
Soil Survey

Billings County North Dakota

By

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and party



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SOIL SURVEY OF BILLINGS COUNTY, NORTH DAKOTA

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INTRODUCTION

The soil survey map and report of Billings County, N. Dak., are intended to convey information concerning the soils, crops, and agriculture of the county to a wide variety of readers.

Farmers, landowners, prospective purchasers, and tenants ordinarily are interested in some particular locality, farm, or field. They need to know what the soil is like on a certain piece of land, what crops are adapted, what yields may be expected, and what fertilization and other soil-management practices are needed for best results. Many people do not wish to read the entire soil survey report, and they need not do so to obtain much of the information essential to their purpose.

A person interested in a particular piece of land should first locate it on the colored soil map accompanying the report. Then, from the color and symbol, the soil may be identified in the legend on the margin of the map. By using the table of contents, the reader can find the description of the soil type or types in the section on Soils. Under each soil type heading is specific information about that particular soil. There is a description of the landscape, including the lay of the land, drainage, stoniness (if any), vegetation, and other external characteristics; and the internal or profile characteristics of the soil—its color, depth, texture, structure, and chemical or mineralogical composition. The description includes information about present land use, crops grown, and yields obtained, and statements concerning possible uses and present and recommended management.

By referring to the section on Productivity Ratings and Land Classification, the reader may be able to compare soil types as to productivity for various crops and suitability for growing crops or for other uses. Further ideas concerning land use and soil management may be obtained from the section dealing with those subjects.

For the person unfamiliar with the area or county, a general description of the county as a whole is included in the first part of the report under the section on County Surveyed. Geography, physiography, regional drainage, relief, vegetation, climate, population, transportation facilities, and markets are discussed there. A brief summary at the end of the report gives a condensed description of the area and the more important facts concerning the soils and agriculture.

The agricultural economist and the general student of agriculture will be interested in the sections on Agriculture, Productivity Ratings and Land Classification, and Land Uses and Agricultural Methods.

Soil specialists, agronomists, experiment station and agricultural extension workers, and students of soils and crops will be interested in the more general discussion of soil in the section on Soils as well as in the soil type descriptions. They will also be interested

¹ The Soil Survey Division was transferred to the Bureau of Plant Industry, July 1, 1939.

² The party consisted of M. J. Edwards, A. C. Anderson, W. H. Buckhannan, F. E. Lesh, C. H. Wanser, K. V. Goodman, and O. C. Rogers, United States Department of Agriculture; and J. K. Ableiter, Charles E. Kellogg, A. P. Nelson, R. A. Erickson, C. J. Fox, A. C. Orvedal, M. G. Cline, G. A. Johnsgard, M. M. Striker, L. L. Anderson, C. A. Mogen, and W. M. Johnson, North Dakota Agricultural Experiment Station.

in the sections on Productivity Ratings and Land Classification and Land Uses and Agricultural Methods.

For the soil scientist, the section on Morphology and Genesis of Soils presents a brief technical discussion of the soils and of the soil-forming processes that have produced them.

COUNTY SURVEYED ³

Billings County is in the southwestern quarter of North Dakota (fig. 1). Its southern boundary is about 48 miles north of the South Dakota line, and its western boundary is about 20 miles east of the Montana line. Medora, the county seat, is 130 miles west of Bismarck. The area of the county is approximately 1,168 square miles, or 747,520 acres.

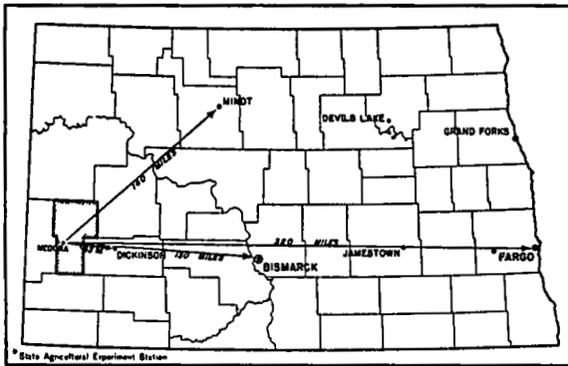


FIGURE 1.—Location of Billings County in North Dakota.

Billings County overlies the Fort Union formation of the Tertiary period (8).⁴ This formation is composed of stratified light-yellow gray, and olive-gray sand, silt, and clay, together with numerous beds of lignite interspersed throughout. The upper layers of this formation are composed of sandstone and shale, and remnants of these consolidated layers protectively cap and preserve the few remaining buttes that rise well above the general plain of the immediately surrounding country. The most conspicuous of these remnants are Bullion, Saddle, and Green River Buttes, Bullion Butte being the largest and most prominent. No part of the county has been subjected to glaciation.

Physiographically, Billings County lies on the gently sloping plain known as the Missouri Plateau, or Missouri Slope. Since the formation of this plateau, severe dissection by stream action has taken place. The Little Missouri River, which enters the county at a point 6 miles east of the southwestern corner and leaves it at the northwestern corner, has been responsible for most of the dissection.

³ The soil survey of Billings County was made at the request of the local county authorities, in order to provide accurate data for the classification and evaluation of rural lands for local taxation purposes. The North Dakota Agricultural Experiment Station made up the land classification from the maps. On completion of their tabulation, these data were turned over to the county auditor's office for use as a basis for assessments. Funds were furnished by the county to pay for the State expenses. An explanation of the land classification is given by Kellogg and Abelter (7).

⁴ *Italic numbers in parentheses refer to Literature Cited, p. 111.*

With the aid of its tributaries, this river has cut a fairly deep gorge-like valley from south to north throughout the county. This strip of rough land, known as the Little Missouri Badlands, borders practically the entire western edge of the county and extends eastward for a distance ranging from 12 to 20 miles (pls. 1 and 2). It covers about two-thirds of the county. Most of the eastern edge of the Badlands forms a distinct drainage divide, as dissection by the Little Missouri River has produced a sharp break in the westward extension of the Missouri Plateau. East of this divide streams flow eastward and southeastward into the Knife, Green, Heart, and Cannonball Rivers.

Figure 2 presents a generalized map of the surface features and drainage of this county. On the bases of surface features the county may be divided into seven sections:

(1) The smooth rolling uplands of the Missouri Plateau east of the drainage divide differ strikingly in relief from the Badlands. For the most part, this section is gently rolling to rolling, and there are few steep bare areas. Tributary streams that head here have gentle gradients. Maximum differences in elevation are about 80 feet. Surface drainage is good. This is the dry-land farming section that produces nearly all of the wheat and most of the other crops grown in the county.

(2) A comparatively narrow valley floor borders the Little Missouri River, flanked on either side by the steep slopes of the Badlands. Favorable topography, protection from winter storms, and available artesian water have led to the establishment of many of the ranch homes here.

(3) Other low terraces and stream bottoms of significant width are those along the Green River, flanked by long gentle slopes, and those along the Knife River, flanked by hills less steep than those along the Little Missouri River. Drainage is good in most places, and there are only a few poorly drained strips.

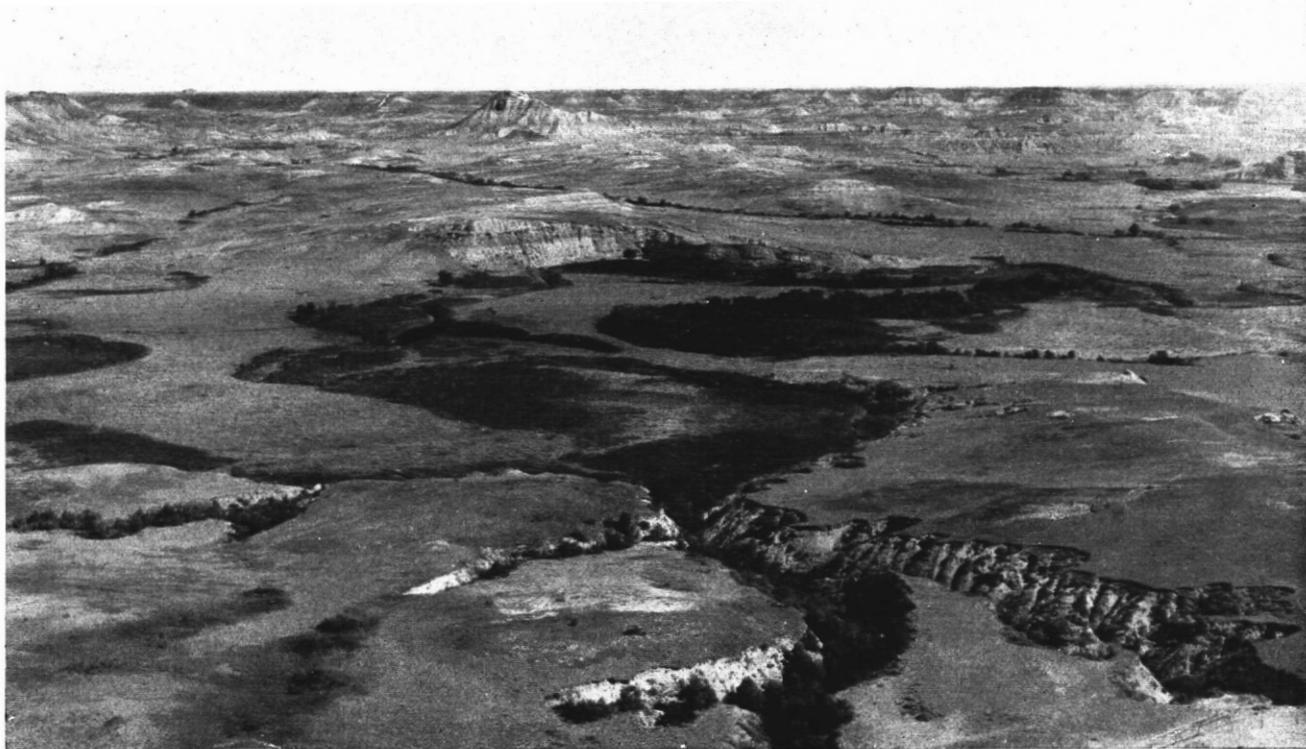
(4) Old high terraces here and there interrupt the rough landscape along the Little Missouri River. Most of these terraces or stream bench remnants have a very gently undulating surface, lie from 100 to 400 feet above the valley floor, and have at least a thin gravelly layer immediately above the underlying Fort Union beds. They occupy small areas, ranging from a few to several hundred acres, generally surrounded by extremely steep slopes.

(5) Rolling to steep grassed uplands occupy the Knife River drainage basin, forming a distinct unit in the northeastern part of the county.

(6) Steep, relatively bare slopes characterize the Badlands nearest the Little Missouri River. The relief becomes more rugged from south to north. Maximum local differences in elevation range from about 200 to nearly 500 feet. In places these steep bare slopes induce excessive and destructive runoff, and deep wide ditches extend through most of the tributary valleys and drainageways.

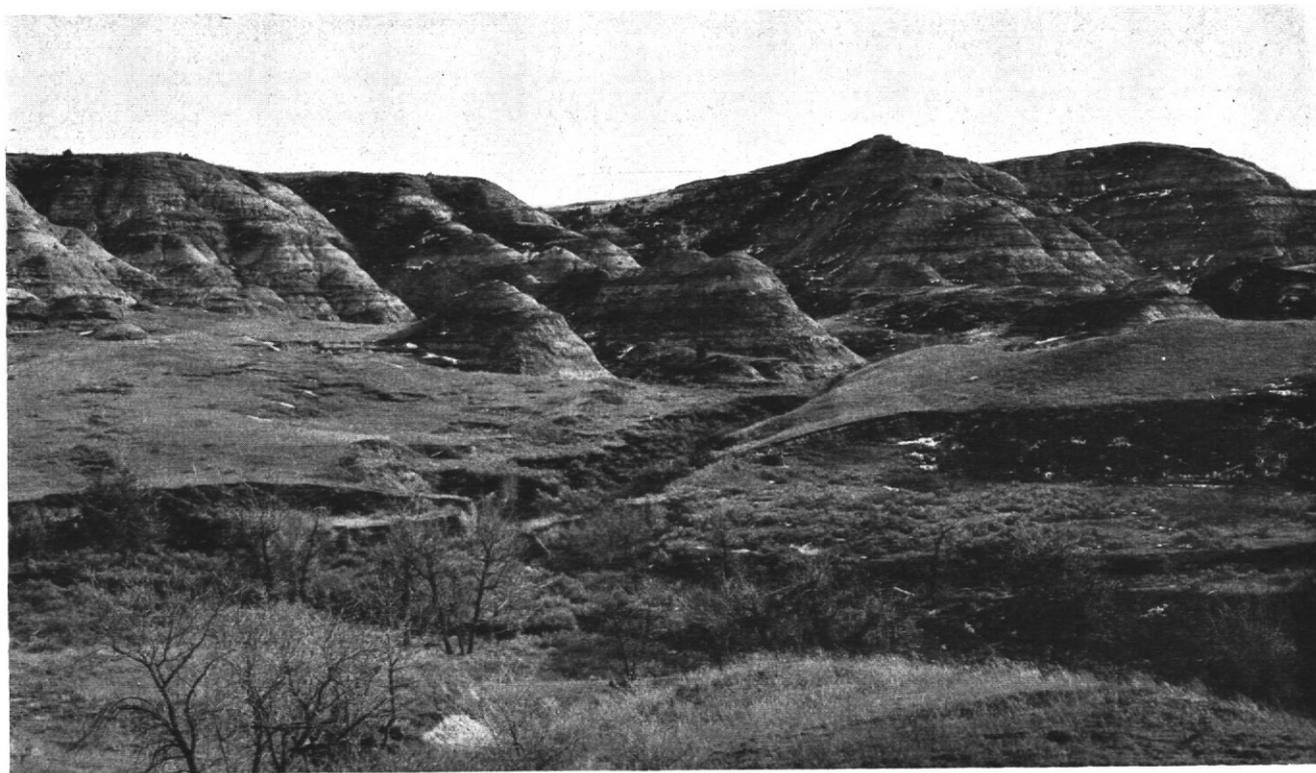
(6A) Farther back from the river the slopes of the Badlands are more generally grass-covered and less precipitous, compared with those bordering the river.

(7) In a few small stony areas on the border between the Badlands and the comparatively smooth upland sections, fragments of indurated sandstone cover the surface or lie just beneath it.



Badlands along the Little Missouri River in Billings County.

