay loams, undifferentiated (S_B).—Terraces or low benches in preglacial stream valleys in northern Lewis and Clark County are occupied by these soils. The larger areas occur along Flat and Auchard Creeks. Outwash glacial gravel underlies the heavy alluvium at varying depths in the upper parts of the valleys, but in the low parts is not conspicuous.

The Savage soils on the terraces in the upper parts of the valleys of Auchard and Flat Creeks have 8 to 9 inches of friable dark-brown to very dark-brown clay loam or heavy clay loam surface soil. The subsoil is prismatic brown heavy silty clay loam, grading to calcareous massive light olive-brown silty clay loam at 13 to 15 inches. The massive silty clay continues down to little altered, stratified, and in places gravelly alluvium at 3 or 4 feet. The Orman soils, chiefly in the lower parts of the valleys, are heavy clays with a thinner and less friable surface soil than the associated Savage soils.

Use and management.—These soils are in stock-raising sections of Lewis and Clark County. They are relatively fertile, but because of heavy texture, slow permeability, and the slow rate at which they give up moisture to plants, they produce low yields except in years of high, well-distributed rainfall or under irrigation. As a result, they are used chiefly for grazing. Water diverted from the Dearborn River irrigates most of the upper parts of the valleys of Flat and Auchard Creeks. Much of the land has been overirrigated and has become seeped; it is therefore used largely for pasture and hay. The better drained irrigated land produces good yields of alfalfa and feed crops. The surface acre-foot of soil contains 6,500 to 7,000 pounds of nitrogen and 2,000 to 2,500 pounds of phosphorus. The soils support a fair growth of western wheatgrass and have a fair carrying capacity.

Scobey loam and clay loam, undifferentiated (S_C).—These soils occur mainly on undulating to rolling slightly hummocky uplands in northern Cascade County. The clay loam, however, is in some sections confined to nearly level areas and depressed flats or shallow basins in these uplands. The soils have developed in glacial till, which south of Benton Lake is underlain at a comparatively shallow depth by Colorado shale. Drainage channels have developed in most uplands, but some drainage is into kettle holes and depressions.

The 1- to 2-inch surface layer of Scobey loam is a loose grayish-brown silt loam mulch. Below this is 5 to 8 inches of friable crumb-structured dark grayish-brown loam. The subsoil is firm prismatic

or blocky calcareous grayish-brown heavy silt loam or clay loam, grading to calcareous stony and gravelly clayey till or drift at 16 to 30 inches. Lime carbonate is uniformly distributed through the upper part of the subsoil but in the lower part occurs largely in splotches and streaks. Boulders and smaller stone fragments are scattered over the surface in places, and through the soil in nearly all areas. The texture of the surface soil often varies within short distances, but fairly large areas of relatively uniform loam and clay loam are common and would be mapped as separate types in a more detailed survey.

The profile of the Scobey clay loam differs from the loam chiefly in having a heavier texture throughout, more massive structure, firmer consistence, and thinner surface and upper subsoil horizons, or layers.

Use and management.—Scobey loam and clay loam, undifferentiated, are among the more important dry-farming soils in Cascade County. Nearly all the tillable acreage is cultivated, chiefly to spring and winter wheat grown on land summer-fallowed in strips. Some of the largest grain farms in central Montana are located on these soils. Surface and internal drainage are adequate for the precipitation received. The soils have high moisture-holding capacity and give up moisture readily to plants. The surface acre-foot of soil contains 3,000 to 4,500 pounds of nitrogen and 2,400 to 3,000 pounds of phosphorus. Spring wheat on summer-fallowed land yields 12 to 15 bushels or more an acre.

About 20 to 25 percent of these soils—mainly the areas adjacent to the Missouri River—are strongly rolling to hilly and suitable mainly for grazing. These hilly areas are shown on the soil map by hachure lines to indicate they are suitable mainly for grazing.

Scobey stony loam (Sd).—This soil occurs south of the Sun River and west of its South Fork in northern Lewis and Clark County. It has developed from glacial drift of the recessional moraines, which are characterized by gravelly basinlike valleys and by many dry glacial lake basins. The parent material is the same as that of Williams stony loam, but this Scobey soil lies at lower elevations and in areas of lower rainfall. The boulders on the Scobey soil, like those on the Williams soil, are mainly of limestone, argillite, and quartzite. The drift is underlain by greenish-gray Cretaceous shale, which outcrops locally or lies at a comparatively shallow depth. There are small included areas of Scobey loam or gravelly loam, of Midway and Regent clay loams around the rock outcrops, of Beaverton gravelly loam on gravelly alluvium, and of McKenzie clay in the dry lake bottoms.

Scobey stony loam in the moraines is not so well developed as in northeastern Montana. In some respects it resembles Zahl stony loam mapped in that part of the State, but the ridges show no appreciable erosion and the soil has all the horizons found in normal soils.

Below a loose grayish-brown loamy mulch, the surface soil of Scobey stony loam is friable dark grayish-brown stony loam of medium crumb structure. It ranges from 5 to 7 inches thick on the ridges to 8 inches or more on the slopes. The subsoil is prismatic calcareous grayish-brown stony loam or clay loam, grading to very stony and gravelly till or drift at 30 or more inches. The included soils in the basinlike valleys are chiefly gravelly loams with very gravelly subsoil.

Use and management.—Scobey stony loam—too stony and hummocky for farming—is used for grazing (pl. 3, A). The small in-

cluded areas of Scobey loam and Regent clay loam west and northwest of Augusta are cultivated, chiefly to feed and forage crops. Surface and internal drainage are good; the water-holding capacity is high. The surface acre-foot of soil contains 4,000 to 5,500 pounds of nitrogen and 2,100 to 2,800 pounds of phosphorus. Grama grass and several species of wheatgrass form a good sod on most areas; 25 acres will carry a steer through an 8- to 9-month grazing season.

Sipple loam (Se).—On higher parts of the tablelands (elevation, more than 4,000 feet) this loam borders the foothills of the Big Snowy Mountains in the southwestern part of Fergus County. The protective covering of limestone gravel is overlain by a mantle of loamy to silty aeolian, or loesslike, material. The tablelands, separated by intervening stream valleys, have smooth surfaces and gradients of 40 to 80 feet to the mile.

The surface 6 to 10 inches of the soil on most of the tablelands is friable crumb-structured very dark grayish-brown loam. The upper part of the subsoil is friable prismatic grayish-brown clay loam containing some limestone gravel. It is underlain at 12 to 18 inches by friable massive light grayish-brown limy clay loam containing a little gravel. The limestone-gravel horizon lies 24 to 36 inches below the surface. The voids, or spaces, between the pebbles are filled with highly calcareous light-gray to yellowish-gray clayey material to a depth of several feet. In places the surface 2 to 3 feet of soil is comparatively free from gravel. A small quantity of angular limestone rock occurs on the surface near the foothills. The shallow drainage courses traversing areas of this soil are usually very gravelly.

Use and management.—Sipple loam, one of the most productive dry-land farming soils in the area, lies in a comparatively high rainfall belt close to the mountains and is deep enough over gravel to retain most of the seasonal moisture. Nearly all the land is cultivated, chiefly to winter and spring wheat. The farms growing grain exclusively have one or more sections of land, and from one-half to two-thirds of the cultivated acreage is planted to crops annually. Stock raising and grain growing are combined on the farms located partly on tablelands and partly in stream valleys or foothills. Most of the winter feed and forage produced on these combination farms is grown on irrigated land in the stream valleys. Crops are grown on land summer-fallowed every second or third year. The fallowing controls weeds and insures soil moisture supplies favorable for fall and spring seeding of wheat and other small grains. In seasons of favorable fall moisture, a fair acreage of winter wheat is seeded on disked stubbleland. The surface acre-foot of soil contains 6,000 to 7,000 pounds of nitrogen and 1,000 to 2,000 pounds of phosphorus. On the better managed farms spring wheat grown on summer-fallowed land yields 22 bushels or more an acre.

Skaggs and Duncom loams and stony loams, undifferentiated (Sf).—In higher foothills and on mountain slopes in Cascade, Judith Basin, Fergus, and Meagher Counties these soils have developed, chiefly or entirely from residual material derived from limestone. The two series are closely associated, but most of individual soil types are sufficiently distinct and in areas large enough to be shown separately on a detailed soil map. Their profiles differ chiefly in depth to slightly altered limestone. The smoother and more gently rolling areas occur

largely on the lower slopes of mountains and on slopes of basinlike valleys between the foothill ridges. Limestone bedrock crops out in many places, and where the outcrops are most numerous they are shown by symbol. Maiden soils, developed on limestone in the Chestnut soil zone in Fergus County, are grouped with the Skaggs soils because of their small extent.

Dominant in the foothills and on most gently rolling areas is Skaggs silt loam. Its surface soil is 6 to 10 inches of friable granular nearly black silt loam. The subsoil is friable calcareous nuciform or fine blocky dark grayish-brown clay loam or silty clay, underlain at 10 to 20 inches by friable fine blocky highly calcareous yellowish-gray silt loam containing soft to hard limestone fragments. Slightly altered limestone is usually about 18 inches from the surface, and except in swales and coves where some colluvial material has accumulated on the surface from the surrounding higher soils, seldom lies deeper than 3 feet. Large angular slabs of limestone occur on some areas.

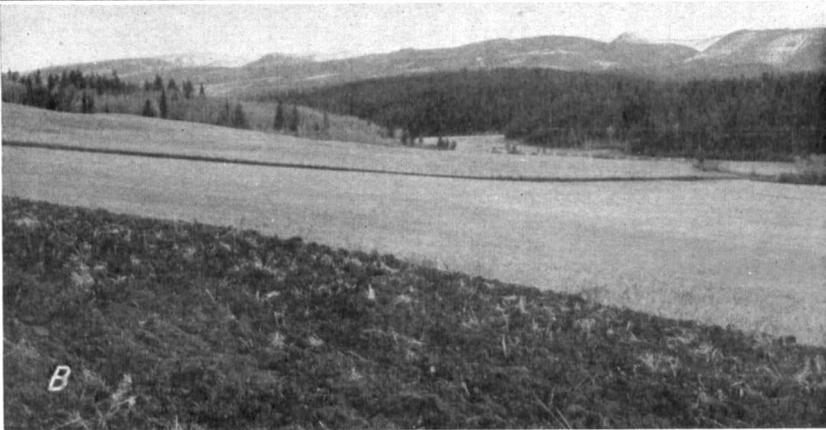
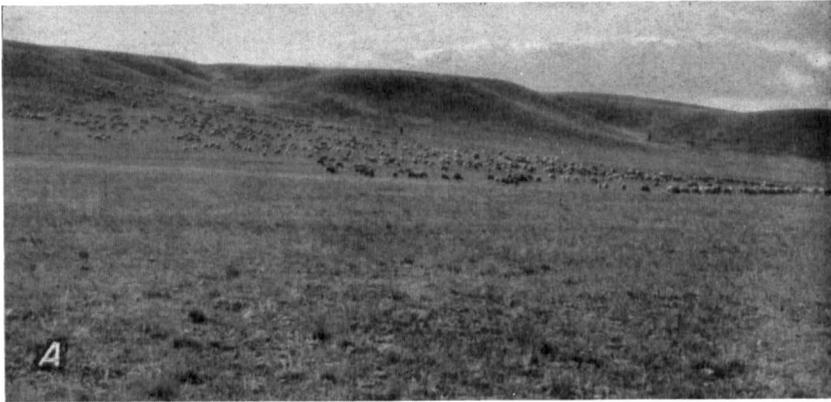
Duncom stony loam and Duncom gravelly loam are dominant on foothill ridges, on some smooth gently rolling areas along the Smith River, and in the southern part of the large area north of Monarch in Cascade County. The 6- to 8-inch surface soil in these sections is calcareous imperfectly granular nearly black silt loam containing many limestone fragments. A stony shallow transitional layer without definite structure and composed of friable calcareous yellowish-brown silt loam to silty clay material underlies the surface soil locally. In most places, however, the surface soil rests directly on limestone.