Courtesy of H. C. Hanson



Close view of Badlands along the Little Missouri River

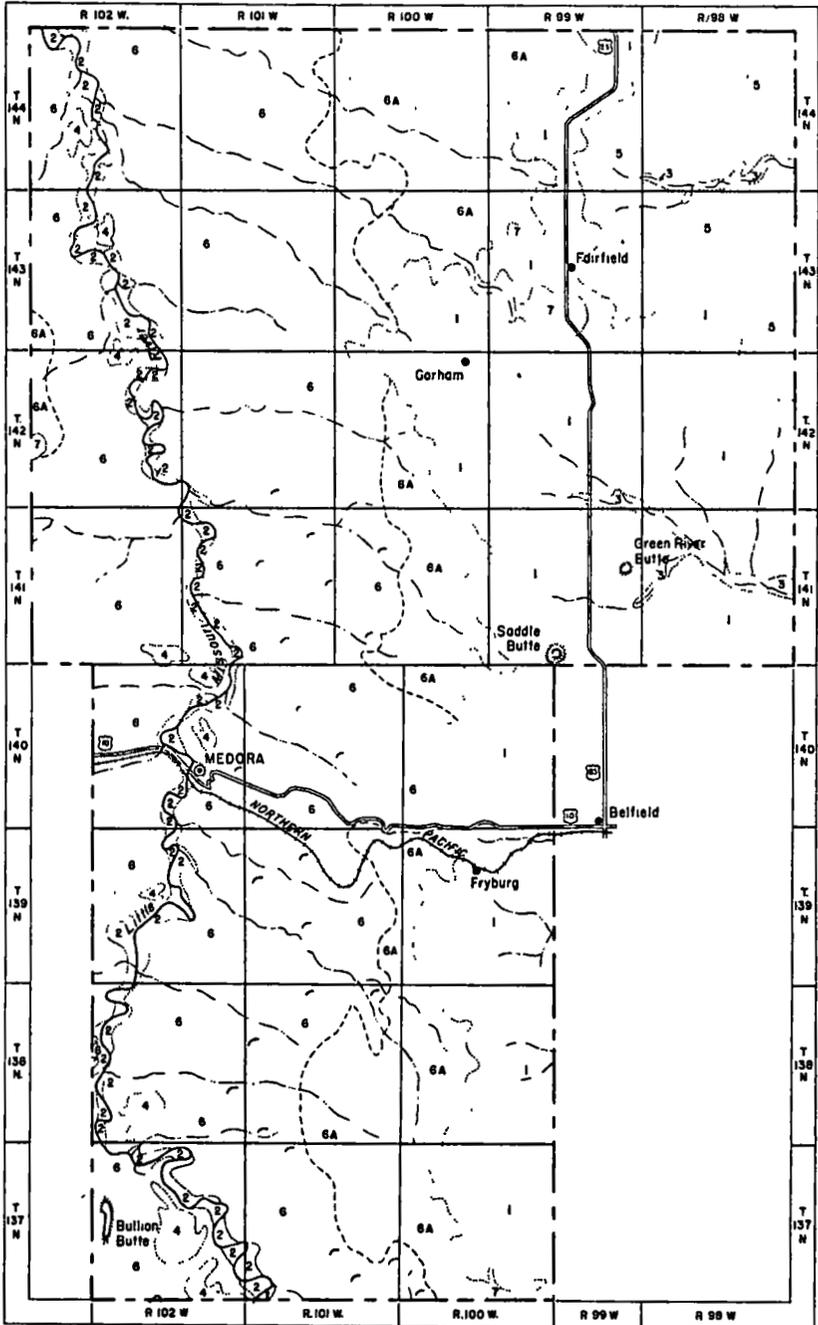


FIGURE 2.—Surface features and drainage of Billings County, N. Dak. 1, Smooth to rolling uplands; 2, Little Missouri River Valley floor; 3, other low terraces and stream bottoms; 4, old, high terraces; 5, rolling to steep uplands of Knife River watershed; 6, Badlands, relatively bare; 6A, Badlands, relatively grass covered; 7, stony areas (indurated sandstone); curves designate the general occurrence of scoria. Broken lines within the Badlands between the 6 and 6A areas are less definite boundaries than the dotted lines.

Following are elevations above sea level of points in and near Billings County:

	<i>Feet</i>
U. S. Coast and Geodetic Survey station, top of Saddle Butte, sec. 33, T. 141 N., R. 99 W.....	2, 846
U. S. Coast and Geodetic Survey station, Badland, on the gently rolling divide between the Heart River and the Little Missouri River, sec. 8, T. 137 N., R. 100 W.....	3, 028
U. S. Coast and Geodetic Survey station, top of Sentinel Butte about 4 miles south of the village of Sentinel Butte and about 18 miles west of Medora, in Golden Valley County.....	3, 420
Belfield railroad station, 2 miles east of the Billings County line and east from Fryburg, in the valley of the Heart River.....	2, 603
Fryburg railroad station, about half a mile east of the crest of the divide between the Heart River and the Little Missouri River.....	2, 790
Medora railroad station, on alluvial flat of the Little Missouri River.....	2, 290

The Badlands are largely grazing land with small tillable areas used mostly to produce forage for winter feeding of range cattle. The eastern part of the county, which is the smoother part, is used partly for subsistence feed crops and partly for cash grain crops, principally hard spring wheat.

Billings County was formed from unorganized territory in 1879, and since that date, parts have been taken from it to form parts or all of Bowman, Slope, Golden Valley, and McKenzie Counties. Its present boundaries were established in 1915, when the last part was taken from it to form Slope County. According to the United States census for 1940, the population of Billings County is 2,531, all classed as rural. The largest village is Medora, which has a population of about 215. Fryburg, the only other village, has a population of about 100. Most of the people of Billings County are of European descent, and approximately one-half of them are foreign-born. Most of the native-born settlers came from States immediately east of North Dakota—principally Minnesota, Wisconsin, and Iowa—and some came from the eastern part of the State. People of Czecho-Slovakian and German-Russian descent dominate in the northeastern part of the county, and most of the people of German descent are located in the district immediately southwest of Belfield, which is in Stark County. People of English, Irish, and German descent predominate along the Little Missouri River. Bohemians, Norwegians, and Poles live in various parts of the county.

Historically, Billings County and the Badlands are of interest because Theodore Roosevelt came here in the eighties in search of health. The former sites of his ranches—one about 30 miles north of Medora and the other about 15 miles south of that town—are still pointed out with pride. It was the dream of Marquis de Mores, a French nobleman, who established himself at Medora in the boom days of ranching, to make Medora the meat-packing center of the Dakotas, Montana, and Wyoming. Wibaux was another Frenchman with big ranching interests. Some of the present ranchers came overland as cowboys in the drives from Texas.

The historical and scenic interest of Medora and its vicinity has led to the establishment of Roosevelt State Park, an area of 3,000 acres, and Roosevelt Recreational Demonstration Area (Federal), totaling 63,635 acres, in some of the most picturesque Badlands country. The Petrified Forest north of Medora is one of the features. Dude ranching is being introduced in anticipation of the tourist trade.

Rail transportation is afforded by the Northern Pacific Railway. Shipping points for produce are Medora, Fryburg, and Belfield. A small number of livestock and a small quantity of wheat are marketed from the northeastern corner of the county at Killdeer, Dunn County, over a branch of the Northern Pacific Railway. Practically all of the livestock and wheat is marketed in St. Paul, Minneapolis, and Chicago. Dairy products, mostly cream, are shipped to nearer markets, for example, Mandan, N. Dak. Poultry is shipped both to nearby and distant markets.

Two well-graded and graveled United States highways serve the county. United States Highway No. 10 traverses it east and west through Medora, and United States Highway No. 85 traverses the eastern part from north to south. These two highways intersect at Belfield. Most of the local roads throughout the smooth uplands are fairly well graded, and a few are surfaced with scoria. Throughout the Little Missouri Badlands road conditions are only fair except on United States Highway No. 10; most of the roads are improved trails that have not been straightened or built to grade. Generally, they are easily traveled by automobile and truck, but they are not suitable for rapid travel or for travel during all weather conditions. Inasmuch as this section specializes in raising cattle, which are marketed on the hoof, road conditions are not so vital a factor in the marketing of produce as in areas where grain or dairy products are the main sources of income.

Water for livestock throughout practically all of the smooth uplands is readily obtained from flowing springs, improved seeps, or drilled shallow wells. Throughout the Badlands watering conditions are variable. The Little Missouri River is the only stream that generally has a permanent flow of water. Artesian wells are obtainable throughout this valley by drilling to a depth ranging from 180 to 650 feet, and practically all of the ranches located in the valley of this stream have one or more artesian wells. Several tributaries of the Little Missouri River have permanent water holes in them, and throughout much of the Badlands springs and seeps afford watering facilities. Probably the largest spring is on the Open A (A) Ranch, in sec. 21, T. 142 N., R. 100 W. In numerous areas, totaling a few square miles, scattered throughout this section summer grazing is not feasible, owing to lack of available water at that time of the year.

VEGETATION ⁵

The native vegetation of Billings County, other than that on the valley floor along the Little Missouri River, consists principally of short grasses with a small quantity of tall grasses intermixed. The most common growth on the well-drained fertile loam soils is a mixture of the blue grama, threadleaf sedge (niggerwool), and western

⁵ The plants mentioned throughout this publication were identified by H. C. Hanson, botanist at the North Dakota Agricultural Experiment Station when this survey was made. Information relative to their occurrence, use, relative values, and their correlation with the important soil groups was obtained as the result of numerous field inspections made with him. The botanical names were verified, so far as possible, by C. O. Erlanson, ecologist, Division of Plant Exploration and Introduction, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture. For further information on the correlation of grassland types and soil types within this section refer to Hanson (3).

needlegrass, with blue grama dominating. Western wheatgrass and blue grama are the most common grasses on the fertile clay and clay loam soils of the uplands and bottoms. Intermixed with these grasses is generally a variable quantity of little clubmoss, occupying, in places, well over 50 percent of the ground surface. Although clubmoss has no value for forage, it is generally considered valuable for protection against erosion in areas that otherwise might be bare. The dominant grasses growing on the sandy soils are niggerwool and sandgrass. Grama and western needlegrass are not uncommon on the loamier parts of these sandy soils. Soils that are at all salty invariably support a high proportion of saltgrass in the cover. Low salty areas, such as those along draws from seeps, support a growth of sedges, reeds, and arrowgrass. The latter is markedly poisonous to livestock. Shallow, droughty, or steeply sloping soils of the uplands commonly support a vegetative cover composed largely of little bluestem, plains muhly, and niggerwool. Redtop and foxtail generally grow along the edges of wet spots. Big bluestem is dominant in many of the small draws where well-drained fertile loamy alluvium has accumulated. Other less common but nevertheless important grasses of the fertile soils of the uplands are buffalo grass, side-oats grama, slender wheatgrass, junegrass, three-awn grass, and Kentucky bluegrass.

Small trees and brush grow in many of the larger drains and coulees. Ash, elm, quaking aspen, and boxelder are the most common trees. This vegetation generally grows in narrow strips, ranging from 50 to 200 feet in width, along the drains or ditches or at the heads of steep drains extending into the larger valleys tributary to the Little Missouri River. Few of the ash, elm, aspen, and boxelder trees reach a height of more than 30 feet and a diameter of more than 8 inches. Throughout the Little Missouri Badlands redcedar is common. Its most common occurrence is in the steep rough gulches of the roughest sections of the Badlands, whereas the most common occurrence of the ash, elm, aspen, and boxelder is in the smoother valleys and the narrow alluvial strips of the less precipitous coulees and drains. A very few scattered ponderosa pine (western yellow pine) trees make their appearance south of a line drawn approximately where United States Highway No. 10 crosses the county. Billings County probably marks the most eastern and northern occurrence of ponderosa pine in North Dakota.

Trees are confined generally to the well-developed coulees and valleys. Brush growth, consisting for the most part of buckbrush, buffalo-berry, pin cherry, chokecherry, plum, silverberry, and juneberry, extends along many of the shallow drainageways and slight depressions that reach into the smooth upland areas.

It is worthy of note that the tree and brush growth in places exposed to the south is scant and more scrubby than that growing on the northward-facing slopes. In fact, throughout the rougher areas it is common for grass-, tree-, or brush-covered northward-facing slopes to be associated with practically bare southward-facing slopes.

Two herbs of importance for their grazing value are winterfat and saltbush. They are common but not abundant. The former is particularly easily exterminated by overgrazing.

Gray sagebrush (*Artemisia cana*) is the most widespread of the sages. False tarragon or green sagebrush (*A. dracunculoides*), big

sagebrush (*A. tridentata*), green sagebrush (*A. caudata*), and pasture sage (*A. frigida*) are common. The presence of the latter on good grazing sites is an indication of overgrazing. Big sagebrush is scattered throughout the Little Missouri Badlands and seems to be more common in Billings County than in McKenzie County. Cacti, especially the ball cactus (*Coryphantha vivipara*), pricklypear (*Opuntia polyacantha*), and small pricklypear (*O. fragilis*), grow throughout the county. The latter commonly grows along the edges of the clay spots or pits of the alkali-claypan (Solonetz) soils.

Two poisonous plants are included in the native vegetation. Locoweed grows in spots, especially on the loam and clay loam soils of the uplands, and arrowgrass grows on practically all of the moist salty clay areas, especially of the alluvial clay soils, undifferentiated, and comprises from 10 to 50 percent of their vegetative cover. Only occasionally do these plants cause losses among livestock.

The native vegetation on the alluvial soils of the Little Missouri River Valley consisted of a growth of cottonwood trees interspersed in many places by fairly large openings of grass or brush; and in a few places there were stands of ash and elm. Cottonwood trees grew most commonly in belts paralleling the river, especially on the sandier natural levees, although in some places they occupied the entire valley. In places, these trees developed a dense stand reaching a height of approximately 60 feet and, in some stands, a diameter ranging from 18 to 24 inches. At present much of the valley has been cleared of trees, although many strips and small groves of cottonwood remain.

The most common brush growth on the soils of the valley includes buffaloberry, wild rose, ash and elm saplings, buckbrush, and sage.

LIST OF PLANTS IN BILLINGS COUNTY, N. DAK.