Use and management.—Strongly rolling to hilly relief make most areas of Skaggs and Duncom loams and stony loams, undifferentiated, suitable only for grazing. The larger and fairly continuous areas of soils having strongly rolling to hilly relief are indicated on the soil map by hachure lines. On a detailed soil survey these would be mapped as hilly phases of Duncom and Skaggs soils.

The smoother gently rolling areas southeast of Riceville in eastern Cascade County, and locally in the foothills and on the divides, are cultivated. These areas have elevations of 4,000 to 5,500 feet or more. Winter wheat, other small grains, and forage crops such as alfalfa are produced at lower elevations, but at the higher the small grains are harvested for winter feed before they mature. Timothy and clover are the chief forage crops at higher elevations. Exclusive stock raising is carried on in the higher and more broken sections.

Skaggs soils have good surface and internal drainage and are very fertile. They contain 6,000 to 8,000 pounds of nitrogen and 3,000 to 3,500 pounds of phosphorus in the surface acre-foot. Most of the foothill grazing land has a dense cover of mountain timothy, redtop, and the fescues and has a high carrying capacity for livestock during the 6- to 8-month snow-free period. In places the shallow Duncom soils support a fair stand of scrubby cinquefoil, the flowers and leaves of which are palatable to sheep.

Spring Creek stony loam (Sg).—Although this soil occurs in most of the mountainous counties in the western part of the area, the largest tracts are in Broadwater, Meagher, and Lewis and Clark Counties. The parent materials weathered from igneous rocks such as granite and andesite. Most of the land is rough, broken, and dissected by deep coulees. Small areas of other soils, chiefly developed on col-



A, Sheep grazing on Scobey stony loam near Augusta, Lewis and Clark County.
B, Cultivated field of Teton loam on south-facing slope of valley in foothills south of Lewistown, Fergus County.
C, Williams stony loam on lower morainal foothills west of Augusta, Lewis and Clark County; Barnes stony loam and loam, undifferentiated, on higher foothills; and Scobey soils on undulating to rolling plains.

luvium or local alluvium at the foot of slopes and too small to map separately, are included. Many outcrops and small areas of bare rock occur in nearly all areas.

The more typical areas in western Broadwater County consist of 3 to 8 inches of grayish-brown stony loam of ill-defined granular or soft crumb structure. The surface soil normally rests directly upon slightly altered igneous and metamorphic bedrock, but near the Little Belt and Castle Mountains in Meagher County it has developed on basalt and rhyolite. In this part of Meagher County the surface soil is brown stony loam, usually resting on bedrock at 3 to 8 inches, but underlain in places by brown or reddish-brown stony clay loam that rests on the bedrock at additional depths of 6 to 10 inches. The soil, as a rule, is not calcareous, but below depths of 10 to 15 inches the seams and cracks in the rocks are coated with lime carbonate.

Use and management.—Spring Creek stony loam is too shallow and stony for farming and is used only for grazing. The natural vegetation on most areas consists of big sage, rabbitbrush, and the bunchgrasses. A few junipers and other trees and shrubs grow along the coulees. The carrying capacity for livestock is low.

Teton-Cheadle loams and stony loams (T_A).—This complex occurs chiefly in foothills and on plateaus north of the Little Belt and the Big Snowy Mountains in Cascade, Judith Basin, and Fergus Counties. The soils have developed largely on sandstone and sandy shale of the Kootenai formation. They are in complex association on undulating and gently rolling uplands, but on the valley slopes some Teton soils are associated with and included in mapping with Adel soils. Small areas of Darret soils formed on the red beds of the Kootenai formation and areas of other soils too small to be shown on the map are also included. Most soils on the plateaus have smooth gently rolling topography; in the foothills, the topography is strongly rolling.

The Teton loam in the complex does not differ greatly from the Teton loam mapping unit. In many places fragments of parent sandstone are on the surface and at all depths in the soil. Usually, however, the fragments are more numerous in the subsoil.

Indurated parent sandstone underlies the Teton soils of this complex at 18 to 30 inches or more. The areas having less than about 12 to 15 inches of soil material are representative of Cheadle soils. Exposures of alternate strata of gray and red sandstone on the plateaus in Cascade County give rise to small bands or strips of soils that have alternately very dark grayish-brown and very dark reddish-brown surface soils.

The Cheadle soils in the complex are dominantly stony loam but include some soils of loamy fine sand texture. The very dark grayish-brown or nearly black 6- to 12-inch surface soil usually rests directly on gray or yellow fragmented and partly weathered moderately indurated sandstone. The sandstone is noncalcareous, but the lower sides of the rock fragments are usually coated with free lime carbonate.

Although a high percentage of soils in this mapping unit are on slopes of relatively low gradient, they are in large part too stony or too shallow over bedrock for crops. Some fairly large areas, as those along the Smith River south of Ulm in Cascade County, have

strongly rolling relief, are suitable only for grazing, and are indicated on the soil map by hachure lines so they may be distinguished from areas that include both farming and grazing soils.

Use and management.—Teton-Cheadle loams and stony loams lie at elevations too high for general farming. Some winter and spring wheat and other small grains are grown on the plateaus in Cascade County. In the foothills and about the borders of the plateaus, stock raising is the chief enterprise, and the cultivated land is used for oats, barley, and other feed crops or for forage crops such as alfalfa, tame grass, and clover. The small irrigated areas in the foothills are used chiefly for feed and forage crops. Most farms and ranches cover several sections of land. The soils have relatively large supplies of essential plant nutrients, good productivity, and a high livestock carrying capacity. The surface acre-foot contains 5,000 to 8,000 pounds of nitrogen and 2,500 to 3,000 pounds of phosphorus.

Teton loam (T_B).—This soil occurs chiefly on the plateau north of the Little Belt Mountain in Cascade County, on the Belt divide between the Little Belt and Highwood Mountains in Judith Basin County, and in the lower foothills of the Big Snowy Mountains in Fergus County. It has developed chiefly over Kootenai sandstone in these counties. Most of the land is smooth and gently sloping. Teton loam is separated from Teton-Cheadle loams and stony loams because the greater part of it is suitable for cultivation.

The Teton surface soil, below a shallow mat of plant residue, is very dark grayish-brown or nearly black ill-defined granular loam, 7 to 10 inches thick. The subsoil is friable, heavy, medium blocky dark to very dark grayish-brown loam that grades to calcareous massive coherent fine sandy loam at 15 to 30 inches. Below 3 feet or more is the parent material, a brown to gray moderately indurated sandstone or sandy shale. No free carbonate of lime occurs in the soil as a rule, but the lower sides of the rock fragments are usually coated with lime. In places the surface layer has been thinned by erosion and the soil is shallow.

Teton loam, as mapped, includes small areas of soils that have developed from red shale and sandstone of the Kootenai formation and from local wash from these and other rocks. The soil developed from red shale consists of friable very dark reddish-brown heavy clay loam underlain by dense lime-splotched red clay at depths of 8 to 10 inches. Soils from this shale occur in the northwestern part of Judith Basin County near Spion Kop and locally in other places. The soil formed over red sandstone is chiefly loam, similar to Teton loam except for color.

Use and management.—Much of Teton loam is cultivated, largely to winter and spring wheat (pl. 3, B). Farmers raising grain exclusively have a section or more of land and annually seed more than 300 acres. The soil has fair water-holding capacity, and in most seasons the rainfall is sufficient for continuous cropping. Much of this land, however, is summer-fallowed every second or third year to conserve moisture, to control weeds, and to insure a good stand of winter wheat in dry fall seasons. The second crop after fallow is usually winter wheat, seeded on disked stubbleland. The surface acre-foot of soil contains 5,000 to 7,000 pounds of nitrogen and 2,500 to 3,000 pounds of phosphorus. No free carbonate of lime occurs in the sur-

face soil, but the soil is not deficient in lime. The yield of spring wheat on summer-fallowed land averages 20 bushels or more an acre on the deeper and more friable areas.

Travessilla-Cushman loams and stony loams (Tc).—This complex occurs on gently rolling to broken areas in the northwestern and southwestern parts, respectively, of Wheatland and Golden Valley Counties, and in Meagher County. The two series grade into one another. Travessilla soils, developed on moderately hard Cretaceous sandstone, occur chiefly on the tops of ridges and on local sandstone outcrops on slopes; Cushman soils occur mainly on slopes of ridges and in narrow valleys below the Travessilla soils. The Cushman soils have developed on shale and sandy shale that are in places interbedded with the harder sandstone. Slabs and blocks of loose sandstone and outcrops of sandy shale and sandstone occur on most areas. Included with these soils in mapping are small areas of Patent clay loam on colluvial slopes, narrow strips of alluvial soils in valleys, and small areas of McKenzie clay in depressions and small enclosed basins. Hachure lines on the soil map differentiate sharply rolling areas suitable only for grazing from areas of smoother relief partly suitable for cultivation.

In most areas the Cushman soils of this complex differ from Cushman loam chiefly in having slabs and fragments of sandy shale and sandstone on and in the soil and a more variable depth to partly decomposed bedrock. In places the Cushman soils are comparatively free from rock fragments. A small quantity of limestone gravel occurs on the surface of some areas bordering the high gravel-capped tablelands.

Travessilla soils are chiefly stony and they are the shallow and very shallow soils of the complex. The surface soil of Travessilla stony loam is 2 to 6 inches of calcareous friable grayish-brown stony loam of soft crumb structure. It is underlain by friable calcareous light grayish-brown sandy loam or loam, which grades to the partly disintegrated parent sandstone at 8 to 12 inches.

Use and management.—Travessilla-Cushman loams and stony loams are used chiefly for grazing. The smoother less stony areas were cultivated in the past but are now almost entirely abandoned. A small acreage is irrigated in Meagher County, but for the most part slopes are too steep for satisfactory irrigation, and in places the bedrock prevents downward movement of excess irrigation water. Many slopes and bottoms in the draws have become seeped and saline. Most of the irrigated land is used for pasture and wild hay. Nonirrigated areas have a fair cover of the short grasses; 30 acres is sufficient to carry a steer through a 10-month grazing season.

Travessilla stony loam (Td).—Steeply sloping and broken upland areas in Musselshell, Golden Valley, and Wheatland Counties, as well as isolated steep or broken areas in other counties, are occupied by this soil. It has developed on moderately to strongly indurated sandstone, largely on gray and brown sandstone of Cretaceous age. Included in mapping, however, are closely associated shallow stony soils developed on the red Kootenai sandstone (also of Cretaceous age). Also included are areas of Terry sandy loam, small deeper patches of soils in the uplands, and Glendive sandy loam on alluvial fan slopes at the base of the uplands along broader valleys and in narrow small valleys.