GRASSES

<i>Agropyron pauciflorum</i> (Schwein.) Hitchc. (<i>A. tenerum</i> Vasey)	Slender wheatgrass.
<i>Agropyron repens</i> (L.) Beauv-----	Quackgrass.
<i>Agropyron smithii</i> Rydb-----	Bluestem, or western wheatgrass.
<i>Agrostis alba</i> L-----	Redtop.
<i>Andropogon furcatus</i> Muhl-----	Bluejoint turkeyfoot, or big bluestem.
<i>Andropogon hallii</i> Hack-----	Turkeyfoot, or sand bluestem.
<i>Andropogon scoparius</i> Michx-----	Prairie beardgrass, or little bluestem.
<i>Aristida longiseta</i> Steud-----	Red three-awn, or triple-awn grass.
<i>Beckmannia syzigachne</i> Steud. Fern	American sloughgrass.
<i>Bouteloua curtipendula</i> (Michx.) Torr.	Side-oats grama.
<i>Bouteloua gracilis</i> (H. B. K.) Lag-----	Blue grama.
<i>Bromus inermis</i> Leyss-----	Smooth brome.
<i>Buchloe dactyloides</i> (Nutt.) Engelm. (<i>Bulbilia dactyloides</i> Raf.).	Buffalo grass.
<i>Calamagrostis inexpansa</i> A. Gray (<i>C. americana</i> Scribn.).	Northern reedgrass.
<i>Calamovilfa longifolia</i> (Hook.) Scribn.	Prairie sandgrass.
<i>Distichlis stricta</i> (Torr.) Rydb	Desert saltgrass.
<i>Elymus canadensis</i> L-----	Canada wild-rye.
<i>Elymus macounii</i> Vasey-----	Macoun wild-rye.
<i>Hordeum jubatum</i> L-----	Foxtail barley, wild barley, or squirrel-tail.
<i>Koeleria cristata</i> (L.) Pers-----	Junegrass, or prairie junegrass.
<i>Muhlenbergia cuspidata</i> (Torr.) Rydb--	Plains muhly.
<i>Poa palustris</i> L-----	Fowl bluegrass, or false-redtop.
<i>Poa pratensis</i> L-----	Kentucky bluegrass.
<i>Poa secunda</i> Presl-----	Sandberg bluegrass.

<i>Puccinellia nuttalliana</i> (Schult.) Hitchc. (<i>P. airoides</i> Nutt.).	Nuttall or Zawadke alkali-grass.
<i>Spartina pectinata</i> Link (<i>S. michauxiana</i> Hitchc.).	Prairie cordgrass.
<i>Sporobolus cryptandrus</i> (Torr.) A. Gray.	Sand dropseed.
<i>Stipa comata</i> Trin. and Rupr.-----	Needle-and-thread, western needlegrass, or green porcupinegrass.
<i>Stipa spartea</i> Trin.-----	Porcupinegrass.
<i>Stipa viridula</i> Trin.-----	Green needlegrass, or feathergrass.

TREES

<i>Acer negundo</i> L.-----	Boxelder.
<i>Fraxinus lanceolata</i> Borkh.-----	Green ash.
<i>Juniperus scopulorum</i> Sarg.-----	Colorado juniper, or western redcedar.
<i>Pinus ponderosa</i> Laws.-----	Ponderosa pine, or western yellow pine.
<i>Populus deltoides</i> Marsh.-----	Cottonwood.
<i>Populus tremuloides</i> Michx.-----	Quaking aspen.
<i>Prunus pennsylvanica</i> L.-----	Pin cherry.
<i>Prunus virginiana</i> L.-----	Chokecherry.
<i>Prunus</i> sp.-----	Wild plum.
<i>Quercus macrocarpa</i> Michx.-----	Mossycup or bur oak.
<i>Salix interior</i> Rowlee.-----	Water willow.
<i>Salix missouriensis</i> Bebb.-----	Diamond willow.
<i>Ulmus americana</i> L.-----	Elm.

OTHER PLANTS

<i>Achillea millefolium</i> L.-----	Common yarrow.
<i>Agoseris glauca</i> (Pursh) Steud.-----	Prairie dandelion.
<i>Ambrosia psilostachya</i> DC.-----	Perennial ragweed.
<i>Amelanchier alnifolia</i> Nutt.-----	Common serviceberry, or Juneberry.
<i>Artemisia cana</i> Pursh.-----	Gray sagebrush.
<i>Artemisia caudata</i> Michx.-----	Green sagebrush.
<i>Artemisia dracunculoides</i> Pursh.-----	False tarragon, or green sagebrush.
<i>Artemisia frigida</i> Willd.-----	Pasture sagebrush, or little sagebrush.
<i>Artemisia gnaphalodes</i> Nutt.-----	Cudweed, or white sagebrush.
<i>Artemisia tridentata</i> Nutt.-----	Big sagebrush, or desert sagebrush.
<i>Asclepias speciosa</i> Torr.-----	Showy milkweed.
<i>Aster ericoides</i> L. (<i>Aster multiflorus</i> Ait.).	Wreath aster, or white prairie aster.
<i>Aster oblongifolius</i> Nutt.-----	Aromatic aster.
<i>Aster ptarmicoides</i> Torr. and Gray.-----	White upland aster.
<i>Astragalus pectinatus</i> Dougl.-----	Narrow-leaved milkvetch.
<i>Atriplex nuttallii</i> S. Wats.-----	Nuttall saltbush.
<i>Campanula rotundifolia</i> L.-----	Harebell, or bluebell.
<i>Carex filifolia</i> Nutt.-----	Threadleaf sedge, or niggerwool.
<i>Carex stenophylla</i> Wahl.-----	Upland sedge.
<i>Cerastium arvense</i> L.-----	Starry cerastium, or prairie chickweed.
<i>Chrysopsis villosa</i> (Pursh) Nutt.-----	Hairy golden-aster.
<i>Chrysothamnus graveolens</i> (Nutt.) Greene.	Rabbitbrush.
<i>Cirsium undulatum</i> (Nutt.) Spreng.-----	Prairie thistle.
<i>Cornus stolonifera</i> Michx.-----	Red-osier dogwood.
<i>Coryphantha vivipara</i> (Nutt.) Britt. and Rose.	Ball cactus.
<i>Crataegus chrysoarpa</i> Ashe.-----	Hawthorn.
<i>Delphinium bicolor</i> Nutt.-----	Low larkspur.
<i>Delphinium virscens</i> Nutt.-----	Tall larkspur.
<i>Dondia</i> sp.-----	Seepweed.

<i>Echinacea angustifolia</i> DC.....	Purple coneflower.
<i>Elaeagnus argentea</i> Pursh.....	Silverberry.
<i>Eriogonum flavum</i> Nutt.....	Yellow eriogonum.
<i>Eurotia lanata</i> (Pursh) Mog.....	Winterfat.
<i>Gaillardia aristata</i> Pursh.....	Common perennial gaillardia.
<i>Glycyrrhiza lepidota</i> Nutt.....	Wild licorice.
<i>Grindelia squarrosa</i> (Pursh) Dunal.....	Curlycup gumweed.
<i>Gutierrezia sarothrae</i> (Pursh) Britt. and Rusby.	Broom snakeweed.
<i>Iva axillaris</i> Pursh.....	Poverty weed.
<i>Juncus balticus</i> Willd.....	Wire rush.
<i>Juncus</i> spp.....	Rush (several species).
<i>Juniperus communis</i> var. <i>depressa</i> Pursh.	Dwarf juniper.
<i>Juniperus horizontalis</i> Moench.....	Creeping juniper, or creeping cedar.
<i>Lactuca ludoviciana</i> (Nutt.) DC.....	Western wild lettuce.
<i>Lactuca pulchella</i> Pursh (DC.).....	Blue wild lettuce.
<i>Lappula occidentalis</i> (S. Wats.) Greene.	Low stickseed.
<i>Lepachys columnaris</i> (Sims) Torr. and Gray.	Long-headed coneflower.
<i>Lepidium densiflorum</i> Schrad.....	Peppergrass.
<i>Liatris punctata</i> Hook.....	Gayfeather, or blazing-star.
<i>Liatris scariosa</i> Willd.....	Gayfeather, or blazing-star.
<i>Linum lewisii</i> Pursh.....	Prairie flax, or Lewis wild flax.
<i>Linum rigidum</i> Pursh.....	Stiffstem flax, or wild yellow flax.
<i>Lomatium daucifolium</i> (Nutt.) Coult. and Rose.	Wild parsley.
<i>Lotus americanus</i> (Nutt.) Bisch.....	Birdsfoot deervetch, or prairie birdsfoot trefoil.
<i>Lygodesmia juncea</i> (Pursh) D. Don....	Skeletonweed.
<i>Malvastrum coccineum</i> (Nutt.) A. Gray..	False-mallow.
<i>Mentha canadensis</i> L.....	Wild mint.
<i>Mertensia lanceolata</i> Pursh (DC.)....	Bluebell, or wild forget-me-not.
<i>Monarda fistulosa</i> L.....	Wildbergamot.
<i>Mustneon divaricatum</i> (Pursh) Coult. and Rose.	
<i>Oenothera serrulata</i> Nutt.....	Tooth-leaved evening-primrose.
<i>Opuntia fragilis</i> (Nutt.) Haw.....	Small pricklypear.
<i>Opuntia polyacantha</i> Haw.....	Pricklypear.
<i>Oxytropis lambertii</i> Pursh.....	Crazyweed, or locoweed.
<i>Penstemon albidus</i> Nutt.....	White beardtongue.
<i>Penstemon eriantherus</i> Pursh (Penste- mon cristatus Nutt.)	Crested beardtongue.
<i>Penstemon gracilis</i> Nutt.....	Slender beardtongue.
<i>Petalostemon oligophyllus</i> (Torr.) Rydb..	White prairie clover.
<i>Petalostemon purpureus</i> (Vent) Rydb..	Purple prairie clover.
<i>Phlox hoodii</i> Richards.....	Moss phlox.
<i>Plantago purshii</i> Roem. and Schult....	Wooly Indianwheat, or prairie plantain.
<i>Polygonum</i> sp.....	Smartweed.
<i>Potentilla strigosa</i> Pall.....	Prairie cinquefoil.
<i>Psoralea argophylla</i> Pursh.....	Silverleaf scurfpea.
<i>Psoralea esculenta</i> Pursh.....	Indian breadroot, Indian turnip, or tipsin.
<i>Rhus rydbergii</i> Small.....	Western poison-ivy.
<i>Rhus trilobata</i> Nutt.....	Lemonade sumac, or three-lobed sumac.
<i>Rosa woodsii</i> Lindl.....	Woods rose, or wild rose.
<i>Salicornia rubra</i> A. Nels.....	Glasswort.
<i>Salsola pestifer</i> A. Nels. (Salsola tra- gus Reichenb.)	Russian-thistle.
<i>Setaginella densa</i> Rydb.....	Little clubmoss.

<i>Senecio perpleæus</i> A. Nels.....	Ragwort.
<i>Shepherdia argentea</i> Nutt. (<i>Lepargyrea argentea</i> (Nutt.) Greene).	Silver buffaloberry.
<i>Solanum triflorum</i> Nutt.....	Cut-leaved nightshade.
<i>Solidago canadensis</i> L.....	Canada goldenrod.
<i>Solidago missouriensis</i> Nutt.....	Early goldenrod.
<i>Solidago nemoralis</i> Ait.....	Oldfield goldenrod.
<i>Solidago mollis</i> Bartl.....	Soft goldenrod.
<i>Solidago rigida</i> L.....	Stiff goldenrod.
<i>Steironema ciliatum</i> (L.) Raf.....	Fringed loosestrife.
<i>Symphoricarpos occidentalis</i> Hook.....	Wolfberry or buckbrush.
<i>Teucrium occidentale</i> A. Gray.....	Wood sage.
<i>Thermopsis rhombifolia</i> (Nutt.) Richards.	False lupine.
<i>Triglochin maritima</i> L.....	Arrowgrass.
<i>Verbena bracteosa</i> Michx.....	Bracted vervain.
<i>Vicia sparsifolia</i> Nutt.....	Wild vetch.
<i>Viola nuttallii</i> Pursh.....	Nuttall violet.
<i>Yucca glauca</i> Nutt.....	Soapweed yucca, or beargrass.
<i>Zigadenus chloranthus</i> Richards.....	Deathcamas.

CLIMATE

The climate, which is typically semiarid and continental, is characterized by long cold winters and short warm summers.

The mean annual precipitation varies considerably from a mean of 15.80 inches at Dickinson, Stark County, N. Dak., and a mean of 16.13 inches at Fryburg. This is about 20 percent less than the precipitation recorded at Fargo, N. Dak. During the period from April 1 to September 30, an average of 12.38 inches, or about three-fourths of the mean annual precipitation, falls at Fryburg; and one-half in the 3 months of May, June, and July. The rainfall during this important period, however, varies considerably from one year to another, and seasons of severe drought are not uncommon.

Periods when hot dry winds blow from the south or southwest occasionally do considerable damage to crops during June or July. Temperatures as high as 110° F. and as low as -47° have been recorded at Dickinson, but such extremes are usually of short duration, although occasionally the low temperature may continue for several days. The summer days are long, warm, frequently windy, and only rarely cloudy. The nights are generally cool. The winter days are short and cold with occasional short periods of rather high temperatures; temperatures of 58° and 63° have been recorded in January and February. The spring season is, in general, short and erratic, the change from winter to summer being fairly rapid.

The average frost-free season at Dickinson extends from May 20 to September 14, a period of 117 days, which is about 10 days shorter than the frost-free season at Fargo. Killing frosts have occurred as late as June 25 and as early as August 9. In the latitude in which this county lies, the hours of sunlight during the growing season are noticeably long.

During late spring and early summer, duststorms are a potential menace to crops and to human comfort, especially in dry years. These storms are more local in character than the great storms that covered large areas in eastern North Dakota. Cultivated fields are particularly susceptible to wind erosion if a comparatively dry period, accompanied by strong winds, comes before the seedlings are firmly established. Under such conditions seedlings of grain and potato shoots may be destroyed and valuable surface soil removed to be drifted along fences and into ditches. As more rolling and sandy land comes into cultivation, and as the organic matter of the soil becomes depleted, the problem of soil blowing becomes serious. Cultural practices, including less plowing and greater use of such tools as the duckfoot cultivator, are being directed against this menace.

Local hailstorms, especially during the hot periods of June and July, frequently damage crops severely; but, owing to their local character, the total damage is not great. The State furnishes excellent protection in the form of insurance at cost against loss from this hazard.

Variations in the summer weather are responsible for great differences in damage by black stem rust of wheat, but varieties of wheat showing resistance to rust have been introduced. The disease is favored by frequent periods of rain interspersed with hot days.

Although the transition from winter to summer is rapid and not altogether pleasant as compared with the long spring season of more eastern sections, the autumns generally are dry and pleasant. During September the nights become cooler and gradually the winter season comes on. Usually the ground freezes before much snow falls. Snowfall is irregular in winter, and frequently the ground remains practically bare of snow throughout this season.

Runoff from spring, summer, and fall rainfall is pronounced, especially in the hillier parts of the county, as the rainfall comes largely as brief heavy showers. A large proportion of the total rainfall in the Badlands runs off the surface, and within a few minutes empty valleys may become courses of raging torrents that subside and disappear shortly after the shower is over. In areas of the same soil material the great differences in the amount of moisture that can penetrate the ground, owing to differences in the degree of slope, are reflected in the character of the soil, the native vegetation, and the adaptability of the various cultivated plants.

Table 1 gives climatic data from the records of the United States Weather Bureau station at Dickinson, Stark County, and table 2 gives precipitation records from the station at Fryburg, Billings County. The data from the Dickinson station are fairly representative of climatic conditions in the smoother parts of Billings County.

TABLE 1.—Normal monthly, seasonal, and annual temperature and precipitation at Dickinson, Stark County, N. Dak.

-[Elevation, 2,543 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total for the driest year (1936)	Total for the wettest year (1914)	Average snowfall
	°F	°F.	°F	Inches	Inches	Inches	Inches
December.....	16.4	60	-37	0.50	0.79	0.29	4.3
January.....	10.5	58	-47	.42	.55	.04	4.0
February.....	13.1	63	-44	.43	.42	.43	3.9
Winter.....	13.3	63	-47	1.35	1.76	.76	12.2
March.....	25.3	85	-29	.74	.59	1.27	5.8
April.....	42.1	92	-6	1.08	.21	.80	3.2
May.....	52.2	106	11	2.33	.61	2.61	1.6
Spring.....	39.9	106	-29	4.15	1.41	4.68	10.0
June.....	61.7	108	27	3.37	.92	7.88	.0
July.....	68.2	108	29	2.17	.29	5.50	0
August.....	66.3	110	24	1.99	1.23	2.05	0
Summer.....	65.4	110	24	7.53	2.44	15.43	0
September.....	56.0	102	12	1.32	.23	1.20	2
October.....	43.6	93	-15	.98	.39	.42	1.6
November.....	28.3	78	-23	.47	.49	.25	4.1
Fall.....	42.6	102	-23	2.77	1.11	1.87	5.9
Year.....	40.3	110	-47	15.80	6.72	22.74	28.7

TABLE 2.—Normal monthly, seasonal, and annual precipitation at Frybury, Billings County, N. Dak.

[Elevation, 2,790 feet]

Month	Mean	Total for the driest year (1936)	Total for the wettest year (1927)	Month	Mean	Total for the driest year (1936)	Total for the wettest year (1927)
	Inches	Inches	Inches		Inches	Inches	Inches
December.....	0.51	0.72	1.48	June.....	3.30	0.55	2.53
January.....	.45	.33	.51	July.....	2.19	.45	2.83
February.....	.47	.26	.32	August.....	1.90	1.23	2.28
Winter.....	1.43	1.31	2.31	Summer.....	7.45	2.23	7.64
March.....	.78	.51	.61	September.....	1.37	.47	4.46
April.....	1.17	.47	2.06	October.....	1.05	.44	.85
May.....	2.39	.58	5.59	November.....	.49	.41	.92
Spring.....	4.34	1.56	8.20	Fall.....	2.91	1.32	6.23
				Year.....	16.13	6.42	24.23

AGRICULTURE

The first agricultural enterprise to be established in the area now included in Billings County was cattle grazing. A few large ranches were located in the valley of the Little Missouri River before 1880. Each operator owned several thousand head of cattle. Very little winter feeding was practiced at that time, and consequently losses of livestock were heavy during severe winters, especially in herds

built up from cattle obtained from dairy herds from States to the east. Cattle destined for market were grazed from 3 to 4 years and shipped to market direct from the range.

As the boundaries were changed as late as 1915, census data prior to 1920 do not apply to the county as now defined. No tilled crops were reported before 1900. In that year there were only 35 square miles of improved land of a total area of 6,150 square miles, the area then included in Billings County. Wild hay occupied a greater acreage by far than all other crops; only 3 acres were devoted to wheat and 21 acres to corn in 1899. Homesteaders rapidly settled the land during the next decade, especially between the years 1907 and 1910. According to the United States census, the area in farms rose from 2.2 percent of the total land area in 1900 to 22.9 percent in 1910. Moreover, although the size of the county diminished to 3,404 square miles in 1910, the total acreage of all grains increased to more than 111,000 acres in 1909. The acreage of tilled land appears to have increased at least until after 1920.

During the decade of rapid settlement, considerable areas that were not adapted to the production of tilled crops were devoted to farming. The result was that many homesteads were later abandoned or vacated and the land leased to ranchers for grazing or to farmers for either cropping or wild-hay meadow. A great part of the homesteads in the Badlands have reverted to grazing lands. Land in farms represented 63.8 percent of the area of the county in 1920, 61.9 percent in 1930, and 48.3 percent in 1940.

Since the end of the period of rapid settlement, the average size of the farms has increased. According to the United States census, the average size of farms was 791.3 acres in 1920, 872 acres in 1930, and 747.6 acres in 1940. During recent years the less productive tilled areas have been allowed to revert to permanent grazing land.

Although some formerly cropped land, especially in the Badlands, has been returned to grazing land, the acreage of grain crops continuously increased, at least until a few years later than 1920. According to the United States census, the acreage of grain and tame forage crops was 46,237 acres in 1919. This acreage increased to 108,278 acres in 1929, but in 1939 it dropped to 54,240 acres. Most of the increased acreage was in the smoother upland area of the eastern part of the county.

At present, two principal types of agriculture are followed in Billings County. The first is purely livestock ranching for the production of meat animals. Most of the ranchers following this occupation live in the rougher parts of the county and own herds of cattle including from 70 to several hundred head. A few own flocks of sheep also, and a very few own sheep exclusively. Most of the ranchers own considerable land and, in addition, lease other acreage to augment their own grazing facilities. The most desirable land is devoted to the production of forage crops, principally hay and corn. The forage is fed to breeding and young animals, or it supplements the range of the entire herd during periods of severe weather in the winter. Grazing, however, serves as the principal source of feed for the main part of the herd in winter as well as in summer. No feeding of grain is practiced. Livestock are sold directly from the range, generally between August 15 and Novem-

Actual acreages of the principal crops, as reported by the Federal census for the years 1909, 1919, 1924, 1929, and 1934, are given in table 2.

TABLE 2.—*Acreages of principal crops in McKenzie County, N. Dak., in stated years*

Crop	1909	1919	1924	1929	¹ 1934
Wheat.....	Acres 25, 613	Acres 99, 841	Acres 129, 060	Acres 216, 317	Acres 31, 921
Oats:					
Threshed.....	18, 244	9, 124	30, 698	12, 677	1, 659
Cut and fed unthreshed.....			2, 785	3, 289	361
Barley.....	1, 093	1, 607	4, 607	18, 997	1, 526
Rye.....	1	20, 806	9, 980	7, 023	128
Flaxseed.....	12, 696	6, 457	23, 995	29, 820	581
Corn.....			14, 152	4, 284	11, 577
For grain.....	1, 343	496	1, 631	618	106
For other purposes.....		2, 202	12, 521	3, 766	11, 471
Dry beans.....	2	18	511	702	413
Dry peas.....				273	43
Potatoes.....	456	804	690	1, 460	1, 609
Sugar beets.....			1, 389	1, 394	3, 639
Hay.....	38, 383	104, 836	61, 132	57, 658	86, 406
Alfalfa.....	322	9, 906	9, 283	7, 598	1, 184
Sweetclover.....			2, 969	6, 010	1, 711
Grains cut green.....	996	40, 017	13, 691	14, 710	13, 480
Other tame hay.....	1, 700	6, 808	7, 265	3, 225	69, 483
Wild hay.....	35, 365	48, 105	27, 924	26, 115	(²)

¹ Year of drought.

² Cut for forage only.

³ Included with other tame hay.

A more accurate study of the trends in acreage of the different crops in the county is available through examining the annual reports of the Division of Crops and Livestock Estimates, Bureau of Agricultural Economics (now the Division of Agricultural Statistics, Agricultural Marketing Service), United States Department of Agriculture, from 1919 to 1933, inclusive. All these data are based on harvested acreages. During the period 1919-33, the harvested acreage of wheat rose from 51.3 percent of the total harvested acreage of all crops, including wheat, rye, flax, potatoes, corn, oats, barley, and tame hay, to 70.4 percent in 1933. There was a general trend upward in the percentage of land devoted to wheat as measured by the harvested acreages. The only exception to this was in the drought year of 1931, when, because of the drought, only a small proportion of the cropland was harvested. During approximately the same period, the percentage of land devoted to oats declined from a peak of 17.5 percent in 1921 to 6.2 percent in 1933. During the period 1919-33 there was a general downward trend of the percentage of land devoted to rye and a general upward trend of the percentage of land devoted to barley. The acreages of corn have not varied much from year to year. The percentage of land in flax has been highly variable. The percentage of land devoted to potatoes exceeded 1 percent in 1 year only, namely, 1922. Nevertheless, potatoes are a very important source of cash income in this county.

The toll taken by drought in the years 1931, 1934, 1936, and 1937 and by a black stem rust in 1935 can readily be seen from table 3.

The harvesting of grain crops is begun in the early part of July. Rye and barley are the first crops to mature, and wheat and oats are generally ready for harvesting about the last of July. Oats require immediate cutting after maturing because of the tendency of this grain to shatter, but the varieties of wheat grown will stand for several weeks without shattering if severe weather conditions do not develop. Flax is harvested in September. The harvesting of small-grain crops is done with binders, combines, and headers. Threshing is generally started about the middle of August and extends well into September. Very little grain is stacked for threshing. Some farmers conserve their straw for bedding and feed; others either burn it or allow it to decay in the piles. The threshed grain to be sold is either stored on the farms, hauled to the elevators to be stored, or sold immediately. Corn is generally harvested in early September, although harvesting dates vary according to seasons. The corn is cut, placed in shocks, and later stacked at a place convenient for feeding. Before cutting the crop, some farmers snap the ears for grain feed for livestock and poultry during the winter.

Hay is generally stacked in the meadows, although a few farmers and ranchers haul it to the feeding corrals, to be either stacked or placed in barns. Sweetclover and alfalfa are cut during midsummer. If moisture conditions are favorable, a second cutting of these two crops is made about the last of August or the first of September. When small grains are used for hay, they are generally cut shortly before they reach maturity. Such crops as millet, sorgo (locally called cane), and wild hay are ordinarily cut during the early fall.

Some plan of crop rotation is practiced by many farmers. Most of them plan either to grow a cultivated crop or to summer-fallow their land every 3 or 4 years. The principal purpose of this practice is to avoid continuous small-grain crops and to keep the growth of weeds in check. It is the common opinion that growing corn or other cultivated crops is just as beneficial to the following crop as summer fallowing and provides an additional crop as well; whereas, if summer fallowing is practiced, the land lies idle. Moreover, if a crop is grown, the ground is protected most of the season from the hazards of soil blowing. Moldboard plows, disk harrows, and duckfoot cultivators are the most common implements used for summer fallowing. The fallowed ground is left as rough or cloddy as possible, in order to minimize soil blowing, as the coarser textured soils, such as the very fine sandy loams, sandy loams, fine sands, and some silt loams, are especially susceptible to blowing. Areas having a bumpy or rolling surface are also particularly subject to soil blowing when summer-fallowed.

One of the most common rotations used is a 3- or 4-year plan involving one crop of corn followed in sequence by 1 or 2 years of wheat and 1 year of barley or oats. If meadow is to be established, the seed is sown with the wheat or barley. When once established, tame-grass meadow is generally left as long as it produces fairly well. Grass seedings are usually difficult to establish, owing to frequent dry summers and to heaving frost during the fall, winter, or early spring. Flax is generally sown following a cultivated crop or summer fallow, because of the ease with which weeds outstrip it when they are in competition with it. Although crop rotation of some

sort is commonly practiced, many farmers sow small grains, especially wheat, year after year in the same field.

Very little fertilization is practiced. A few farmers use what manure becomes available, although this valuable material is very commonly piled in ditches or otherwise disposed of without benefit to their land. When utilized it is generally spread thinly and put on land to be devoted to a cultivated crop or wheat the following year. According to the United States census for 1940, no commercial fertilizer or other soil amendments are used.

Most labor is of local origin. At present it is abundant and fairly efficient. Most farm help is hired by the month, and some ranch help is hired by the year.

According to the United States census, land tenancy is increasing. Tenants operated 10.4 percent of the farms in 1920, 20 percent in 1930, and 46.5 percent in 1940. Records show 112 owners, 137 part owners, and 219 renters in 1940. In that year renters operated 116,731 acres, as compared with 220,370 acres of land operated by owners or part owners. Land rented for grazing or for the production of feed crops is generally leased on a cash basis, and that for cash grain production is leased on a share basis. The most common arrangement is for the renter to furnish all work animals and labor and to assume one-half of the cost of the twine and threshing bill; the owner furnishes the grain seed, assumes one-half of the twine and threshing bill, and pays the property taxes; and the harvested crop is divided equally. If grass seed is to be sown, it is furnished by the owner. Modifications of this plan are used to some extent. The renter may furnish all the seed, do all the work, assume all costs of harvesting the crop, and deliver the owner's part of the crop to the elevator. Under such conditions the renter receives three-quarters of the grain harvested. On some farms the owner furnishes most of the equipment and power and receives a larger proportion of the harvested crop.

Farm equipment has depreciated in value and in amount during recent years. Under more favorable crop conditions, most farms were equipped with machinery to seed, cultivate, and harvest their own crops. Threshing machines are generally owned by cooperative groups or by individuals who make a business of doing such work. Buildings on few farms are extensive, although shelter for a few work animals and a few cattle is generally afforded, and practically all farms have storage room for grain. Most of the hay is stacked. Some farmers and ranchers provide some protection for their farm implements, although a great part of this equipment stands in the open throughout the year. There are very few silos.

The Federal census reports 179 tractors in the county in 1940. Horses furnish the rest of the farm power. The number of draft horses per farm ranges from 6 to 12, and practically all ranchers and farmers have 2 or more saddle horses in addition.

According to the United States census, the average total value of farm property in 1940 was \$6,024, of which land and buildings represented \$4,060, livestock \$1,439, and implements \$525. The average value of land and buildings per acre fell from \$8.95 in 1930 to \$5.43 in 1940.

Since about 1910, cash crops have been a large source of income to farmers. Throughout this period their importance as measured by relative acreage has steadily increased, and they now account for well over one-half of the cropped acreage. The principal cash crops are wheat, flax, and rye.

According to the United States census, wheat always has been the most important cash crop and has consistently gained in relative acreage. All the wheat is spring sown, and most of it is hard Marquis red spring wheat. In the early years of wheat growing this was the most popular variety grown. It was gradually replaced by Ceres until 1935, when the black stem rust epidemic did such serious damage to Ceres wheat. Thereafter there was a general decline in the acreages of both Marquis and Ceres varieties and a replacement by the more recent more rust-resistant Thatcher variety. A few farmers are still growing miscellaneous varieties.