The surface soil on most areas is 2 to 6 inches of friable brown to grayish-brown stony loam of soft crumb structure. The subsoil is massive calcareous friable light grayish-brown stony sandy loam or stony loam, grading to partly disintegrated parent sandstone at 8 to 12 inches. Little-altered sandstone is at a depth of about 2 feet. Outcrops and ledges of sandstone occur in most areas. The soils developed on red Kootenai sandstone are reddish at all depths.

Use and management.—Too shallow, stony, steep, and broken for farming, Travessilla stony loam is used exclusively for grazing. Short grasses are the predominant natural vegetation; 30 acres or more is required to carry a steer through a 10-month grazing season.

Two Dot loam and gravelly loam, undifferentiated (T_E).—These soils have developed in moderately thick loamy to silty loesslike material underlain by limestone gravel. They occupy several undulating areas on the gravel-capped tablelands in Musselshell County. They are associated with Musselshell and Crago soils, from which they differ in having greater thickness over the gravel. In a more detailed survey the loam and gravelly loam types would be mapped separately and additional areas now included with the Musselshell and Crago soils would be shown.

The 5- to 8-inch surface soil of Two Dot loam is friable crumb-structured grayish-brown loam. The subsoil is prismatic calcareous light grayish-brown clay loam, grading into fine blocky calcareous very light grayish-brown or nearly white clay loam at 10 to 20 inches. This light-colored clay continues down 30 or more inches, or to the water-worn limestone gravel. The spaces between the pebbles are filled with almost white limy clayey material. In most places a scattering of limestone gravel occurs above the gravel bed, and in places enough gravel is on the surface to give the soil a gravelly texture.

Use and management.—Most of this land is cultivated to spring wheat. Surface and internal drainage and water-holding capacity are good. The surface acre-foot of soil contains an average of 4,000 pounds of nitrogen and 1,800 pounds of phosphorus. The areas remaining in native sod have a good cover of short grasses; 25 acres will carry a steer through a 10-month grazing season.

Ulm fine sandy loam (U_A).—Undulating benchlike areas along Flat Willow Creek and other rolling areas in central and southern Petroleum County are occupied by this soil that has developed over stratified sandstone and shale of Cretaceous age. The borders of areas along Flat Willow Creek are steep sandstone escarpments, indented with deep coulees. Included with this soil in mapping are small areas of Glendive sandy loam on colluvial-alluvial slopes and small sandy alluvial fans in narrow valleys, and of Flasher stony loam around local outcrops of sandstone.

The surface 3 to 5 inches of the Ulm soil is friable grayish-brown fine sandy loam of flaky or mulchlike structure. This is underlain by compact friable blocky brown sandy clay loam, which grades to friable highly calcareous light-brown sandy clay loam at 8 to 15 inches. The parent material, consisting of disintegrated light-brown sandstone or sandy shale, lies at depths of 18 to 30 inches.

Use and management.—Most of Ulm fine sandy loam is within the boundary of the Federal Land Purchase area of central Montana. Many farms on this soil were purchased by the Government, and the

cultivated parts seeded to crested wheatgrass. Most areas are now used for grazing. Parts of the land south of Flat Willow Creek are cultivated, largely for production of spring wheat and feed crops. The soil has good surface and internal drainage and is fairly productive in seasons of favorable rainfall. The surface acre-foot contains 2,400 to 3,000 pounds of nitrogen and 1,200 to 1,500 pounds of phosphorus. Spring wheat, grown largely on continuously cropped land, yields 8 to 10 bushels an acre. During the droughts of 1930 to 1937 soil blowing and drifting were active; now the soil on many farms is strip-cropped. A common practice is to alternate strips of small grain and corn on land summer-fallowed the previous year. The short grasses predominate; 25 to 30 acres will carry a steer through a 10-month grazing season.

Utica gravelly loam (U_B).—The more gravelly and stony parts of high limestone-gravel capped tablelands in Judith Basin and Fergus Counties and local areas near the mountains in Wheatland County are occupied by this soil. It is associated with Judith and Doughty soils on the tablelands but has a thinner and more gravelly solum.

The soil resembles Utica gravelly loam in the Judith-Utica loams and gravelly loams, undifferentiated, mapping unit. In Judith Basin and near the mountains in Wheatland and Meagher Counties some subangular limestone and other rock lies on the surface, and locally soils of stony loam texture are included. The surface soil on several high benches on the mountain slopes in Judith Basin County consists largely of dark-colored fibrous organic matter.

Use and management.—On the borders of the tablelands and on the more stony areas near the mountains, Utica gravelly loam is used chiefly for grazing. Formerly, the larger areas on tablelands were in considerable part cultivated to spring and winter wheat, but they are now largely abandoned. Yields of spring wheat are low. Wind has removed the surface soil from some abandoned land on several high benches west of Antelope Creek in Judith Basin County and locally from areas near the mountains. Where the surface soil is gone the fields are now barren limestone-gravel outcrops. Most areas had a good grass cover before they were plowed.

Utica-Judith gravelly loams (U_C).—This complex occupies high tablelands in Judith Basin County and occurs locally on tablelands in the west-central part of Fergus County. The tablelands in Judith Basin County lie above 4,000 feet and are capped with limestone gravel and cobblestones and some gravel of other kinds over which is spread a thin mantle of silty aeolian, or loesslike, material. These tablelands have gradients of 60 to 80 feet to the mile and are dissected by deep coulees.

This unit contains a larger percentage of the shallow and somewhat lighter colored Utica soils than Judith-Utica loams and gravelly loams, undifferentiated. The individual soils of the two mapping units do not differ appreciably, but this complex, as a whole, has thinner coherent layers over the underlying loose gravel than the Judith-Utica complex, more gravel in the surface layers, and in places, particularly near the mountains, some large stones.

From place to place the upper part of the gravel bed is moderately to strongly cemented with lime carbonate, as it is in Ashuelot soils.

Areas with cemented subsoil are not continuous over a very large acreage, and it was not feasible to separate them at the scale of mapping used. Other variations or inclusions are found southwest of Geyser, where the gravel deposit is thin and the lower part of the subsoil consists of red and brown clay loam or silty clay loam derived from underlying Kootenai sandstone and shale. Also, near Hobson, there are areas with a loam or fine sandy loam surface soil relatively free of gravel and a subsoil consisting principally of stratified limestone gravel and sand. In several areas north of Wolf Creek (Fergus County) the soils are dominantly a complex of Utica and Doughty soils. Doughty soils differ from Judith soils chiefly in having a lower content of organic matter and nitrogen and a lighter colored surface soil.

Use and management.—A large quantity of gravel in the surface soil, an average shallow depth to gravel beds, and resultant relatively low water-holding capacity make most Utica-Judith gravelly loams low in productivity and best suited to grazing. The deeper and more productive Judith soils occurring within the general range-land areas are used to grow feed crops for wintering the livestock grazed on the shallow soils. Hachure lines on the soil map show a few relatively small areas on steep slopes that are suitable only for grazing.

Most areas of this complex were once cultivated. They produced fair yields of winter wheat until the droughts of 1918 to 1921, when most of them were abandoned. The abandoned cropland became tax delinquent and was taken over by the county and sold. A fair percentage has now been seeded to crested wheatgrass for the production of seed and for grazing. In places the deeper soils have again been brought into cultivation. The deeper and less gravelly soils occurring south and southwest of Geyser and locally in other sections are in large part cultivated, chiefly to spring and winter wheat.

On the average, there is less nitrogen and phosphorus in the surface acre-foot of this complex than in Judith-Utica loams and gravelly loams, undifferentiated. It is also less productive when considered as a whole. Wind erosion has been active on nearly all areas, and in some places the limestone-gravel horizon has been exposed. Spring wheat on this complex averages less than 10 bushels an acre on the shallow gravelly soils and a little more than 15 bushels on those deeper and less gravelly. The State Water Conservation Board completed a storage dam and canals in 1940 for irrigating several thousand acres on the bench south of Hobson.

Vebar sandy loam (VA).—On undulating to gently rolling uplands—principally in Judith Basin, Fergus, and Wheatland Counties—this soil has developed chiefly over the soft or only moderately hard sandstone of Cretaceous age that occurs in central Montana. In places the soil appears to be from sand almost entirely reworked by wind. It is associated with soils of the Flasher and Travessilla series, which occupy the steeper ridges and coulee slopes.

On most areas in Judith Basin and Fergus Counties the surface soil is 8 to 10 inches of dark grayish-brown sandy loam. It is underlain by firm light-brown sandy loam of macro-prismatic structure. The lime carbonate horizon, below 10 to 20 inches, is compact gray fine sandy loam. The lime carbonate layer grades to semicoherent gray to brown calcareous fine sand or to partly weathered sandstone

at 30 or more inches. In Wheatland County some of the included soils have a grayish-brown loamy sand surface soil and a gray incoherent sand or loamy sand subsoil below depths of 24 to 30 inches.

Use and management.—In Judith Basin and Fergus Counties most areas of this soil are cultivated, largely to spring and winter wheat. Land is not generally summer-fallowed because the soil drifts and because the yield of small grain on land regularly summer-fallowed is little more than the yield on that part summer-fallowed only occasionally to control weeds. Part of the included coarser sandy loams in Wheatland County were once cultivated, but most of them have been abandoned because of severe wind drifting. In places wind has removed all of the soil and exposed the bedrock.

The surface acre-foot of soil in Fergus and Judith Basin Counties contains 2,000 to 3,000 pounds of nitrogen and 1,500 to 2,000 pounds of phosphorus. Spring wheat on the sandy loam yields 8 to 12 bushels an acre. Tall grasses predominate on most areas remaining in native sod. The forage on 20 to 25 acres will carry a steer through the usual grazing season of 10 months.

Wade clay loam (WA).—A few square miles in a terraced basin south of Buffalo in southwestern Fergus County are occupied by this soil. Other areas of it occur through central Montana but are too small to be shown separately on the soil map and are therefore included with surrounding soils. Wade soil is characterized by a claypan subsoil and micro-depressions, commonly known as "slick spots," "gumbo spots" and "buffalo wallows." A small part of the soil is saline, and in places it is characterized by the "puff spots" typical of certain saline or salty soils.

The 5- to 7-inch surface soil in the grass-covered areas covering 75 to 80 percent of the total acreage is friable very dark grayish-brown clay loam, which is underlain by dense columnar dark grayish-brown clay, 3 to 5 inches thick. Below the claypan, the subsoil is gray highly calcareous silty clay loam containing spots of accumulated salts.

Bare spots occur on 20 to 25 percent of the soil area. They show where the friable surface soil has been removed by wind or water erosion and the claypan is exposed. In most areas the claypan is at all stages of development, and in places it is being degraded, or weathered, to form a light-gray silty layer at the place where the friable surface soil and the claypan subsoil meet.

Use and management. Wade clay loam is classed as a farming soil but has low agricultural value. The surface is slowly permeable, and the claypan is very slowly pervious to water. Tall grasses predominate on the vegetated parts, and these have a fair livestock carrying capacity.

Williams stony loam (WB).—This soil is mapped on stony recessional glacial moraines west of the South Fork of the Sun River and on the moraines near the mouth of the North Fork Dearborn River in Lewis and Clark County (pl. 3, C). The morainic areas are characterized by knolls, low hills, and many glacial lakes and gravelly basins. The boulders are largely of limestone, argillite, and quartzite. The areas on the higher and more rugged drift-covered ridges near the mountains grade to Barnes stony loam and loam, undifferentiated.

Sandstone and shale crop out in more broken sections near the mountains where the mantle of glacial till is thin.

The surface 1 or 2 inches is friable granular grayish-brown silty mulch of flaky or platy structure. Below this is the subsurface soil, a friable blocky or prismatic very dark grayish-brown stony loam, 5 to 7 inches thick. The subsoil, a firm prismatic brown stony clay loam, grades to highly calcareous light grayish-brown stony clay loam at 10 to 15 inches. This calcareous layer continues down to the little-altered calcareous light olive-brown stony clay loam parent till or drift, which is at a depth of 30 inches or more. Most of the soil in the basins between the ridges is dark-colored gravelly loam with very gravelly subsoil.

Use and management.—Williams stony loam is used chiefly for grazing because it is stony and rough. A few stock ranches are located in the basins. The land on the less stony slopes and in the basins is cultivated, chiefly to feed and forage crops. Yields are good. Some included poorly drained soils between the ridges produce good yields of wild hay, and the basins in the vicinity of the Dearborn River are irrigated. The surface acre-foot of soil contains 5,000 to 6,000 pounds of nitrogen and 2,000 to 2,500 pounds of phosphorus. Nearly all of this soil in its native state supports a dense cover of tall grasses and scattering shrubs. It has a high carrying capacity for livestock during the 7- to 8-month snow-free period. Patches of timber occur at higher elevations.

Winifred clay loam (Wo).—Isolated areas occur in most counties, but most of this soil is on undulating to gently rolling shale uplands in Cascade, Judith Basin, and Fergus Counties. The soil has developed over dark-colored moderately hard to soft clayey shale of Cretaceous age in nearly all the counties. In most places it has a shallow surface deposit of locally washed material. It is normally associated with Pierre clay and its overwash material is usually from that soil. In many places, however, its material is from other soils of lighter texture. In the brown soils area this soil occurs in basinlike valleys and lower gentle slopes receiving supplemental runoff from the higher levels.

In most places the surface soil is crumb-structured grayish-brown to dark grayish-brown clay loam, 3 to 8 inches thick. The subsoil is prismatic or fine blocky dark olive-brown clay, grading to massive or ill-defined blocky dark olive-brown calcareous clay at 8 to 18 inches. This olive-brown layer has an accumulation of lime carbonate. The slightly altered shale or clay bed is 18 to 40 inches from the surface. The large area north of the Missouri River in Cascade County consists of massive calcareous dark grayish-brown clay underlain by calcareous olive-brown clay that continues to a depth of 3 or 4 feet. Many areas below the high tablelands and benches in Fergus County, as well as some areas in other counties, have a sprinkling or thin covering of limestone and quartzitic gravel on the surface.

Use and management.—A fairly high percentage of Winifred clay loam is cultivated in the dark-brown soils area, but in the brown soils area much of it once cultivated has been abandoned because of low crop yields and frequent crop failure. The soil is plastic when moist and hard when dry. Tillage is difficult except within a narrow range of moisture conditions. Most areas have enough slope to insure good

surface drainage, but the soil is slowly permeable and tends to become waterlogged under irrigation. Some of the irrigated land in Lewis and Clark and in other counties has become seeped and is impregnated with soluble salts or alkali. The cultivated land in nonirrigated areas is used chiefly for winter and spring wheat grown on summer-fallowed land. Irrigated land is planted largely to feed and forage crops, principally alfalfa.

The surface acre-foot of soil contains 3,000 to 4,000 pounds of nitrogen and 1,500 to 2,000 pounds of phosphorus. The yield of spring wheat on summer-fallowed land is between 10 and 12 bushels an acre in Fergus County. Some higher areas near the mountains produce 15 bushels or more. When well-pulverized, this soil is drifted by wind in spring as readily as the light-textured soils. Western wheatgrass predominates in native sod, 25 acres or less of which will carry a steer through the usual 10-month grazing season.

Winifred-Pierre clay loams and clays (W_D).—This complex occupies undulating to rolling areas of clay shale upland, chiefly in the northern part of Fergus County, and shale valleys in the southern part of Meagher County. In Fergus County the shale belongs to the Bear Paw and associated formations of heavy shale, and in Meagher County, to shales of the Colorado group. In Meagher County the shales lie mainly below higher areas of sandstone uplands and hog-back ridges. The two series of the complex differ mainly in that the Winifred soils are 30 or more inches deep over shale, whereas the Pierre soils average 24 inches deep and range from 15 to 30 inches deep.

Winifred soils usually occupy concave slopes of low gradient and have developed, at least partly, from material that washed from higher parts of the slopes. In places Winifred soils occupy nearly level ridge crests and divides, and their greater depth seems to result from a thin accumulation of loess or alluvium deposited over the general area before the streams cut down to their present level.

The Winifred surface soil, lying below 1 to 2 inches of brownish-gray flaky or platy clayey surface mulch, is 5 to 8 inches of crumb-structured dark grayish-brown clay loam, silty clay, or clay. Below this is the subsoil, a medium blocky grayish-brown silty clay or clay that grades into massive calcareous olive-brown clay at 15 inches. This clay, in turn, grades to little-altered shale at about 3 feet.

In representative areas of Pierre soils there is an inch of flaky or granular clayey surface mulch underlain by the 4 to 7 inches of coarse blocky dark grayish-brown silty clay or clay surface soil. The surface soil grades quickly to the subsoil, a dense massive or irregularly blocky mildly calcareous olive-brown clay. The subsoil continues to partly weathered stratified clay or parent shale, which is at depths of 18 to 30 inches. In some places the partly weathered shale lies only a few inches below the surface; in others, particularly on steeper slopes, it outcrops at the surface.

Soils of this complex have adequate surface drainage. On steeper areas runoff is high and considerable water is lost before it can be used by crops and native plants. The soils are slowly permeable, and though they are capable of holding large quantities of moisture, they give it up so slowly that plants grown on them are much sooner damaged by drought than on more friable lighter textured soils.

Use and management.—A large part of Winifred-Pierre clay loams and clays was once cultivated, but because of low crop yields and frequent crop failures most of this has been abandoned. A small acreage is still cultivated in Fergus County; areas southeast of Ringling are used chiefly for winter wheat and feed crops. Water diverted from Sixteen Mile Creek irrigates a small area northeast of Ringling, but most of this irrigated land has become seeped and saline and is used only for pasture and wild hay.

The surface acre-foot contains 3,500 to 4,000 pounds of nitrogen and 2,400 pounds of phosphorus. The average yield of nonirrigated spring wheat on summer-fallowed land is less than 10 bushels an acre, but occasionally yields of 25 to 30 bushels are obtained in favorable seasons. Uncultivated areas have a moderate to heavy cover of big sage, with western wheatgrass and other grasses filling in the more open places. The forage on 30 acres or more is required to carry a steer through a 9- to 10-month grazing season.

Winnett silt loam (We).—A strongly developed clayey subsoil characterizes this soil. It was developed over silty to clayey shale and occupies undulating to gently rolling uplands in the east-central part of Petroleum County. Slick, or bare, spots are common where wind has removed the friable surface soil and exposed the heavy subsoil. The heavy claypanlike subsoil is not everywhere continuous. Probably 20 to 25 percent of the included soils are fairly typical of Cushman soils.

The 3- to 5-inch Winnett surface soil is friable grayish-brown silt loam of a flaky mulchlike structure. It has a sprinkling of leached gray silt or a thin gray layer where it abruptly contacts the subsoil. The subsoil is brown silty clay loam of medium columnar structure; it grades to calcareous blocky grayish-brown clay loam at 6 to 10 inches. This calcareous layer continues down to partly weathered grayish-brown silty or clayey shale at 24 to 30 inches.

Use and management.—Much of Winnett silt loam was placed under cultivation during the homesteading period, but most of this was abandoned because of low crop yields caused by drought and poor soil-moisture conditions. This land is now included in a Federal Land Purchase area, and much of the abandoned acreage has been seeded to crested wheatgrass and retired to grazing. Stock raising is the chief enterprise on the few farms on this soil, and the land cultivated is largely in feed and forage crops. Spring wheat is grown on a few farms as a cash crop, but the average yield is less than 10 bushels an acre. The slope is sufficient to give good surface drainage, but the subsoil is very slowly permeable. The surface acre-foot of soil contains 3,000 to 3,900 pounds of nitrogen and 1,500 to 1,800 pounds of phosphorus. Short grasses predominate on virgin areas; 25 to 30 acres is required to carry a steer through a 10-month grazing season.

ESTIMATED YIELDS

Average acre yields of principal crops to be expected over a period of years under prevailing practices of farm management and the average livestock carrying capacity of soils in the Central Montana area are listed in table 7.

TABLE 7.—Estimated crop yields and grazing capacity of soils under prevailing farm practices in 10 central Montana counties¹

Soil	Dry land farming					Acres required per animal unit for 8- to 10-month grazing season	Irrigation farming			
	Spring wheat	Winter wheat	Barley	Oats	Wild hay		Spring wheat	Barley	Oats	Alfalfa
Adel and Teton loams and stony loams, undifferentiated	Bu.	Bu.	Bu.	Bu.	Tons 1. 0-1. 5	10-12				
Adel stony loam and loam, undifferentiated					1. 0-1. 5	10-12				
Amsterdam loam and silt loam, undifferentiated	10-12	12-15	20-25	25-30	. 3- . 5	30-35	25-30	45-50	50-55	3. 0-4. 0
Arvada and Wade loams and clay loams, undifferentiated					. 4- . 6	25-30				
Arvada clay loam and clay, undifferentiated					. 2- . 3	35-40				
Ashuelot loam and gravelly loam, undifferentiated					. 4- . 5	30-35	12-15		30-35	2. 0-3. 0
Avalanche loam and gravelly loam, undifferentiated					. 3- . 4	30-35				1. 5-2. 0
Bainville, Travessilla, and Flasher loams and stony loams, undifferentiated					. 4- . 5	30-35				
Barnes stony loam and loam, undifferentiated					1. 0-1. 5	8-10				
Beaverton and Gilcrest loams and gravelly loams, undifferentiated					. 3- . 4	35-40	10-12	15-20	25-30	1-1. 5
Beaverton gravelly loam					. 3- . 4	35-40	10-12	15-20	25-30	1-1. 5
Belt clay loam and clay, undifferentiated	13-18	18-22	35-40	40-45	1. 0-1. 2	15-20				
Berthoud and Larimer loams and gravelly loams, undifferentiated					. 4- . 6	30-35				
Berthoud loam and stony loam, undifferentiated	8-10		15-20	20-25	. 3- . 5	30-35	20-25	25-30	30-35	2. 0-3. 0
Billings-Arvada clay loams					. 3- . 4	30-35				
Boyd and Spring Creek clay loams and stony clay loams, undifferentiated					. 6- . 8	15-20				

See footnotes at end of table.