The yield per acre during the period 1911-26 for wheat harvested in this county averaged 8.3 bushels and ranged from 2 bushels in the worst year to 20 bushels in the best year; whereas during the period 1929-36 it averaged 7 bushels for spring wheat, other than durum, and ranged from 1 bushel in 1936 to 12.5 bushels in 1932.⁶

The North Dakota Agricultural Experiment Station has conducted continuous comparative trials on a number of these hard red spring wheats at the Dickinson substation in Stark County. During the period 1930-39, Thatcher wheat yielded 10.8 bushels per acre, Marquis 9, Ceres 11, Red Fife 7.6, and Haynes 7.4. In a more recent 5-year comparison (1935-39) Thatcher yielded 11.1 bushels, Marquis 7.7 bushels, Ceres 9.4 bushels, Red Fife 5.3 bushels, Haynes 5 bushels, Pilot 11.9 bushels, and Rival 12.2 bushels per acre. Thatcher, Pilot, and Rival have greater resistance to rust than any other wheat.⁷

Very small acreages are devoted to durum wheats. Consequently, some reference to comparative yields of durum and hard red spring wheats, where tests are made under comparable conditions, should be of interest. During the period 1923-37, excluding 1936 because of total crop failure, the following comparable yields were obtained at the Dickinson substation: Durum wheats—Kubanka 14.5 bushels an acre, Mindum 13.1 bushels, and Pentad Red Durum (D-5) 14.5 bushels; hard spring wheats—Marquis 13.3 bushels, Ceres 15.9 bushels, Red Fife 12.2 bushels, and Haynes Bluestem 11.9 bushels.⁸

Flax was the second most important cash crop on the basis of acreage in 1929. The trend of production is slightly downward. Much of the flax has been grown on comparatively newly broken land. It is necessary to grow wilt-resistant varieties. Buda and Bison are the best two varieties for North Dakota, according to the North Dakota Agricultural Experiment Station. Flax fits in well with wheat farming because it is both sown and harvested later. The greatest difficulty in the production of this crop is control of weeds. Flax grows slowly during the first few weeks of its develop-

⁶ All data concerning yields during the period 1911-26 mentioned throughout this report are taken from North Dakota Agricultural Experiment Station Bulletin 212 (25), and all data concerning yields during the period 1929-36 are taken from the records of the Division of Agricultural Statistics, Agricultural Marketing Service, United States Department of Agriculture.

⁷ For further information on testing spring wheat, see bulletin by Ralph W. Smith (11).
⁸ STOA, T. E., and others. YIELDS FROM SMALL GRAIN VARIETY TESTS. N. Dak. Agr. Expt. Sta. Agron. Cir. 66, 32 pp. 1937. [Mimeographed.]

ment, and its comparatively thin foliage allows weeds to overtake it easily. Ground free from weeds, therefore, is favored for this crop. Soil blowing on some soils causes serious damage during the early period of growth, because of the lack of foliage and roots to protect the surface soil from being blown away.

The yield during the period 1911-26 averaged 5.5 bushels per acre and ranged from 1.5 to 10 bushels. During the period 1929-36 the yield averaged 2.7 bushels per acre and ranged from failure in 1934 and 1936 to 3.3 bushels in 1935.

Average acre yields of wilt-resistant varieties of flax at the Dickinson substation over the period 1928-39 (excluding some years because of total failure owing to drought, damage from black stem rust, and damage from grasshoppers) were as follows: Bison, 4.4 bushels; Buda, 3.2 bushels; Linota, 3.9 bushels; N. D. R. 114, 3.5 bushels; Redwing, 4.1 bushels; and Rio (L-79), 4.3 bushels. Over the same period average acre yields at the Northern Great Plains Field Station, Mandan, N. Dak., were as follows: Bison, 5.7 bushels; Buda, 4.8 bushels; Linota, 5.1 bushels; Redwing, 4.7 bushels; and Rio (L-79), 5.2 bushels.⁹

Rye ranks third in acreage of cash crops, although the acreage fluctuates considerably. All rye is fall sown and is commonly used for grain, hay, or pasture. The average yield over the 16-year period 1911-26 was 11.1 bushels per acre, and the yields ranged from 3 to 30 bushels. During the 8-year period 1929-36 the average was 8.5 bushels, and the range was from failure in 1934 and 1936 to 12.4 bushels in 1932.

The United States census shows that barley was the most important grain grown as a subsistence crop in 1929. Its acreage has increased consistently since 1919. This crop is grown principally as a grain feed for cattle, hogs, and poultry. Very little, if any, is sold as a cash crop. The annual yield during the 16-year period 1911-26 averaged 16 bushels per acre and ranged from 2 to 34.5 bushels; whereas during the period 1929-36 it averaged 11.5 bushels and ranged from failure in 1936 to 20.5 bushels in 1932.

According to the United States census, the acreage of oats was about three-fourths that of barley in 1929. This crop is widely grown and is used as a grain feed for cattle, sheep, and horses, particularly the latter. It is the best adapted grain for emergency hay crop use, and the threshed straw is the most desirable for roughage. The range in annual yields was from 3 to 47.3 bushels per acre, with an average, over the 16-year period 1911-26, of 21.2 bushels. The range over the 8-year period 1929-1936 was from failure in 1934 and 1936 to 20.5 bushels in 1932.

The acreage of corn is relatively small and, according to the United States census, has shown but little increase. As a subsistence crop it is of some importance, as it produces relatively more forage than other crops in dry seasons. Moreover, in some years the distribution of precipitation is comparatively unfavorable for the production of small grains and hay but is favorable for the development of the corn crop. Because of this, the inclusion of corn as a subsistence crop

⁹ STOA, T. E., and others. YIELDS FROM SMALL GRAIN VARIETY TRIALS IN NORTH DAKOTA. N. Dak. Agr. Expt. Sta. Agron. Cir. 70, 30 pp. 1939. [Mimeographed.]

serves as a partial assurance of feed. Both the grain and the forage are valued highly as feed for cattle, sheep, and horses. The most common variety grown is Northwestern Dent; some Falconer Semident is grown, and also a small amount of Gehu Yellow Flint. The first two are preferred because they produce more grain and are easily handled. The total acreage of corn for grain and other purposes was 2,145 acres in 1929, which was a small proportion of the total area cropped in that year. The annual yield during the 16-year period 1911-26 ranged from 5 to 30 bushels per acre and averaged 16 bushels; whereas during the 8-year period 1929-36 it ranged from 1.5 bushels in 1936 to 17.5 bushels in 1932 and averaged 12.4 bushels.

Potatoes are the most important crop grown for home consumption, and very few are sold. The total acreage for the county in 1939, according to the United States census, was 124 acres, and the average yield was about 50 bushels per acre. Practically all of the potatoes are grown in small patches and, consequently, on the more desirable soils. Early Triumph and Early Ohio are the most common varieties grown. The common garden crops, such as tomatoes, cabbage, sweet corn, squash, and melons, do well where moisture conditions are favorable. Very few cultivated berries and fruits are grown. Wild plums, chokeberries, and buffaloberries are plentiful in most parts of the county and are commonly used for jams and other purposes.

Hay occupies the largest acreage of all subsistence or feed crops and is second to wheat in acreage of all crops. In 1939 nearly one-half of the acreage devoted to subsistence crops was occupied by hay. The trend of the acreage of this crop, however, is downward. There is more tame hay grown now than formerly. In 1909 and earlier, more than 90 percent of the hay was wild hay. Tame hay occupied 7,961 acres in 1939, and wild hay 14,899 acres. The average yields were 0.98 and 0.59 ton, respectively. Of the 7,961 acres of tame hay, 2,753 acres were in grains cut green. The acreage of this kind of hay varies according to the probable yield of other tame-hay crops, the scarcity of carried-over feed, and the possibility of failure of the grain yield. Oats are considered the most desirable grain to sow for hay.

Sweetclover occupied about 2,339 acres in 1939, and alfalfa occupied 159 acres. Most of the alfalfa and sweetclover are grown on the alluvial soils of the Little Missouri River Valley. These two crops afford the most desirable forage crops for both dairy and beef cattle. They are seeded with small-grain nurse crops and are not subjected to grazing or cutting the first year. It is probable that greater success in establishing stands of the two crops, especially on the upland soils, would result if they were seeded without a nurse crop on land freed of weeds by a season of summer fallowing or by the growth of a cultivated crop. As sweetclover is primarily a biennial, it yields only during one full season. Frequently two crops are harvested per year, or, after the first crop has been removed, the second may be grazed. If allowed to mature some seed each year, this crop will at least partly perpetuate itself by reseeding. If seed is desired for harvesting, the second crop may be used for that purpose. Two varieties, yellow and white, are grown, but the yellow is preferred, principally because of its greater palatability to livestock. Yellow sweetclover is also better adapted to grazing, as cattle are able to eat practically all of the plant, and it is undoubtedly

one of the most desirable crops grown for tame pasture. Its nutritive value is high, it is palatable after cattle become accustomed to it, and it produces green foliage more persistently through dry periods than any of the other grazing crops. The yield in 1939 was slightly less than 1 ton an acre.

Alfalfa is probably the most desirable hay crop grown, but it has a high water requirement, even significantly higher than that of sweetclover, and great care must be taken in the choice and preparation of the ground on which it is to be grown. The average acre yield for alfalfa is 0.94 ton.

Of the other crops grown for tame hay, millet, sorgo, ryegrass, and soybeans are the most important. The two most common varieties of millet are Siberian and German, the latter being preferred by most farmers. Volunteer wild oats and Russian-thistle are commonly cut for hay. In some localities wild oats grow readily on idle fields where the seed has been distributed at some time. Russian-thistle, although ordinarily considered a weed, affords an important source of forage in years when moisture is too scarce to develop other crops for hay. The thistles spring up in fields seeded to crops, and in dry years they generally develop a fair stand of vegetation, which is cut for hay about midsummer. Summer seasons must be extremely dry to prevent at least a fair growth of this volunteer weed, but during seasons with sufficient moisture to develop the seeded crops the thistles are thoroughly suppressed.

Crested wheatgrass, although as yet not commonly grown, appears to be destined to become an important grass in this section. According to Westover and others (14), crested wheatgrass (*Agropyron cristatum*) is especially well adapted to the Northern Great Plains, as it is suitable for both hay and pasture, is more productive over a period of years than such grasses as slender wheatgrass and brome grass, and is hardier than alfalfa. It is a very desirable grass for early spring and fall grazing, but it should be supplemented by a pasture crop better adapted to midsummer grazing (13), such as sweetclover or deferred native pasture grasses.

Harvested acreage and production of the principal crops, from the United States census and the records of the Division of Agricultural Statistics, Agricultural Marketing Service, United States Department of Agriculture, are given in table 3.

TABLE 3.—Harvested acreage and production of principal crops in Billings County, N. Dak., in stated years

Crop	1919 ¹		1924 ¹		1929 ²		1930 ²		1931 ²		1932 ²	
	Acres	Bushels	Acres	Bushels	Acres	Bushels	Acres	Bushels	Acres	Bushels	Acres	Bushels
Corn, all purposes.....	262	286	2,760	575,862	2,000	23,000	2,000	19,000	5,000	88,000	6,000	105,000
Wheat, all.....	18,231	40,375	46,162	575,862	2,000	15,000	1,000	7,000	42,000	92,000	72,000	900,000
Durum.....					62,000	428,000	58,000	429,000	5,000	20,000	14,000	287,000
Other spring.....					8,000	92,000	8,000	85,000	8,000	32,000	11,000	226,000
Oats.....	1,829	7,904	11,321	280,536	8,000	77,000	10,000	80,000	8,000	24,000	9,000	112,000
Barley.....	639	1,358	4,046	83,859	6,000	60,000	9,000	85,000	3,000	6,000	7,000	20,000
Rye.....	450	888	392	4,553	10,000	31,000	13,000	30,000	3,000	18,000	200	13,000
Flax.....	1,475	2,181	9,169	55,505	200	10,000	300	16,000				
Potatoes.....	307	7,871	143	11,410								
Tame hay.....	21,744	Tons 9,145	5,941	Tons	11,000	Tons 900	22,000	Tons	27,000	Tons 20,000	14,000	Tons 15,000

Crop	1933 ²		1934 ²		1935 ²		1936 ²		1937 ²		1938 ²	
	Acres	Bushels	Acres	Bushels	Acres	Bushels	Acres	Bushels	Acres	Bushels	Acres	Bushels
Corn, all purposes.....	4,000	50,000	4,000	8,000	6,000	78,000	1,000	1,000	1,653		3,348	
Wheat, all.....											50	250
Durum.....											11,878	18,383
Other spring.....	67,000	382,000	6,000	15,000	51,000	255,000	1,000	1,000	11,795	18,460	11,878	25,201
Oats.....	9,000	112,000			10,000	176,000			808	6,653	2,240	18,383
Barley.....	8,000	76,000	1,000	5,000	9,000	135,000			1,381	5,749	1,772	17,055
Rye.....	4,000	24,000			1,000	10,000			8,409	51,337	1,063	6,713
Flax.....	3,000	8,000			3,000	10,000			87	72		
Potatoes.....	200	6,000	100	2,000	200	10,000			50	1,284	78	2,309
Tame hay.....	11,000	Tons 600	900	Tons 300	19,000	Tons 21,000		Tons		Tons		Tons

¹ Data from the United States census.

² Data from records of the Division of Agricultural Statistics, Agricultural Marketing Service, United States Department of Agriculture. Data for the years 1929-36 to the nearest 1,000, or, in the case of potatoes, nearest 100.

³ Grain only.

The acreage in wild hay diminished considerably in 1929 when the total acreage (8,006 acres) was about one-half of that in 1919. In 1939 it increased to 14,899 acres which represented about two-thirds of the total hay acreage cut. The grass mixture of the wild hay varies considerably. The most desirable wild hay is composed wholly of western wheatgrass. It grows most commonly on well-drained alluvial clay loam or silty clay soils, but very little of this type of meadow remains in the county. A mixture of western wheatgrass, western needlegrass, blue grama, and prairie junegrass is more common and makes desirable hay if cut after the needles have fallen from the needlegrass. Blue grama furnishes but a very small part of the hay crop, as only the seedstalks are high enough to be cut by a mower. This grass mixture grows on heavy loam soils of the uplands. A common mixture on the coarser textured soils (sandy loams and sands) includes western needlegrass, prairie junegrass, blue grama, and two sedges (niggerwool and upland sedge). Although the grama and sedges may comprise a large percentage of the grass cover, they yield but a small part of the hay because of their short growth. Undesirable grasses commonly growing in such meadows as this are sandgrass and little bluestem. They grow in patches, the latter especially on the more exposed or barren spots. Most farmers do not cut a meadow of this type more than once every 2 years. The grass is clipped as close to the ground as possible and is collected with a buncher attached to the mower.