TABLE 7.—Estimated crop yields and grazing capacity of soils under prevailing farm practices in 10 central Montana counties¹—Continued

Soil	Dry land farming					Acres required per animal unit for 8- to 10-month grazing season	Irrigation farming			
	Spring wheat	Winter wheat	Barley	Oats	Wild hay		Spring wheat	Barley	Oats	Alfalfa
	Bu. 15-18	Bu. 18-22	Bu. 35-40	Bu. 45-50	Tons .7-1.0		Bu. 15-18	Bu. 18-22	Bu. 35-40	Tons 45-50
Boyd clay loam.....					.7-1.0	12-15				
Bridger stony loam.....					1.0-1.5	10-12				
Castle clay and clay loam, undifferentiated.....	15-20	20-25	40-45	50-55	1.0-1.5	8-10				
Castner-Morton loams and stony loams.....	10-12	12-15	20-25	25-30	.6-.8	25-30				
Castner stony loam.....					.5-.7	25-30				
Cheadle stony loam.....					.6-.9	12-15				
Cheyenne-Beaverton gravelly loams.....	8-10	10-12	20-25	25-30	.6-.7	25-30				
Cheyenne loam and gravelly loam, undifferentiated.....	10-12	12-15	25-30	30-40	.6-.8	20-25				
Crago gravelly loam.....					.3-.4	30-35				
Cushman-Bainville loams and silt loams.....	8-10	10-12	15-20	25-30	.4-.5	25-30				
Cushman loam.....	10-12	12-15	20-25	25-30	.4-.6	25-30				
Danvers silty clay loam.....	15-20	20-25	30-40	40-45	1.0-1.2	10-15	25-30	45-50	50-60	2.0-3.0
Darret loam and stony loam, undifferentiated.....	12-15	15-20	30-35	35-40	.7-1.0	20-25				
Delpine shaly loam.....					.4-.6	25-30				
Doughty and Utica loams and gravelly loams, undifferentiated.....	10-12	12-18	25-30	35-40	.8-1.0	15-20				
Fairfield loam and gravelly loam, undifferentiated.....	10-12	12-15	25-30	35-40	.8-1.0	15-20				2.5-3.0
Fairfield stony loam.....					.8-1.0	10-15				2.0-3.0
Farland and Fergus loams, undifferentiated.....	16-20	23-28	40-45	50-60	1.0-1.2	15-20				
Flasher-Cushman fine sandy loams.....	8-10	10-14	15-20	25-30	.4-.6	25-30				
Gilcrest loam and gravelly loam, undifferentiated.....					.2-.4	35-40	20-25	30-35	35-40	2.0-3.0
Gilt Edge clay loam and gravelly clay loam, undifferentiated.....					.3-.4	35-40				

Goshen loam.....	12-15	18-22	35-40	40-45	1. 0-1. 2	15-20				
Hanson stony loam.....					1. 0-1. 5	8-10				
Hilger loam and stony loam, undifferentiated.....	12-15	15-20	30-35	40-45	. 8-1. 0	15-20				
Judith-Utica loams and gravelly loams.....	12-15	15-20	25-30	35-45	1. 0-1. 2	10-15				
Laporte silt loam and stony loam, undifferentiated.....					. 4. 6	20-25				
Larimer gravelly loam.....					. 3. 5	25-30				
Larimer stony loam.....					. 4. 6	35-40				
Lihen sandy loam.....					. 4. 6	25-30				
Lismas clay.....					. 1. 2	40-60				
McKenzie clay.....					. 2. 4	30-40				
Maginnis clay loam.....	8-10	12-15	20-25	25-30	. 4. 6	25-30				
Manhattan sandy loam.....					. 4. 5	30-35			2. 0-2. 5	
Manvel-Midway loams.....	8-10	12-15	20-25	25-30	. 4. 6	25-30				
Martinsdale loam and gravelly loam, undifferentiated.....	8-10	10-12	20-25	25-30	. 5. 6	20-25			2. 0-3. 0	
Midway-Bainville-Cushman loams and stony loams.....					. 4. 6	25-30				
Midway-Patent clay loams.....	6- 8	8-10	12-15	15-20	. 4. 5	25-30				
Moline and Arvada loams and clay loams, undifferentiated.....					. 2. 3	35-40				
Morton-Darret loams and clay loams.....	12-15	15-20	25-30	35-40	. 7-1. 0	20-25				
Morton fine sandy loam.....	8-10	10-15	18-25	20-25	. 5. 7	25-30				
Morton silt loam.....	12-15	15-20	30-35	35-40	. 7-1. 0	20-25				
Musselshell-Crago loams and gravelly loams.....	6- 8	8-10	15-20	20-25	. 4. 6	25-30	25-30	30-40	40-50	2. 0-3. 0
Orman clay and clay loam, undifferentiated.....					. 6. 8	30-35				
Patent clay loam.....	8-10	10-12	15-20	20-25	. 4. 6	25-30	20-25	25-35	30-40	2. 0-3. 0
Pierre clay.....	6- 8	8-10	12-15	15-20	. 2. 4	30-40				
Regent clay loam.....	8-12	12-15	20-30	30-35	. 6. 8	20-25				
Regent-Rhoades clay loams.....					. 5. 6	25-30				
Regent stony loam-clay loam.....	8-12	12-15	20-25	25-30	. 5. 7	25-30				
Ringling loam-shaly loam.....					. 2. 3	40-50				
Rocky Ford silt loam.....					. 3. 5	30-35	30-35	40-45	50-55	2. 0-3. 0
Roy stony loam.....					. 4. 6	25-30				
Sage-Arvada clay loams and clays.....					. 3. 5	30-35				
Savage and Orman clays and clay loams, undifferentiated.....	8-10	10-12	15-20	20-25	. 7-1. 0	10-15				1. 5-2. 0
Scobey loam and clay loam, undifferentiated.....	12-15	18-22	20-30	35-40	. 6. 8	20-25				
Scobey stony loam.....					. 6. 8	25-30				
Sipple loam.....	20-25	25-30	45-50	45-55	1. 0-1. 5	7- 9				
Skaggs and Duncom loams and stony loams, undifferentiated.....			40-45	50-55	1. 0-1. 5	6- 8				

See footnotes at end of table.

TABLE 7.—Estimated crop yields and grazing capacity of soils under prevailing farm practices in 10 central Montana counties¹—Continued

Soil	Dry land farming					Acres required per animal unit for 8- to 10-month grazing season	Irrigation farming			
	Spring wheat	Winter wheat	Barley	Oats	Wild hay		Spring wheat	Barley	Oats	Alfalfa
	Bu.	Bu.	Bu.	Bu.	Tons		Bu.	Bu.	Bu.	Tons
Spring Creek stony loam.....					. 2- . 3	35-40				
Teton-Cheadle loams and stony loams.....	10-15	15-20	30-40	35-45	1. 0-1. 5	² 10-15				2. 0-2. 5
Teton loam.....	15-20	20-25	35-45	40-50	1-0-1. 5	² 10-12				
Travessilla-Cushman loams and stony loams.....	8-10	10-12	15-20	20-25	. 3- . 5	30-35				
Travessilla stony loam.....					. 4- . 6	25-30				
Two Dot loam and gravelly loam, undifferentiated.....	8-10	10-15	20-25	25-30	. 5- . 7	20-25				
Ulm fine sandy loam.....	8-10	11-12	15-20	20-25	. 4- . 6	25-30				
Utica gravelly loam.....					. 7-1. 0	² 15-18				
Utica-Judith gravelly loams.....	8-12	12-15	20-25	25-30	. 7-1. 0	² 15-20	15-20	40-45	45-50	2. 0-2. 5
Vebar sandy loam.....	8-12	12-15	20-25	25-30	. 5- . 7	20-25				
Wade clay loam.....					. 6- . 8	20-25				
Williams stony loam.....					. 8-1. 0	² 15-20				
Winifred clay loam.....	10-12	12-15	15-20	25-30	. 5- . 7	25-30				
Winifred-Pierre clay loams and clays.....	8-10	10-12	20-25	25-30	. 4- . 6	30-35				2. 0-2. 5
Winnett silt loam.....					. 3- . 5	25-30				

¹ The miscellaneous land types Alluvial soils, undifferentiated (dark-colored); Alluvial soils, undifferentiated (light-colored); Badlands; Bouldery and gravelly outwash; Riverwash; Rock outcrop; Rough mountainous land (thin shrub and grass); and Rough mountainous land (timbered) have not been rated. McKenzie clay, composed mostly of intermittent lakes, has not been rated and

supports mainly annual weeds and grasses or is bare of vegetation. Flasher-Terry fine sandy loams, once cultivated but now used for grazing, also were not rated.

² Grazing season of 6 to 8 months.

³ Grazing season of 4 to 6 months.

The crop yields to be expected for the dry lands are based on yields obtained on summer-fallowed land, and those for irrigated land from field data obtained in the different irrigated sections. The carrying capacity for livestock is based on the number of acres required to produce sufficient forage to carry a steer through the grazing season. In some parts of the area the grazing season is 4 to 6 months, in others 6 to 8, and on the plains 8 to 10. Most of the grazing information was obtained from stockmen in the area and from grazing experts of the United States Forest Service at Missoula, Mont., who checked the estimates made by the soil men.

MORPHOLOGY AND GENESIS OF SOILS

Soils are natural media for the growth of plants. They are mixtures of fragmented and partly or wholly weathered rocks and minerals, organic matter, water, and air, in greatly varying proportions, and have more or less distinct layers or horizons developed under the influence of climate and living organisms. The cross section of horizons from the surface to the parent material is known as the soil profile. The degree of profile development is dependent on the intensity of the activity of the different soil-forming factors, on the length of time they have been active, and on the nature of the materials from which the soils have developed . . . (3).

The prevailing climate of the Central Montana area is semiarid mid-continental, but it varies with elevation and with the affect of the mountains on movements of air masses and the fall of rain and snow. Elevation ranges from about 2,700 feet in Petroleum County, near the Missouri River in the northeastern part of the area, to more than 8,000 feet in the mountains.

The eastern two-thirds of the surveyed area lies within the unglaciated Missouri Plateau section of the Great Plains province; most of the rest lies in Northern Rocky Mountains province, but a small part along the northern border is in the glaciated parts of the Missouri Plateau section (6).

The Missouri Plateau section includes spur ranges of the Rocky Mountains and outlying mountainous areas bordered by dissected remnants of high plateaus, broken foothill areas, alluvial fans, and gravel-capped benchlands. Northward and eastward, these local physical features merge somewhat abruptly with the undulating to strongly rolling and broken typical plains section of the area.

Some of the outlying mountains are of intrusive volcanic rocks flanked by sedimentary rocks of several kinds and ages. Other mountainous areas are principally of sedimentary Pennsylvanian and older rocks, many of them strongly metamorphosed. These rocks include limestone, quartzite, argillite, and hard thin platy slatelike shale. Local igneous intrusions, principally granite, rhyolite, and andesite, occur in places in the mountains.

The Northern Rocky Mountains province includes several deep nearly enclosed intermountain basins where the land is level to rolling in contrast to the large tracts of rugged mountains. Geologists think these basins were formed during late Cretaceous and early Tertiary times when the crust of the earth was folded and faulted to form the Rocky Mountains. Some of the basins, such as Helena, Townsend, and Smith River Basins, were occupied by lakes that overflowed from valley to valley and finally emptied into the river system of that period.

The ancient lakes received sediments washed from neighboring mountains and, from time to time, showers of volcanic ash that filled them to a depth of several hundred feet before the rivers cut outlets through the mountains and drained them. During the many hundreds of thousands of years since the lakes were drained, a large part of the old lake sediments have been removed by streams. In places the streams are entrenched in the hard rocks below the Tertiary lake sediments. The silty and gravelly deposits in the old lake beds have been dissected to form high benchlike terraces separated by ravines and low hills.

Very extensive alluvial and outwash fans were formed on the plateaus adjacent to the mountains during Miocene, Pliocene, and early Pleistocene times. Many of the soils in Judith Basin, the Musselshell River valley, and elsewhere about the mountains have developed on tablelands and bench remnants of these old fans. Younger and usually lower lying fans, benches, and terraces have been formed adjacent to the old fans and along the present streams flowing out of the mountains. Many differences in soil development on the alluvial-fan deposits may be ascribed to differences in the length of time soil-forming processes have been operating on the material.

During Pleistocene times, a small part of the Missouri Plateau lying along the northern border of the surveyed area was glaciated. Mountain glaciers, now extinct, have modified the terrain of some of the high mountain valleys, particularly along the main range of the Rockies and along the Rocky Mountain front west of Great Falls, where terminal moraines of the mountain glaciers merge with till deposited on the Great Plains by the continental glaciers.

Pleistocene and recent deposits, largely alluvial, provide material for soil formation on some of the lower stream terraces and nearly level bottom lands, as well as on the tops of some of the high tablelands.

As a result of a wide range in elevation, complex local physiography, and varied climate, the soils of central Montana differ greatly in morphological characteristics. Generally speaking, the climate varies with differences in elevation, and the soils vary with differences in climate and related differences in vegetation.

The lighter-colored soils of the Brown soils zone, with thin and only slightly leached solums, occur mainly at lower elevations in areas of dry semiarid climate and short-grass vegetation. Vegetation is more luxuriant at higher elevations where the climate is cooler and precipitation is greater. The short grasses of the Brown soils merge with the mixed tall and short grasses of the Chestnut soils zone, and these give way to the tall-grass association of the Chernozem and Prairie zones. The dark soils of the Chernozem and Prairie groups have thicker solums and are more deeply and more thoroughly leached of their carbonates than the Brown and Chestnut soils. The soils on the middle and the upper slopes of the grasslands belong to the Chestnut and Chernozem groups. Prairie soils are in the high park-land areas in the mountains.

Local mountainous areas and the orientation of the main axes of these areas with respect to the prevailing direction of rainstorms have a marked local influence on the climate and on the soils. For example, Chestnut and Chernozem soils occur at lower elevations and at greater distances from the mountains on the northward-facing slopes of the

mountains and the tablelands north of the mountains in Judith Basin than they do on the southward-facing slopes and on the tablelands south of these mountains in the valley of the Musselshell River.

The soils have formed from the weathered products of an extremely wide variety of bedrock and from unconsolidated materials, some of which are derived dominantly from one kind of rock and some from many kinds of rocks. Along the northern border of the area, the soils have developed in glacial drifts, chiefly till, and some glaciolacustrine deposits; in the eastern and northeastern parts, from interbedded silty and clayey shale and from clay shale, chiefly of late Cretaceous age; in the southeastern part, principally in the location of the Bull Mountains Upland, from shale and sandstone of early Tertiary age; and in the foothills of outlying mountainous areas, from sandstone and interbedded sandstone, and shale, and limestone chiefly of early Cretaceous age. Some of the early Cretaceous rocks are moderately to strongly metamorphosed.

Although the basins of the Northern Rocky Mountains province are relatively high above sea level, they are drier than the surrounding humid to subhumid mountains and foothills. They have semiarid or dry semiarid climates much like those of the dry plains east of the Rocky Mountains. Descending warm air currents in winter, known as chinook winds, reduce considerably the moisture effectiveness in the soils of the basins. Much of the snow melts rapidly, evaporates, and is lost to the soils. Although precipitation in the basins is somewhat higher than on the plains, vegetation is more sparse because of the drying effect of the chinook winds. Soils, therefore, are lighter colored in the basins as a whole than on the plains.

The soils in the lower parts of the basins are little darker than Sierozems, and many of them are calcareous at or only a few inches below the surface. Usually, however, they have neutral or only slightly alkaline surface soil and horizons of moderate to strong lime carbonate accumulation 6 to 10 inches below the surface. The soils are darker on the higher slopes of the basins and grade into fairly typical Chestnut soils in a narrow belt below the timbered slopes of the mountains.

Within generally timbered areas in the higher parts of the basins, near the lower limits where trees grow well, are parklike grass areas where the soils are typical of Chernozems and have very dark grayish-brown or dark-brown surface soils, brown moderately well developed blocky upper subsoil layers (B₂ horizons), and strongly developed lime carbonate horizons 16 to 30 inches below the surface. The best examples and largest areas of Chernozems occur in an irregular belt high on the slopes of the main range of the Rockies west of Great Falls, eastward from Great Falls on the high northward-facing slopes, and on high benchlands north of the Big Belt, Little Belt, and Big Snowy Mountains in the higher parts of the Missouri Plateau section.

Nearly black Prairie soils with slightly to moderately acid surface soil and no free carbonates in their solums or substratums to depths of 5 feet or more occur on moderately sloping to steeply sloping areas in small and narrow elongated valleys high in the subhumid heavily timbered mountains. Most of these soils have developed on local alluvial-alluvial deposits on the lower slopes of the narrow valleys, on sloping alluvial fans around the heads of the valleys, and at the apexes

of some of the larger fans that extend out of the mountains into the plains.

The soils of the timbered mountains, largely within national forests, were not mapped. They are shown on the soil map only as a broad physiographic unit of rough mountainous land. With the exception of small included park and mountainous areas where the stands of timber are thin, all of these soils are podzolic in character. They include the Gray Podzolic or Gray-Wooded soils² (5, 8), much like those of Manitoba, Saskatchewan, and Alberta; some Podzols and Brown Podzolic soils; and associated Wiesenboden, Alpine Meadow, Bog, and Half Bog soils.

Table 8 shows the relationship among the soils developed on each principal soil material in the different soil zones of central Montana.

In the first column of the table are listed the principal kinds of bedrock and unconsolidated deposits in which the soils of the area have developed and their age and relief. Succeeding columns show the zonal soils and the associated principal azonal and intrazonal soils developed from each kind of parent rock. The azonal and intrazonal soils are indicated by footnotes and are listed under one or another of the soil-zone headings to show their relation to the zonal groups of soils with which they are most commonly associated.

Many azonal and intrazonal soils occur in at least two major climatic zones. To bring out this fact, each of these soil names is listed in at least two zones. Further, certain of the clayey soils as the Winifred and Pierre, are mapped in both the Chestnut and Brown soil zones. In semiarid regions their heavy texture prevents the development of marked differences in the color of their surface soils and in the thickness of solums.

The Cushman soils, although not very extensive in this surveyed area, are representative of the Brown soils. They are developed in medium-textured material weathered in place from silty shale. The following describes a profile of Cushman loam somewhat thicker than the average for the type.

- 0 to 2 inches, grayish-brown³ (10YR 4.5/2, dry) to dark grayish-brown (10YR 3/2, moist) friable loam mulch; weak platy or flaky primary structure; fine granular secondary structure; neutral to mildly alkaline.
- 2 to 9 inches, grayish-brown (10YR 4.5/2, dry) to dark grayish-brown (10YR 3/2, moist) heavy loam; fine granular or crumb structure; neutral or slightly alkaline in the upper part, calcareous in the lower.
- 9 to 17 inches, pale-brown (10YR 6/3, dry) to brown (10YR 5/3, moist) clay loam; medium blocky structure; mildly calcareous.
- 17 to 42 inches, light-gray (10YR 7/2, dry) to grayish-brown (10YR 5/2, moist) clay loam; ill-defined medium blocky structure; calcareous. The upper 10 or 12 inches is the horizon of greatest accumulation of carbonate of lime; lime is chiefly in disseminated form.
- 42 to 53 inches, light-gray (10YR 7/2, dry) to light brownish-gray (10YR 6/2, moist) silty weathered parent shale material; calcareous; structure of shale fairly well preserved.

Most of the Cushman soils comprise areas of gently rolling to rolling land. The Bainville soils are the associated Lithosols on rolling, hilly, and broken areas. Terry and Flasher soils are associated zonal

² Department of soils, University of Alberta; Dominion Experimental Farms Service; Alberta Research Council and Department of Agriculture. Soil zones of Alberta as established by Alberta Soils Surveys. (Map.) 1945.

³ Provisional soil survey color names based on Munsell color charts.

TABLE 8.—*Classification of the soil series of central Montana*

UPLANDS

Parent source, age, and relief	Soil zone				
	Prairie and Podzolic	Chernozem	Chestnut	Brown	Sierozem
Limestone: Hard, blue gray, massive, and thin bedded; Cretaceous and older; foothills and mountains.	} Duncom ¹ -----	{ Skaggs ² ----- Duncom ¹ -----	} Laporte ³ -----		
Sandstone: Hard, gray and light-brown sandy shales; chiefly Cretaceous and older; mountains, foothills, and plains.				{ Teton ² ----- Cheadle ³ -----	} Castner ³ -----
Soft, gray and light brown; chiefly Tertiary-Cretaceous; undulating to rolling and broken plains.		{ Vebar----- Flasher ³ -----	Terry ³ ----- Flasher ³ -----		
Sandstone and sandy shale, interbedded: Moderately hard, gray and brown; Tertiary chiefly; undulating to rolling plains.				Ulm ^{2 4} -----	Winnett ⁵ -----
Moderately hard gray interbedded silty and clayey very fine-grained sandstone; late Cretaceous and Tertiary transition; undulating to rolling plains.				Midway ³ -----	
Shale, weakly to moderately indurated: Red, interbedded silty, clayey, and sandy; Cretaceous, red Kootenai; foothills and high plateau remnants.			Darret ² -----		
Gray; silty chiefly, but interstratified heavier and lighter textures; Tertiary (chiefly Fort Union) but some Cretaceous (chiefly Colorado); undulating to rolling and broken plains.			{ Morton----- Bainville ³ ----- Rhoades ⁵ -----	Cushman----- Bainville ³ ----- Winnett ⁵ -----	

See footnotes at end of table.