The grasses here discussed as the important meadow grasses are likewise the important grazing grasses. Whereas blue grama is of little value as a hay crop, it is in many ways equal or even superior to western wheatgrass for grazing. The most desirable natural grazing cover is a mixture of western wheatgrass and blue grama. Side-oats grama, buffalo grass, prairie junegrass, and Kentucky bluegrass also furnish good grazing but are less common, especially less so than blue grama. Buffalo grass is more common throughout Billings County than it is in central and northern McKenzie County. The needlegrasses are of value but are objectionable, especially to sheep, during the period when the needles are mature but have not yet dropped from the seedstalks. Although the upland sedges are less palatable than the above-mentioned grasses, they are important as pasture forage because they grow on sandier sites than many of the more desirable species. Other important but less common grazing grasses and shrubs are big bluestem, Sandberg bluegrass, quackgrass, winterfat, and saltbush. The most common grasses having little or no grazing value are little bluestem, sandgrass, foxtail, three-awn, and plains muhly.

Natural stands of grass are radically altered by such artificial influences as overgrazing and tillage. These changes almost always injure the quality and carrying capacity of the range so treated. Many of the grasses are destroyed and are very hard to reestablish after they have once been severely depressed. Tillage, for example, even though practiced for but 1 year, practically destroys the grama and buffalo grass. Western wheatgrass and quackgrass, however, will reestablish themselves after tillage, provided this practice is not continued for several years. Overgrazing is particularly injurious to western wheatgrass, much of which has been eradicated in this way.

Fortunately, blue grama can stand considerable overgrazing. As a consequence, areas that once were occupied by a cover composed almost entirely of western wheatgrass now have a stand made up almost wholly of blue grama. Most of the injurious grazing of western wheatgrass is done by cattle and horses, as sheep prefer practically all other grasses and some weeds to western wheatgrass. Excessive and continuous overgrazing of bluegrass, especially by sheep, will injure the stand severely. The grass in such pastures is displaced by weeds and pasture sagebrush. Ruthless overgrazing can destroy the well-established native sod to such an extent as to expose the soil to ruinous wind and water erosion. Grazing should be intelligently supervised with the objective of regulating the rate of grazing to avoid depressing the virgin or natural grass cover.¹⁰

The Land Utilization Division of the Resettlement Administration (later transferred to the Bureau of Agricultural Economics and more recently to the Soil Conservation Service) has been acquiring extensive areas in Billings, Golden Valley, and McKenzie Counties, which can best be utilized as range and meadow land. It is developing grazing districts from these acquired areas and leases grazing rights within them to livestock producers. Under such a system it is to be expected that overgrazing will be avoided to a great extent, unproductive tilled areas will be developed into grassland, and livestock grazing in these districts will be considerably more stabilized than it was in the past.

The production of beef cattle is the most important livestock enterprise. The principal breed raised is the Hereford, and purebred sires are commonly used. The United States census reports approximately 15,492 head of cattle on farms on April 1, 1930. Some of this number are listed as dairy cattle. Dairying has not reached the point of development where the use of specific breeds can be recognized, but most dairy animals are of Holstein-Friesian or Guernsey breeding. On April 1, 1940, the total number of cattle over 3 months old was 11,254, of which 1,872 were milk cows.

According to the United States census, there were 12,678 sheep in the county on April 1, 1930. The number of sheep has increased considerably since 1920, although it is not so large as it was prior to 1910. The number dropped to 4,958 over 6 months old on April 1, 1940. Most of the sheep are owned by ranchers and are grazed in parts of the county where watering facilities are comparatively convenient. Dual-purpose animals are the most common. A common practice is to use American Merino or Rambouillet rams with Shropshire ewes. Both wool and mutton are important products in this area. Shearing is done in the late spring, and lambs for mutton are generally sold in the late fall, being shipped directly from the range to the market without being fed any grain.

The Federal census reports 6,122 horses and 64 mules on farms on April 1, 1930, and on April 1, 1940 there were only 3,306 horses over 3 months old.

Hogs are not so commonly raised for market as are sheep and cattle. Most of the pork produced is for local consumption. The total number of swine on farms April 1, 1930, according to the United States census, was 4,378. The number declined to 823 over 4 months

¹⁰ For further information on ranch conditions refer to North Dakota Agricultural Experiment Station Bulletin 237 (4).

old on April 1, 1940. The greatest obstacles to hog raising are poor pasture conditions, the great distance to market, and low and unreliable yields of corn. Barley and corn are the principal grains used for hog feed. Some farmers grow rape for hog pasture.

Poultry, principally chickens and turkeys, are commonly raised throughout the county. Very little attempt at specialization is made, most of the poultry being owned in small farm flocks. Eggs and poultry are sold locally and to private buyers, who ship poultry by the carload and truckload during certain seasons of the year, principally in the late fall. Only a few ducks and geese are raised.

SOIL SURVEY METHODS AND DEFINITIONS

Soil surveying consists of the examination, classification, and mapping of soils in the fields.

The soils are examined systematically in many locations. Test pits are dug, borings are made, and exposures, such as those in road or railroad cuts, are studied. Each excavation exposes a series of distinct soil layers or horizons, called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail; and the color, structure, porosity, consistency, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil¹¹ and its content of lime and salt are determined by simple tests.¹² The drainage, both internal and external, and other external features, such as the relief, or lay of the land, are taken into consideration, and the interrelation of soil and vegetation is studied.

The soils are classified according to their characteristics, both internal and external, special emphasis being given to those features influencing the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics the soils are grouped in classification units. The three principal units are (1) series, (2) type, and (3) phase. In places two or more of these principal units may be in such intimate or mixed pattern that they cannot be clearly shown separately on a map but must be mapped as (4) a complex. Some areas of land, such as coastal beach or bare rocky mountainsides, have no true soil, and these are called (5) miscellaneous land types.

The most important of these groups is the series, which includes soils having the same genetic horizons, similar in their important characteristics, and arrangement in the soil profile, and developed from a particular type of parent material. Thus, the series includes soils having essentially the same color, structure, and other important internal characteristics, the same natural drainage conditions, and the same range in relief. The texture of the upper part of the soil, including that commonly plowed, may differ within a series. The soil series are given names of places or geographic features near which they were first found. Thus Morton, Farland, Bainville, and Grail are names of important soil series in Billings County.

¹¹ The reaction of the soil is its degree of acidity or alkalinity expressed mathematically as the pH value. A pH value of 7 indicates precise neutrality, higher values indicate alkalinity, and lower values indicate acidity.

¹² The total content of readily soluble salts is determined by the use of the electrolytic bridge. Phenolphthalein solution is used to detect a strong alkaline reaction.

Within a soil series are one or more soil types, defined according to the texture of the upper part of the soil. Thus, the class name of the soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, is added to the series name to give the complete name of the soil type. For example, Morton loam and Morton clay loam are soil types within the Morton series. Except for the texture of the surface soil, these soil types have approximately the same internal and external characteristics. The soil type is the principal unit of mapping, and because of its specific character it is usually the soil unit to which agronomic data are definitely related.

A phase of a soil type is a variation within the type, which differs from the type in some minor soil characteristic that may have an important practical significance. Differences in relief, stoniness, and the degree of accelerated erosion are frequently shown as phases. For example, within the normal range of relief for a soil type, certain areas are adapted to the use of machinery and the growth of cultivated crops and others are not. Even though no important differences are evident in the soil itself or in its capability for the growth of native vegetation throughout the range in relief, there may be important differences in respect to the growth of cultivated plants. In such an instance the more sloping parts of the soil type may be segregated on the map as a sloping or hilly phase. Similarly, soils having differences in stoniness may be mapped as phases even though these differences are not reflected in the character of the soil or in the growth of native plants.

The soil surveyor makes a map of the county or area, showing the location of each of the soil types, phases, complexes, and miscellaneous land types, in relation to roads, houses, streams, lakes, section and township lines, and other local cultural and natural features of the landscape.

SOILS

With a few exceptions the soils of Billings County have developed in a semiarid climate under a cover of short grasses or mixed short and tall grasses. They exhibit, therefore, the characteristics of the Chestnut soils unless their development has been modified by local influences, such as steep relief, poor drainage, or other factors. The well-drained loam soils of the undulating to rolling uplands developed from the sandstones, shales, and clays of the Fort Union formation are representative Chestnut soils, and accordingly they are characterized by (1) a dark-brown or dark grayish-brown surface soil, (2) a well-defined prismatic structure to a depth of about 16 inches, and (3) a visible accumulation of carbonates at a depth of about 16 inches or more. Prismatic structure in these soils refers to that arrangement of the soil particles whereby the aggregates appear in place as elongated prisms ranging from 4 to 8 inches in length. The prisms are firm but on removal fall readily into smaller nutlike aggregates that are held together by grass roots. When broken horizontally their outline is subangular or irregularly rounded. The common range in diameter is from $\frac{1}{2}$ to $1\frac{1}{2}$ inches. The reaction is commonly neutral or slightly acid in the surface soils and alkaline in the subsoils. These soils are easily tilled, and they are inherently fertile. Lack of adequate moisture is the principal limitation to crop production.

Although most of the soils of this county tend to possess in some degree the characteristics listed above, a considerable range exists. Depending on the character of the parent material, the texture ranges from loamy fine sand to clay; and depending largely on the content of organic matter, the color ranges from very dark grayish brown to brownish gray. The range in consistence—from loose loamy fine sand to intractable and massive clay—is extremely wide. The surface relief, or lay of the land, covers the entire range from flat depressions to overhanging cliffs. Other variations occur in respect to depth to carbonates, degree of influence of salts or "alkali," drainage, stoniness, and accelerated erosion.

Certain of these characteristics are commonly associated. For example, hilly relief, slight depth to carbonates, a comparatively light color of the surface soil, low content of organic matter, and good to excessive surface drainage feature many of the soils of the Badlands. In contrast, dark color of the surface soil, greater depth to carbonates, increased content of organic matter, and poor surface drainage characterize the soils of the smooth depressions. Lack of adequate surface drainage, and seepage from the adjoining uplands, may result, however, in the soils of the depressions being characterized by accumulations of salt and alkali. Other soils of the depressions or those at the foot of slopes may be composed of light-colored comparatively coarse sediments that have been recently deposited as raw local alluvium from the adjoining uplands and Badlands. These examples tend to illustrate the variable local situations that give rise to a considerable number of soils differing in productivity according to particular combinations of characteristics.

The soils of Billings County are classified in 18 series, which include 24 types, 10 complexes, and 25 phases, and in addition 6 miscellaneous land types are mapped.

The Morton series includes the dark grayish-brown friable soils having a comparatively well developed prismatic structure to a depth of about 16 inches, below which lies a zone of carbonate accumulation. The Morton soils occur on the uplands, and they have developed from silt and clay of the Fort Union geologic formation. The Searing series includes the reddish-brown friable soils that have a fairly well developed prismatic structure and lie on scoria beds of the Fort Union formation. The Arnegard series includes the very dark grayish-brown friable soils having a well-developed prismatic structure. They are developed on local alluvium that has been deposited in shallow well-drained depressions throughout the uplands. Light-brown or grayish-brown friable soils of the uplands are members of the Bainville series. They are developed from silt and clay of the Fort Union formation, and they exhibit less prismatic structure than the Morton soils. Carbonates of sufficient quantity to cause effervescence when the soil is treated with an acid are at or within a few inches of the surface. The Flasher series includes the sandy soils of the uplands, developed from sandy material of the Fort Union formation. A considerable range in the color of the soil and in the depth to carbonates exists, corresponding closely to the variations in the lay of the land.

The Patent series includes the brownish-gray or grayish-brown soils occurring on the gentle valley slopes, composed principally of

fine-textured local alluvium. Developed from material similar to that underlying the Patent soils and occupying gentle valley slopes are the Grail soils, which are dark grayish-brown or very dark grayish-brown silty clay loam soils. Soils of the Farland series are the counterparts of soils of the Morton series, except that the Farland soils are developed on the well-drained alluvial benches. For the most part, the underlying material is silt and clay. The Cheyenne series includes friable dark grayish-brown soils having a prismatic structure, and they overlie gravelly alluvium. Friable light-brown or brownish-gray fine-textured soils on the well-drained alluvial clayey benches, particularly along the Little Missouri River and its larger tributaries, are included in the Cherry series. The Huff series includes the light grayish-brown soils having sandy subsoils and developed on natural levees, alluvial fans, or terraces along the larger streams. The dark grayish-brown soils on sandy terraces are also included in this series because of their small acreage.

The Rhoades, Moline, and Wade series represent soils in which a claypan has developed. The claypan is known technically as a form of Solonetz development, which in turn is a result of the influence of sodium on the soil. Transitional stages that vary from the true Solonetz type of soil profile occur in these soils. A distinguishing characteristic of these conditions is the occurrence of bare clay spots. The Rhoades series includes the grayish-brown to dark grayish-brown claypan soils developed on the upland from Fort Union material. The Moline soils are brownish-gray to grayish-brown claypan soils developed on the gentle valley slopes of local alluvium. The Wade series includes the very dark brownish-gray and dark grayish-brown claypan soils developed on the alluvial flats and benches along the streams, particularly those of the eastern part of the county. A comparatively large acreage of these soils is influenced by soluble salts. Such soils are technically called Solonchak. As these claypan soils develop locally in spots of a few feet or rods in diameter, individual areas cannot be shown on the soil map of the scale used. They are mapped as complexes with the associated soils and are named accordingly. Thus, Moline clay loam (complex with Patent or Grail clay loams), Rhoades loam (complex with Morton or Bainville loams), Wade-Farland silty clay loams, and others appear on the map.

Where the claypan characteristics are less well developed, either in area or in intensity, the soils are also shown as complexes; but in these instances the compound series name begins with the name of the member not possessing the claypan characteristics. Ordinarily the claypan features of the soil do not prevent tillage of these areas. Thus, the Morton-Rhoades complex represents areas of Morton soils in which the claypan or clay spots are moderately developed; the Bainville-Rhoades complex represents areas of Bainville soils in which the claypan or clay spots are moderately developed; the Patent-Moline complex represents areas of Patent soils in which the claypan or clay spots are moderately developed; and the Farland-Wade complex represents areas of Farland soils in which the claypan or clay spots are moderately developed.

The McKenzie series includes the grayish-black hard intractable alkali soils developed on alluvium of old pond sites. The Sage series

is represented by the light-colored clay soils developed on alluvium having a high content of carbonates and other salts. The Havre series includes the brownish-gray friable silty clay soils of the bottom lands along the Little Missouri and Knife Rivers. Members of the Banks series are light-brown or grayish-brown sandy soils developed on the bottom lands along the Little Missouri River and a few of its larger tributaries. Alluvial soils, undifferentiated, comprises fresh alluvium of variable character along the smaller streams and drains.

Rough broken land includes the rough, steep, partly bare areas of sedentary sands, silt, and clay of the Fort Union formation; scoria includes rough, steep, partly bare areas of scoria; and riverwash includes areas of loose bare sand adjacent to the larger stream channels.

Table 4 shows the principal characteristics of the soil series in Billings County.

TABLE 4.—Principal characteristics of soil series in Billings County, N. Dak.

Series	Position	Topography	Parent material	Dominant native vegetation	Color of surface soil	Other characteristics	Principal crops or uses ¹
Arnegard.....	Slight depressions in the uplands.	Nearly flat.....	Medium - textured local alluvium.	Mixed tall and short grasses	Very dark grayish brown	Good moisture holding capacity.	Wheat.
Bainville.....	Rolling to steep uplands.	Undulating to steep.	Chiefly silts and clays of Fort Union formation.	do.....	Grayish brown.....	Commonly shallow to carbonates.	Grazing, some wheat on smoother parts.
Banks.....	Bottom lands.....	Flat to undulating..	Sandy alluvium recently deposited	Cottonwood, elm, boxelder.	Grayish brown to brownish gray.	Underlying sand loose and porous, relatively high water table	Feed crops.
Cherry.....	Low terraces.....	Flat to gently sloping.	Fine - textured local alluvium.	Mixed tall and short grasses, a few shrubs and trees.	Brownish gray.....	Soil and underlying material relatively heavy.	Feed crops, grazing.
Cheyenne.....	Terraces.....	Flat to undulating; except for steep phase.	Medium- or coarse-textured old alluvium.	Short grasses.....	Dark grayish brown..	Easily tilled, slightly droughty.	Wheat.
Farland.....	do.....	Flat to undulating.	Medium- to fine-textured old alluvium.	do.....	do.....	Easily tilled, good moisture relationships	Do.
Flasher.....	Rolling to hilly uplands	Undulating to steep.	Sandstones of Fort Union formation	Mixed tall and short grasses.	Grayish brown to brown.	Relatively loose and porous, absorptive of moisture, subject to soil blowing.	Grazing.
Grall.....	Lower slopes.....	Gently sloping to sloping.	Fine-textured local alluvium and colluvium.	do.....	Dark or very dark grayish brown	Relatively heavy and plastic.	Wheat and grazing.
Havre.....	Bottom lands.....	Nearly flat.....	Fine-textured general alluvium.	Elm, ash, and cottonwood.	Brownish gray.....	Easily tilled, good moisture relationships.	Wheat and feed crops.
Huff.....	Natural levees, alluvial fans, and low terraces	Gently sloping.....	Coarse- or medium-textured local alluvium.	Mixed grasses, sage and other shrubs, and trees.	Brownish gray or grayish brown	Droughty, little development of a dark-colored surface layer.	Grazing, feed crops
McKenzie.....	Sites of former ponds	Nearly flat.....	Fine-textured lacustrine material.	Annuals, wheatgrass..	Very dark gray or black	Intractable clay, massive.	Grazing, hay.
Moline.....	Lower slopes.....	Gently sloping to sloping.	Fine-textured local alluvium and colluvium.	Scattered short and tall grasses, cacti, and other vegetation.	Grayish brown or brownish gray.	Claypan or Solonch condition, closely associated with Patent soils	Grazing, wheat.
Morton.....	Smooth to rolling uplands	Undulating to rolling.	Chiefly silts and clays of Fort Union formation	Short grasses.....	Dark grayish brown...	Easily tilled, good moisture relationships.	Wheat.
Patent.....	Lower slopes.....	Gently sloping to sloping.	Fine-textured local alluvium and colluvium	Mixed short and tall grasses	Brownish gray.....	Relatively heavy, shallow, calcareous.	Grazing, wheat.

¹ Some oats, barley, and flax are commonly grown on the soils on which wheat is indicated as the principal crop. Corn, oats, millet, sorgo, grain sorghums, and small grains cut for hay are the principal feed crops.

TABLE 4.—Principal characteristics of soil series in Billings County, N. Dak.—Continued

Series	Position	Topography	Parent material	Dominant native vegetation	Color of surface soil	Other characteristics	Principal crops or uses
Shoades....	Smooth to rolling uplands.	Smooth to rolling....	Silts and clays of Fort Union formation.	Scattered short and tall grasses, cacti, and other vegetation	Grayish brown.....	Claypan or Solonetz condition, closely associated with Morton soils.	Grazing, wheat.
Sage.....	Depressions, largely on bottom lands and low terraces.	Nearly flat.....	Fine-textured local alluvium.	Sage, a few mixed grasses, and cacti.	Brownish gray or grayish brown.	Relatively high content of soluble salts.	Grazing.
Searing.....	Smooth to rolling uplands.	Undulating to rolling.	Silts and clays of Fort Union formation and scoria.	Mixed short and tall grasses.	Dark reddish brown..	Reddish-brown color and scoria fragments.	Wheat and feed crops on smooth parts, grazing.
Wade.....	Bottom lands and low terraces.	Nearly flat.....	Fine-textured alluvium.	Scattered mixed grasses, cacti, and other vegetation.	Dark grayish brown.	Claypan or Solonetz condition, closely associated with Farland silty clay loam.	Grazing, wheat.

The soils are classified in five slope classes, or groups, according to the lay of the land.¹³

The first class includes soils of nearly level areas or those that do not have a slope in excess of about $2\frac{1}{2}$ percent. In other words, the elevation changes less than $2\frac{1}{2}$ feet for every 100 feet of horizontal distance. Such a gradient characterizes the smoothest parts of the first bottoms occupied by such soils as Havre silty clay. These soils are very desirable for the use of farm machinery, but their surface drainage is slow, and under abnormally moist conditions some of them may be handicapped by excess moisture.

The second class includes those soils having gently undulating, gently rolling, or gently sloping surfaces. The slope ranges from about $2\frac{1}{2}$ to 7 percent. This is the usual range in relief for the soils of the smooth uplands, such as Morton loam. Farm machinery is easily handled on these soils, surface drainage is good, and the depth of the comparatively fertile surface soil is uniform.

The third class includes those soils the surfaces of which are rolling or markedly sloping, the slope ranging from about 7 to 15 percent. This slope class includes the various rolling and slope phases, such as Morton loam, rolling phase, and Patent clay loam, slope phase. So far as their slope is concerned, these soils are considered suitable for crops demanding tillage; but machinery, particularly heavy machinery, is handled with considerably greater difficulty than on the smoother areas. In general, drainage is excessive, especially on the steeper parts, the depth of the comparatively fertile surface soil is markedly uneven, and the more exposed areas are subject to considerable accelerated erosion if tilled.

The fourth class includes soils that occupy sharply rolling or hilly areas where the slope ranges from about 15 to 30 percent. This slope class includes the various hilly phases, such as Bainville loam, hilly phase. Such land is considered too steep to be suitable for tillage. The fertile surface soil is shallow, especially on the steeper areas. The soils are generally droughty and markedly subject to erosion. Moreover, farm machinery is handled with great difficulty. The grass cover is variable but in general averages fairly good.

The fifth class includes soils that have a slope exceeding 30 percent. This class includes the steep phases of the various soils, such as Bainville loam, steep phase. These steep phases are suitable only for grazing and are characterized primarily by having a noticeably poorer grass cover than the less steep phases; consequently they have a comparatively lower carrying capacity for grazing. All steep land of which more than 50 percent of the surface is bare is classified as rough broken land.

It should be noted that the soils of each series are limited in their range of slope, and no one series has soil types within all slope classes. This is based on the scientific fact that changes in soil morphology are associated with changes in slope, but the changes in morphology do not have a consistent relation to slope. Obviously, then, slope cannot rightfully be considered independently of other soil characteristics.

¹³ It will be noted that in the Soil Survey of McKenzie County (2), joining Billings County on the north, a less satisfactory four-class system for soil slope was used. For this reason some of the soil groupings do not appear, at first glance, to be consistent between the two counties.

In the progress of the survey, observations and records were made of the relative abundance of surface stone. Certain soil types are stone-free or comparatively so, whereas others have a considerable range of stoniness. Stony areas are shown on the map by symbol wherever stoniness becomes an important consideration in management of the land. Excessively stony areas are included in rough stony land. Stoniness is not so widely distributed in Billings County as in McKenzie County.

Areas of claypan and clay spots that develop as a result of the adverse influence of sodium are not confined altogether to the Rhoades, Moline, Wade, and McKenzie soils and the several complexes. Isolated spots occur within areas of other soils. Accordingly symbols are used on the map to indicate the smaller areas affected by claypan or Solonetz development in those soils that ordinarily do not have such conditions.

In a similar manner appropriate symbols are used to designate the local areas affected by relatively high salt concentrations.

The soil types, phases, and complexes are placed in five major groups, largely on the basis of topographic position, in order to point out more directly the relationships between the landscape and the soils, as follows: (1) Soils of the undulating and rolling uplands, (2) soils and land types of the hilly uplands and the Badlands, (3) soils of the depressions and lower (concave) slopes, (4) soils of the terraces, and (5) soils of the alluvial bottoms and fans.

Each major group comprises several subgroups, arranged largely according to the color and texture of the surface soils. In this way it is hoped that certain of the relationships between soil series, phases, and types and their capabilities for use may be clarified. These major groups, their subgroups, and the several types, complexes, and phases are listed in the table of contents. In the following pages the soils of Billings County are described in detail, and their agricultural importance is discussed; their distribution is shown on the accompanying soil map; and their acreage and proportionate extent are given in table 5.

TABLE 5.—Acreage and proportionate extent of the soils mapped in Billings County, N. Dak.

Soil type	Acre	Per- cent	Soil type	Acre	Per- cent
Morton loam.....	47,616	6.4	Morton-Rhoades clay loams, rolling phases.....	1,664	0.2
Morton loam, rolling phase.....	9,280	1.2	Bainville-Rhoades loams.....	1,152	.2
Morton clay loam.....	10,560	1.4	Bainville-Rhoades loams, rolling phases.....	832	.1
Morton clay loam, rolling phase.....	2,560	.3	Bainville-Rhoades clay loams.....	2,304	.3
Bainville loam.....	10,048	1.3	Bainville-Rhoades clay loams, rolling phases.....	2,176	.3
Bainville loam, smooth phase.....	1,728	.2	Rhoades loam (complex with Morton or Bainville loams).....	2,688	.4
Bainville clay loam.....	3,776	.5	Rhoades loam, rolling phase (complex with Morton or Bainville loams, rolling phases).....	192	(¹)
Bainville clay loam, smooth phase.....	1,152	.2	Rhoades clay loam (complex with Morton or Bainville clay loams).....	1,920	.3
Searing loam.....	1,600	.2	Rhoades clay loam, rolling phase (complex with Morton or Bainville clay loams, rolling phases).....	512	.1
Searing loam, rolling phase.....	4,224	.6			
Flasher fine sandy loam.....	16,640	2.2			
Flasher fine sandy loam, rolling phase.....	13,824	1.8			
Flasher loamy fine sand.....	2,368	.3			
Morton-Rhoades loams.....	16,384	2.2			
Morton-Rhoades loams, rolling phases.....	2,432	.3			
Morton-Rhoades clay loams.....	17,792	2.4			

TABLE 5.—*Acreage and proportionate extent of the soils mapped in Billings County, N. Dak.—Continued*

Soil type	Acres	Per-cent	Soil type	Acres	Per-cent
Bainville loam, hilly phase.....	25, 280	3.4	McKenzie clay.....	576	0.1
Bainville loam, steep phase.....	40, 320	5.4	Sago clay.....	64	(1)
Bainville clay loam, hilly phase....	35, 584	4.8	Farland silt loam.....	4, 480	.6
Bainville clay loam, steep phase....	48, 320	6.5	Farland silt loam, high-terrace phase.....	7, 808	1.0
Cheyenne gravelly loam, steep phase.....	1, 472	.2	Farland silty clay loam.....	2, 048	.3
Flasher loamy fine sand, hilly phase.	6, 080	.8	Cheyenne loam.....	1, 984	.3
Flasher loamy fine sand, steep phase	4, 544	.6	Cheyenne gravelly loam.....	768	.1
Rough broken land.....	142, 208	19.0	Huff very fine sandy loam, high-terrace phase.....	1, 536	.2
Rough stony land.....	3, 520	.5	Cherry silty clay loam.....	12, 416	1.7
Scoria.....	45, 568	6.1	Farland-Wade silty clay loams.....	4, 928	.7
Arnegard silt loam.....	3, 008	.4	Wade-Farland silty clay loams.....	3, 456	.5
Grail silty clay loam.....	9, 856	1.3	Banks clay loam.....	704	.1
Patent silt loam.....	1, 216	.2	Havre silty clay.....	1, 152	.2
Patent silt loam, eroded phase.....	14, 400	1.9	Banks very fine sandy loam.....	4, 800	.6
Patent clay loam.....	10, 688	1.4	Banks loamy fine sand.....	4, 672	.6
Patent clay loam, slope phase.....	25, 088	3.3	Huff very fine sandy loam.....	4, 032	.5
Patent clay.....	1, 024	.1	Alluvial loam soils, undifferentiated.....	16, 192	2.2
Patent-Moline clay loams.....	45, 952	6.1	Alluvial clay soils, undifferentiated.	4, 608	.6
Patent-Moline clay loams, slope phases.....	6, 400	.9	Riverwash.....	5, 952	.8
Moline clay loam (complex with Patent or Grail clay loams).....	17, 344	2.3			
Moline clay loam, slope phase (complex with Patent or Grail clay loams, slope phases).....	2, 048	.3	Total.....	747, 520	100.0

¹ Less than 0.1 percent.

SOILS OF THE UNDULATING AND ROLLING UPLANDS

The soils of the undulating and rolling uplands occupy, for the most part, the smoother and higher lying uplands that form a distinct and nearly continuous topographic unit in the eastern part of the county. Certain soils of this group, however, are associated with soils of other groups. This is true particularly of those areas of the rolling phases of the Bainville and Flasher soils associated with the hilly and steep phases that are included in the second group—soils and land types of the hilly uplands and Badlands. The rolling uplands also include soils, such as the Arnegard and Grail, of the depressions and gentle slopes.

This grouping places many otherwise dissimilar soils together solely on their common characteristic, in addition to geographic association, the external one of slope or range in relief. Parent material ranges from sands to clays, internal drainage from inadequate to excessive, workability from easy to difficult, and productivity for wheat from comparatively high to poor. Despite their individual differences, these soils, as a whole, by occupying the smooth to rolling uplands, form a distinct and readily recognized topographic unit.