TABLE 8.—Classification of the soil series of central Montana—Continued

UPLANDS—Continued

Parent source, age, and relief	Soil zone				
	Prairie and Podzolic	Chernozem	Chestnut	Brown	Sierozem
Shale, weakly to moderately indurated—Con. Gray, moderately clayey; Tertiary chiefly, heavy beds Lance and Fort Union; undulating to rolling plains.	}		{ Regent ⁵ ----- Rhoades ⁵ -----	} Winnett ⁵ -----	
Dark gray to black, clay and clayey, highly calcareous; Cretaceous, chiefly Colorado; foothills.		Castle ^{2 6} -----	Castle ^{2 6} -----		
Gray to dark gray, clay and clayey, slightly calcareous; Cretaceous-Bear Paw (Pierre); undulating, rolling, and broken plains.	}	Boyd-----	{ Winifred----- Pierre ² ----- Lismas ³ -----	{ Winifred----- Pierre ² ----- Lismas ³ -----	
Shale, metamorphosed, hard, slaty:					
Red, thin platy; Pennsylvanian and older; intermountain basin and basin foothills.			Ringling ³ -----	Ringling ³ -----	
Gray, thin platy; Pennsylvanian and older; intermountain basins and basin foothills.			Delpine ³ -----	Delpine ³ -----	
Gray, thick or coarse platy; Cretaceous, chiefly Colorado; dissected plateaus and low foothills.			Maginnis ³ -----	Maginnis ³ -----	
Igneous intrusive and metamorphic rocks:					
Granite and andesite chiefly; intermountain basins and basin foothills.			Spring Creek ³ ---	Spring Creek ³ ---	
Modified (wind and water reworked) materials of old continental deposits:					
Dominantly silty, loesslike in upper part, stratified sandy and silty below; Tertiary-Bozeman Lake Beds; high benchlike slopes, intermountain basins.				Amsterdam-----	

Dominantly sandy, stratified sandy and sandy gravelly in lower part; Tertiary-Bozeman Lake beds; high benchlike slopes, intermountain basins. Glacial till: Loamy to moderately clayey; continental and mountain glaciers; rolling to hilly.				Manhattan
		Barnes	{ Williams Scobey ⁷	}

HIGH TABLELANDS, BENCHES, AND BROAD ALLUVIAL FANS

Gravel-capped, gently to moderately sloping: Thin light-colored silty loesslike mantle over limestone gravel embedded in silty high-lime (calichelike) material, 4 to 6 feet thick over loose gravel; probably Pliocene or older. Loamy light-colored gravel, argillite, and quartzite chiefly, embedded in silty high-lime (calichelike) material, 3 to 4 feet thick over loose gravel; probably Pliocene and younger. Loamy light-colored gravel and stone, igneous and metamorphic materials, chiefly granite, andesite, and quartzite; probably Pliocene and Pleistocene ages. Loamy to silty light-colored fine earth material containing sedimentary and metamorphosed stone fragments; Pleistocene and recent deposits.	}	}	}	}	}				
							{ Sipple Judith ⁸ Utica ⁹	{ Danvers Doughty ⁸ Utica ⁹ Gilt Edge ⁵	{ Two Dot Musselshell ⁶ Crage ⁹ Gilt Edge ⁵
								{ Fairfield Ashuelot ¹⁰	{ Martinsdale ⁶
						Bridger	Hanson	{ Hilger Gilt Edge ⁵	{ Roy ⁶ Gilt Edge ⁵
Adel									

LOW BENCHES AND STREAM, GLACIAL LAKE, AND FAN TERRACES

Stream and fan terraces and low benches: Loamy light-colored gravel over loose gravel at depths ranging from 1 to 4 feet; from argillite, quartzite, and igneous rocks; chiefly Pleistocene.	}	}	}	}	}

See footnotes at end of table.

TABLE 8.—*Classification of the soil series of central Montana—Continued*
 LOW BENCHES AND STREAM, GLACIAL LAKE, AND FAN TERRACES—Continued

Parent source, age, and relief	Soil zone				
	Prairie and Podzolic	Chernozem	Chestnut	Brown	Sierozem
Stream and fan terraces and low benches—Con.				Gilcrest	
Sandy gravelly light-colored material of mixed origin, slightly coherent and loamy in the upper part; chiefly late Pleistocene.					
Sandy light-colored material including sandy outwash partly reworked and in places redeposited by the wind; chiefly late Pleistocene.			Lihen		
Loamy to silty medium-textured light-colored fine earth material, deep.	}		{ Farland	} Arvada ⁵	Rocky Ford
Silty to clayey moderately heavy light-colored fine earth material, deep.			{ Wade ⁵		
Silty to clayey moderately heavy red fine-earth material, deep.			{ Savage		
Clayey and clay heavy olive-brown fine-earth material, slightly to moderately saline.			{ Wade ⁵		
Glacial lake terraces:			{ Sage ¹¹		
Clayey moderately heavy deposits in drained basins.			Fergus		
Clay heavy deposits in undrained basins			Orman	Billings	Billings.
Local colluvial-alluvial fans and fan terraces of the narrow valleys:			Belt ¹²		
			McKenzie ¹³	McKenzie ¹³	

Loamy to silty medium-textured dark-colored materials.	}	}	Goshen	Goshen
Loamy to silty medium-textured light-colored materials.			{ Berthoud ¹⁴	
Silty to clayey medium-textured to moderately heavy light-colored materials.			{ Moline ⁵ Patent ¹⁴	{ Arvada ⁵

¹ Complex of Alpine Meadow soils and Lithosols as mapped in this area.
² Medium depth and moderately shallow although normal or nearly normal zonal soils (15 to 30 inches deep over bedrock).
³ Lithosols—azonal soils with some characteristics in common with the zonal soils under which they are listed.
⁴ Semiclaypan soils with some included small areas of Solonetz and zonal soils.
⁵ Intrazonal—Solonetz soils dominantly associated with the zonal soils under which they are listed.
⁶ Intrazonal—Rendzinalike soils with some of the characteristics of zonal soils under which they are listed.
⁷ Light Chestnut soils or dark Brown soils, an intergrade.
⁸ Moderately thin solum although about normal soils over

unconsolidated materials (solum averages about 24 inches thick).
⁹ Thin and very thin solum lithosolic soils over unconsolidated materials (solum averages about 10 inches thick).
¹⁰ Soils with lime-cemented hardpan B₂ horizon 4 to 10 inches thick but otherwise not different materially from associated zonal soils.
¹¹ Intrazonal—Solonchak soils dominantly associated with zonal soils under which they are listed.
¹² Claypan soils with small included areas of Solonetzlike or Solodized Solonetzlike soils.
¹³ Intrazonal—Wiesenboden and Solonetz soils.
¹⁴ Light-colored soils with weakly developed zonal characteristics.

soils and Lithosols, respectively, developed on moderately hard sandstone interbedded in places with shale that gives rise to Cushman and Bainville soils.

The **Midway** soils, Lithosols of the Brown soil zone, are in places associated with Cushman soils, but they have developed on rocks of somewhat different character, chiefly clayey and sandy shale.

The **Winnett** series includes Solonetz associates of the Cushman and Bainville soils on nearly level to undulating uplands. These soils are representative Solonetz soils of dry semiarid regions. Following is the profile description of a sample of Winnett silt loam collected in the area:

- 0 to 3 inches, light brownish-gray (10YR 6/2, dry) to grayish-brown (10YR 4/2, moist) friable silt loam; thin platy or flaky structure; neutral or slightly acid.
- 3 to 12 inches, grayish-brown (10YR 5/2, dry) to (10YR 4/2, moist) clay loam or clay; strongly developed columnar or prismatic structure; neutral to strongly alkaline; no free carbonate of lime.
- 12 to 31 inches, gray (10YR 6/1, dry) to dark-gray (10YR 4/1, moist) silty clay loam; medium blocky structure; calcareous.
- 31 to 42 inches, light brownish-gray (2.5Y 6/2, dry) to grayish-brown (2.5Y 4/2, moist) silty clay loam; massive or ill-defined irregular medium blocky structure; calcareous.
- 42 to 48 inches, light brownish-gray (2.5Y 6/2, dry) to grayish-brown (2.5Y 4/2, moist) partly weathered moderately hard calcareous shale containing flecks and streaks of gypsum and possibly other salts.

The surface soil of Winnett silt loam ranges from a thin light-gray surface mulch over the round-topped columns to brownish-gray (dry) friable loam or silt loam 6 to 8 inches thick, averaging between 4 and 6 inches. This series includes all stages of Solonetz development, and included in mapping are small areas of Solonchak and as much as 25 or 30 percent of solodized-Solonetz containing a leached gray silty A₂ horizon 1 to 2 inches thick, which contacts the claypan subsoil abruptly.

In the present classification all Solonetz soils developed in residuum from shale in the Brown soils zone are included in the Winnett series. In some places they are associated with Midway soils on the lighter textured shale and with **Winifred**, **Pierre**, and **Lismas** soils—deep, moderately shallow, and shallow (Lithosols) soils, respectively—developed in heavy clay shale materials. As a rule, however, the extremely heavy shale materials are so slowly permeable that they retain enough free salts and lime carbonate to retard dispersal of the clay and development of the columnar structure typical of Solonetz soils.

Morton soils are Chestnut soils developed in the same kind of parent material as Cushman soils of the Brown soil zone. They differ from the Cushman soils chiefly in having darker surface soils, thicker surface and subsoil horizons, and lower lying horizons of lime carbonate accumulation. **Bainville** soils (Lithosols) occur in both the Chestnut and Brown soil zones and are associated with both Morton and Cushman soils. The Bainville soils in the Chestnut soil zone, however, have slightly darker A horizons than in the Brown soil zone.

The **Rhoades** series includes Solonetz and solodized-Solonetz soils associated with Morton and other soils in the Chestnut soil zone developed in residual materials from shale. They are the Chestnut analogs of the Winnett soils in the Brown soil zone and differ from Winnett

chiefly in having slightly darker surface soils and thicker and darker claypan horizons.

On the high plateau remnants and in the high foothills adjacent to the mountains in areas of moist semiarid climate, the Teton soils are representative of Chernozem soils developed in friable materials weathered from underlying bedrocks. The parent rocks consist of slightly calcareous fine-textured sandstone and sandy shale of the Kootenai (Dakota) formation. Although the parent rocks from which Teton soils are derived differ lithologically somewhat from the parent rocks of Cushman and Morton soils, the texture and consistence profiles of these soils are closely similar. Teton soils are the Chernozem analogs of Morton (Chestnut) and Cushman (Brown) soils developed in parent materials of similar friability but in different climatic zones.

Description of a somewhat thicker than average profile of Teton loam:

- 0 to 1 inch, very dark-brown (10YR 2/2, dry) to black (10YR 2/1, moist) loamy organic mulch.
- 1 to 14 inches, very dark-brown (10YR 2/2, dry) to black (10YR 2/1, moist) loam; granular structure; neutral or slightly acid.
- 14 to 23 inches brown (10YR 4.5/2, dry) to dark-brown (10YR 3/3, moist) friable clay loam; coarse prismatic or blocky structure; about neutral.
- 23 to 32 inches, yellowish-brown (10YR 5/4, dry) to dark yellowish-brown (10YR 4/4, moist) heavy loam or fine sandy clay loam; ill-defined blocky structure; neutral or slightly alkaline but no free carbonate of lime.
- 32 to 42 inches, brownish-yellow (10YR 6/6, dry) to yellowish-brown (10YR 5/6, moist) massive friable loam; moderately to weakly calcareous. In materials low in lime, the carbonate in this horizon consists chiefly of a thin crust on the lower sides of the rock fragments in the lower part of the solum.

A few to abundant fragments of the partly weathered fine-grained sandstone are present on the surface and throughout the solum. In places enough stone is on the surface to give the soil a stony texture. Cheadle soils are the Lithosol associates of Teton soils.

The Skaags soils in the same general area as the Teton soils have developed in materials weathered from limestone of Cretaceous and older formations. These soils are about normal although moderately shallow (18 to 24 inches thick) Chernozems. They have surface soils and upper B horizons about as thick as the Teton soils, but their B₃ and C horizons are thinner.

Castle soils are developed from heavy dark-gray to black highly calcareous shale, which is interbedded with the limestone from which Skaggs soils have developed. The Castle soils have nearly black granular surface soils, but otherwise they show little horizon development other than a slight accumulation of lime carbonate in the partly weathered shale. The soils may be classed as Rendzinas.

Profile description of Castle clay:

- 0 to 2 inches, dark grayish-brown (10YR 4/1.5, dry) to very dark grayish-brown (10YR 3/1.5, moist) clay mulch high in organic matter; fine granular structure; calcareous.
- 2 to 12 inches, dark grayish-brown (10YR 4.5/1.5, dry) to very dark grayish-brown (10YR 3/1.5, moist) clay; coarse granular or nuciform structure; calcareous.
- 12 to 21 inches, grayish-brown (10YR 5/1.5, dry) to very dark grayish-brown (10YR 3.5/1.5, moist) clay; fine blocky structure; strongly calcareous.

- 21 to 30 inches, dark-gray (N 5/, dry) to very dark-gray (N 3/, moist) clay; massive or coarse blocky structure; strongly calcareous; contains white spots and streaks of free lime.
- 30 to 42 inches, gray (N 5/, dry) to very dark-gray (N 3/, moist) partly weathered clay shale; stratification of shale still discernible; cracks and seams in shale thinly coated with free lime carbonate.

A wide variety of soils have developed from materials of the alluvial-fan and outwash deposits. These deposits occur over a range in elevation of several thousand feet, from high in the subhumid mountains to well out into the dry semiarid plains. The differences in age and lithology of the materials account for a number of soil series within a given climatic zone, but the number of soil series increased because the materials occur in two or more climatic belts. Some materials, each of relatively uniform lithology, occur in the Prairie, Chernozem, Chestnut, and Brown soil zones. These same materials are known to occur in the timbered mountainous areas where the soils were not classified on the basis of series and type.

A detailed study of the soils in timbered areas no doubt would reveal many series of several zonal, intrazonal, and azonal great soil groups developed under podzolization processes. The Gray-Wooded soils of Canada ⁴ (5, 8) which may be correlatives of the Gray Forest soils of the Russian classifications (13), are almost certainly represented. In addition, it is likely that detailed studies would reveal a few areas of Podzols and Brown Podzolic soils. Lithosolic, Bog, and Half Bog soils also are known to exist in central Montana.

The Bridger series includes Prairie soils that have zonal analogs in the Chernozem, Chestnut, and Brown soil zones. These soils have developed in gravelly to stony alluvial-fan and outwash materials derived from a variety of rocks including sedimentary, strongly metamorphosed sedimentary, and a large quantity of igneous rocks (chiefly andesite, rhyolite, and granite).

Profile description of Bridger stony loam:

- 0 to 2 inches, dark grayish-brown (10YR 3/2, dry) to very dark-brown (10YR 2/2, moist) loamy mulch; high organic-matter content; fine granular structure; slightly acid to neutral; fairly abundant subangular and rounded gravel, cobblestones, and large stones scattered over the surface and embedded in the soil.
- 2 to 20 inches, very dark-brown (10YR 2/2, dry) to black (10YR 2/1, moist) stony loam; coarse granular or fine nucliform structure; about neutral.
- 20 to 32 inches, grayish-brown (10YR 4.5/2, dry) to dark grayish-brown (10YR 3/2, moist) heavy stony loam or stony clay loam; medium blocky structure; neutral to slightly alkaline.
- 32 to 40 inches, grayish-brown (10YR 5/2, dry) to (10YR 4/2, moist) stony loam; ill-defined blocky structure; slightly alkaline but no free carbonate of lime present.

Bridger soils occupy a relatively narrow belt on the high slopes of mountains near the timber line, and scattering trees and clumps of trees and shrubs are common on many areas.

Hanson soils, occurring at slightly lower elevations than the Bridger, where precipitation is lower or where precipitation effectiveness is not so great, are not completely leached of their carbonate of lime. They have a horizon of lime carbonate accumulation and may be classed as Chernozems. Surface soils have a slightly higher

⁴ See footnote 2, p. 122.

pH range than those of Bridger soils but otherwise Hanson soils do not differ appreciably except for the presence of free lime carbonate in the subsoil. At successively lower elevations and in dryer sites, Hanson soils grade into Hilger (Chestnut) soils, and these into Roy (Brown) soils.

The soils of the four distinct climatic zones do not necessarily form contiguous areas, but in a few places on broad alluvial fans they grade downward from Chernozem soils on the high apexes of the fans to Chestnut soils on the middle parts of the fans and Brown soils on the lowest parts of the fans farthest from the mountains.

Soils developed on remnants of extremely old alluvial fans—said to be of Miocene, Pliocene, early Pleistocene, and probably older deposition—composed largely of limestone gravel, comprise eight series in three major climatic zones in the present classification. The upper part of the solums in most of these soils seems to have developed in a thin layer of silty loess or loesslike material, but the substratum consists principally of water-worn limestone gravel with the interstices between the gravel filled with firm or slightly indurated very highly calcareous silty lime carbonate or caliche.

Profile description of **Two Dot** loam, a representative Brown soil:

- 0 to 1 inch, grayish-brown (10YR 4.5/2, dry) to dark grayish-brown (10YR 3/2, moist) loamy mulch; flaky or thin platy structure; crushes to friable crumblike mass; effervesces weakly with dilute hydrochloric acid.
- 1 to 4 inches, grayish-brown (10YR 4/2, dry) to dark grayish-brown (10YR 3/2, moist) loam; soft crumb structure; weakly calcareous.
- 4 to 8 inches, light brownish-gray (10YR 6/2, dry) to grayish-brown (10YR 4/2, moist) heavy loam; medium blocky structure; strongly calcareous.
- 8 to 17 inches, light-gray (10YR 6.5/2, dry) to grayish-brown (10YR 4/2, moist) heavy loam or clay loam; medium blocky structure; contains an abundance of accumulated lime carbonate and a sprinkling of gravel.
- 17 to 26 inches, light-gray (10YR 7/2, dry) to grayish-brown (10YR 5/2, moist) heavy loam; ill-defined medium blocky structure; contains an abundance of accumulated lime and slightly more gravel than the horizon above.
- 26 to 34 inches, very pale-brown (10YR 7/3, dry) to brown (10YR 5/3, moist) gravelly loam; no definite structure; strongly calcareous.
- 34 to 44 inches, yellow (10YR 7/6, dry) to yellowish-brown (10YR 5/6, moist) mixture of loose fine sand and limestone gravel; calcareous. This is the little-altered substratum of old alluvium that is usually irregularly stratified and contains lenses of silt and fine sand. Some brown stains are usually present in the upper part of the substratum.

The associated soils with solums of intermediate thickness are classified as the **Musselshell** series, and the soils with very shallow solums (Skeletal soils) on steep slopes are mapped as the **Crago** series.

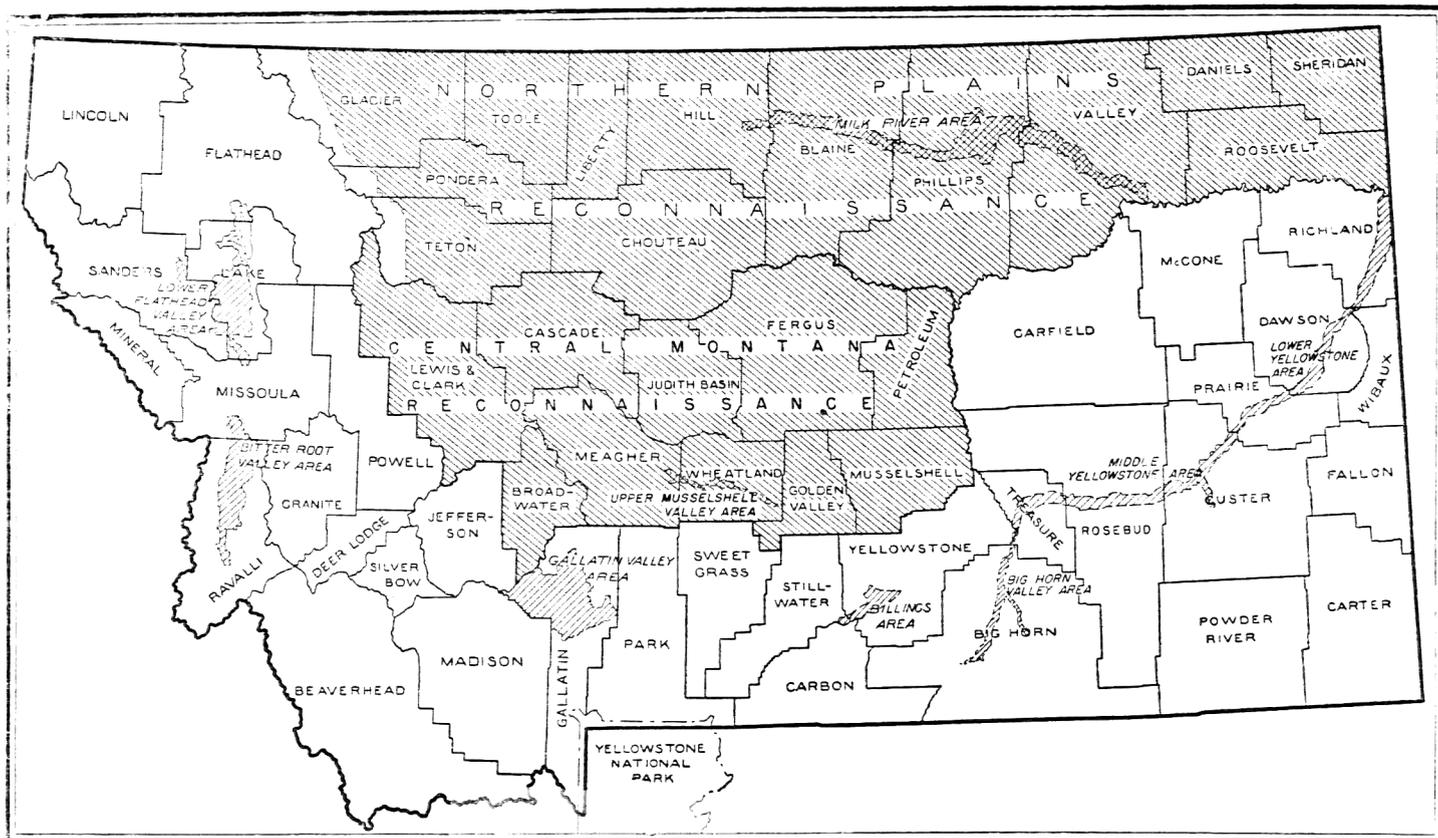
In the present classification, the **Gilt Edge** series includes Solonetz and solodized-Solonetz soils associated with **Two Dot** and related soils as well as with all soils developed in terrace and alluvial-fan gravel formed through processes of solonization in the Brown and Chestnut soil zones. Solonetz soils on the gravelly terraces and fans are confined largely to areas where the gravel deposits are relatively thin over moderately to strongly saline shale or to areas where the dust blown from the saline shale has formed a thin mantle of loess over the gravel. Because of this association, it would appear that the salts necessary to produce salinization and solonization are from a source other than the source of the gravel, and in all probability the saline condition was brought about after the gravel was deposited.

The **Fairfield** (Chestnut) and **Martinsdale** (Brown) series have developed in gravelly materials on high fans, benches, and terraces of age comparable to that of the gravel on which the Two Dot and associated soils occur. The gravel of these soils consists chiefly of rounded fragments of argillite and quartzite, but, as with the gravel beneath the Two Dot soils, the interstices between the gravel in the upper part of the substratum are filled with very limy silty calichelike material. In this respect Fairfield and Martinsdale soils differ from **Cheyenne** (Chestnut) soils on the lower and younger terraces. Cheyenne soils have a fairly well developed horizon of lime-carbonate accumulation in the fine earth material above the gravel but no marked accumulation of lime in the gravel.

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Areas surveyed in Montana shown by shading. Detailed surveys shown by northeast-southwest hatching; reconnaissance surveys shown by northwest-southwest hatching; cross-hatching indicates areas covered by both detailed and reconnaissance surveys.

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