The soils of this group hold a very important place in the agriculture of the county, as they produce, together with associated soils of other groups, a large part of the wheat crop (pl. 3, A). Morton loam, the most extensive member of the group, ranks relatively high in productivity for wheat and the other common crops. Although stoniness, claypan spots, small areas of loamy fine sands, and rolling relief detract from the value of some of the soils within the group, Morton loam dominates it and causes it to rank high agriculturally.

DARK GRAYISH-BROWN LOAMS AND CLAY LOAMS

The subgroup of dark grayish-brown loams and clay loams is so designated because of the loam and clay loam texture of the surface soils and the dark grayish-brown color that extends to a depth of about 16 inches. These soils also have a rather friable consistence, a prismatic structure, and freedom from abundant carbonates to about this same depth.¹⁴ Morton loam, Morton clay loam, and their respective rolling phases compose the soils of this subgroup. Morton loam is one of the most desirable soils in the county. Its natural fertility, good tilth, good water-holding capacity, and smooth surface makes it well adapted to the crops commonly grown. Soil blowing is not a serious problem. Wheat and other small grains, grown for both grain and hay, other hay crops, and corn occupy most of the acreage. Morton clay loam is slightly less desirable because of its heavier texture, less satisfactory moisture relationships, and more limited adaptation to the common crops. The rolling phases are distinctly less suited for the production of cereals than are the typical soils, because of the increasing difficulty of tillage and harvesting operations, less satisfactory moisture relationships, less uniformity of soil character, and greater susceptibility to soil blowing. In their undisturbed condition, however, they support good stands of native grama and needlegrass.

Morton loam.—Morton loam is the dark grayish-brown loam that occupies the smooth uplands (pl. 3, *B*). Some of the most extensive areas are in that part of the county lying north and northeast of Saddle Butte. Although this is one of the most extensive cropland soils, very few individual areas are more than 2 square miles in extent.

The surface is undulating to gently rolling, and it is all easily traversed by farm machinery. Both surface and subsurface drainage are good.

To a depth of about 6 inches, the surface soil is dark grayish-brown loam that crushes readily when handled. Below this layer and extending to a depth of about 12 inches, the soil material assumes a well-defined prismatic structure,¹⁵ although it does not change color. Beginning at a depth of 12 inches, however, the color gradually becomes lighter, and at a depth of about 18 inches small white flecks of carbonates appear. The friable prismatic structure disappears rapidly below this depth. At a depth of 25 inches the brown color is almost wholly lacking, and the material is for the most part yellowish-gray sandy loam or clay loam.

Some areas include patches that have a claypan, the characteristics of which are set forth in the description of Rhoades loam complex. These areas are indicated on the soil map by appropriate symbols. Blue grama, intermixed with some western wheatgrass and needlegrass, and buffalo grass in small patches make up most of the native vegetation. Some niggerwool grows on the sandier areas. Little clubmoss is common.

¹⁴ The term "abundant carbonates" is used here to indicate the presence of sufficient carbonates to cause effervescence when a sample of the soil is treated with a dilute acid solution. Generally, although not everywhere, the most productive soils are free of abundant carbonates to a depth of 10 or 12 inches.

¹⁵ For explanation of prismatic structure see p. 27.



A, Wheat harvest on soils of the rolling upland. *B*, Smooth to undulating surface of Morton loam, much of which is devoted to small grain. Russian-thistles are the dominant vegetation in exceptionally dry seasons.



A, Rolling and hilly land suitable only for grazing. Bainville loam in foreground, Bainville loam, hilly phase, in background. B, Patent clay loam bordered by rough broken land.

Morton loam is productive, easily handled, and is adapted to a wide range of crops. Where market facilities are not too remote, cash crops, especially wheat, predominate. This crop probably occupies more than 50 percent of the tilled acreage, and flax and rye are grown to some extent. Subsistence crops, especially tame hay and corn, predominate on many of the areas closely associated with extensive grazing areas and occupy a large acreage in the livestock farming districts. The acreage of corn appears to be increasing. Small grains, especially oats for hay, are grown extensively in the more remote areas. Other commonly grown hay and forage crops are slender wheatgrass, millet, and sorgo. Crested wheatgrass, although not a common crop as yet, seems to be well adapted to this soil. Little alfalfa and sweet-clover are grown. Some sort of crop rotation and some summer fallowing are commonly practiced, but very little fall plowing is done. As mentioned earlier, in the section on Agriculture, the common use in the past of the moldboard plow has developed a plow sole in certain areas. A change in tillage implements and in depth of plowing are recommended.

Although wheat yields are not so high on this soil as on a few other soils, they are above the average for the county. In normal seasons wheat probably yields from 10 to 12 bushels an acre, and corn, when cut for fodder including the grain, probably yields from 1 to 3 tons an acre. Areas that are not tilled are devoted to grazing. The carrying capacity of such grazing land is high, as the grass cover is both palatable and nutritious and the growth ordinarily is good. According to grazing experiments conducted at the Northern Great Plains Field Station of the Bureau of Plant Industry, United States Department of Agriculture, near Mandan, N. Dak., it requires about $7\frac{1}{2}$ acres of Morton loam to carry a 2-year-old steer satisfactorily through a 5-month grazing season (10).

Inasmuch as it is difficult to obtain data on the value of land in terms of dollars, a relative value only is given in the discussion of the soils of this county. The most nearly ideal soil for agricultural use, which is Arnegard silt loam, is given a value of 100; all other soils are given a rating according as to how their agricultural value compares to that of Arnegard silt loam.¹⁰ The relative value of Morton loam is about 85 as compared with 100 for Arnegard silt loam for both tilled crops and grazing.

Morton loam, rolling phase.—Morton loam, rolling phase, includes those areas of Morton loam having a surface that is smooth enough to be tilled but is so rolling that heavy agricultural machinery is used only with difficulty. The lay of the land is rolling or billowy, making it subject to soil washing and soil blowing when intertilled crops are grown or when the surface of the soil is otherwise exposed. The slope in general ranges from $7\frac{1}{2}$ to 15 percent; in other words, the elevation changes from $7\frac{1}{2}$ to 15 feet for every 100 feet of horizontal distance.

The soil layers of Morton loam, rolling phase, are similar to those of the typical soil, except that in general the depth to which the dark grayish-brown color extends varies according to the lay of the

¹⁰ These ratings are based entirely on the capability of the soils to produce the crops commonly grown. Such factors as accessibility and distance to market do not enter into the compilation of these ratings.

land. In the smoother parts, especially in the draws or lower areas, the soil is identical with typical Morton loam; but on some of the steeper slopes and knobs the brown color extends to a depth of only a few inches. Frequently, plowed fields of this soil show lighter colored patches, indicating that the dark color does not extend to the bottom of the plow layer. Some areas include claypan spots, which are described under the Rhoades loam complex (see p. 52). These areas are indicated on the soil map by appropriate symbols.

The soil is well drained, excessively so in the steeper areas. It is widely distributed throughout the eastern uplands. Areas of this rolling phase are associated with the typical areas, but they are more irregular in shape, and few of them occupy more than a few hundred acres, most of them ranging from 40 to 200 acres in extent.

The native vegetation is similar to that on the typical soil, except that where the dark grayish-brown layers are thin or where the soil tends to be more sandy, less desirable plants grow, principally niggerwool and little bluestem. These undesirable plants and the droughty character of the shallow or sandy spots reduce the grazing value of this soil to about 65 percent of that of the most desirable grazing land.

Probably 65 percent of this land is tilled. It is devoted largely to the same crops as the typical soil, and wheat occupies the largest acreage. Because of the variation in thickness of the surface soil and the droughty character of the shallow knobs, yields are lower and less uniform than on the typical soil. Land values are about one-half of those placed on Morton loam.

Morton clay loam.—Morton clay loam is similar in color and soil structure to Morton loam, but the entire soil has a heavier texture. The surface soil is dark grayish-brown heavy silt loam, underlain at a depth of about 6 inches by dark grayish-brown clay loam that has a well-defined prismatic structure. Although this layer is heavy in texture, the fragments are fairly friable. Below a depth of about 12 inches the color grades to a lighter shade, and below a depth of 18 inches the material is olive-drab clay or clay loam. In most places there is an abundance of white salt flecks below this depth.

A variation of this soil is associated with exposures of hard dense siliceous rock. In such places the surface soil to a depth of about 4 inches is dark-brown loam or clay loam containing some angular rock fragments. Below this and extending to a depth of about 9 inches is dark-brown clay loam having a fairly well defined prismatic structure and containing some rock fragments. This rests either on a hard rock shelf or on a matrix of soil material that encloses rock fragments and is, therefore, impenetrable to a spade. The surface of this soil is strewn with rock fragments ranging from 2 to 20 inches in diameter. These stony areas of Morton clay loam ordinarily are not tillable. They are indicated on the map by stone symbols. One of the most extensive stony areas is about 1 mile south of Fairfield. These stony areas are associated, for the most part, with the rocky or stony tracts of rough stony land.

The surface slope and drainage of Morton clay loam are similar to those features of Morton loam, except that the subsoil is invariably

clay, whereas that of Morton loam is generally more nearly a loam and consequently more open.

Blue grama dominates the native vegetation as on Morton loam, but needlegrass is not so plentiful and western wheatgrass is more abundant. The grass cover is not so uniform on the stony areas as on the typical soil, owing to the many spots that are shallow over the bedrock.

This soil is widely distributed over the eastern uplands, but it is not so extensive as Morton loam.

Probably 65 percent of the nonstony land is tilled. It is devoted largely to cash crops, chiefly wheat. Morton clay loam is better adapted to wheat, whereas much of Morton loam is better adapted to corn or other cultivated crops. Practically all of the common cash and subsistence crops are grown successfully on the clay loam. As on Morton loam, some of the soil is farmed with a crop rotation consisting of corn followed by wheat, barley, or oats. Flax is grown on this soil successfully when the growth of weeds is controlled. Both summer fallowing and fall plowing are practiced when moisture conditions are favorable. Cultivated crops are displacing summer fallow to some extent, and the soil is not so heavy or hard as to preclude spring plowing for satisfactory preparation of the seedbed.

Yields of small grain about equal those obtained on Morton loam, and yields of corn are about the same or possibly a little less. The principal agricultural difference between these two soils is that Morton clay loam is a little harder to manage and has somewhat less desirable moisture relations. For cultivated crops, such as corn, Morton loam is generally preferable.

The agricultural value of typical Morton clay loam is about the same as that of Morton loam. Its value for grazing is fully as high as that of the loam, but the grazing value of the stony areas is not more than two-thirds that of typical Morton clay loam.

Morton clay loam, rolling phase.—Morton clay loam, rolling phase, differs from the typical soil primarily in having a rolling surface, the gradient ranging from $7\frac{1}{2}$ to 15 percent. Because of this more rolling surface, the land is less easily farmed, the exposed knobs are drier, and the thickness of the dark grayish-brown friable surface layer is extremely variable and, on the average, much less than in the typical soil. Plowed fields of this soil almost invariably show numerous lighter colored patches, indicating that the brown color does not extend to the bottom of the plow layer. Several small areas in the vicinity of Fairfield are more or less covered with stones, consisting of comparatively hard dense angular siliceous rock fragments that range in diameter from 2 to 18 inches. Their presence is indicated on the soil map by appropriate symbols. Where the stones are plentiful, the areas are nontillable and consequently are devoted entirely to grazing. This soil is well drained, the steeper parts excessively drained. Small areas are scattered over the northern and eastern parts of the county.

The native vegetation is similar to that on the typical soil, except where the dark grayish-brown surface layer is thin, and in such places less desirable grasses predominate, principally niggerwool and little bluestem. Probably 65 percent of this rolling soil is tilled. It is devoted largely to the production of small grains, especially wheat. Because of the lower fertility and the more droughty character of the

more exposed slopes, crops are less uniform and yields are less than on the typical soil. This soil is valued at about 40 percent of the value placed on the best cropland in the county and 65 percent of that placed on the best grazing land.

GRAYISH-BROWN LOAMS AND CLAY LOAMS

The grayish-brown loams and clay loams differ essentially from the dark grayish-brown loams and clay loams in having (1) a thinner and lighter colored surface soil layer, (2) a slighter depth to carbonates, (3) a less well defined prismatic structure, and (4) a generally more rolling relief. These are the principal differences between the Bainville and the Morton soils.

These characteristics make the Bainville soils less productive than the Morton soils. Their water-holding capacity also is lower, their tilth is less uniformly good, and their adaptation is somewhat less elastic. Some of the soils of this subgroup, particularly because of their weaker structure, compared with that feature of the Morton soils, are more susceptible to soil blowing. Although most of the land is tilled, a greater part is devoted to grazing than of the soils of the first subgroup. Wheat and other small grains (grown for both grain and hay), other hay crops and corn occupy most of the tilled acreage.

Bainville loam.—Bainville loam is the relatively light colored loam soil that occupies rolling areas of the uplands. Because of its rolling surface, the character of the soil varies markedly. Small bodies of smooth land generally occupy the narrow ridge tops, and if more extensive they would be shown on the soil map as Bainville loam, smooth phase. The 4- or 5-inch surface soil is grayish-brown or dark grayish-brown friable loam or silt loam. This is underlain by yellowish-gray or gray material, and below a depth of about 10 inches there is olive-gray silty material containing an abundance of flecks of carbonate. Carbonate sufficient to cause effervescence when the soil is treated with acid are at or within a few inches of the surface. The soil on the rolling areas or slopes, although by far the more extensive, is much more irregular in character. In general it is more decidedly gray, and the surface layer is thinner. The exposed soil, particularly in cultivated fields, almost invariably shows a mixture of the olive-gray material from lower layers, and in such places carbonates are abundant at the surface.

Bainville loam is developed, for the most part, from very fine sand and silt of the Fort Union formation. The surface of this soil is about as rolling as that of Morton loam, rolling phase; the slope ranges from about $7\frac{1}{2}$ to 15 percent. Surface drainage consequently is excessive, and the soil on the slopes is noticeably more droughty than that of smoother areas. The native vegetation for the most part is blue grama, a sedge (niggerwool), and, on the steeper parts, considerable little bluestem.

The aggregate area of this soil is about one-fifth that of Morton loam, being 15.7 square miles. It occurs in comparatively small scattered areas commonly associated with the smoother areas. It is distributed widely over the county, both in the Badlands and on the eastern uplands.

This soil is used for both crops and grazing, and probably not more than 50 percent of it is tilled. Because of its rolling relief and consequent less fertile condition, it is more difficult to handle than the smoother soils, is subject to both soil blowing and water erosion, and is more droughty and less productive. The tilled areas are devoted to general farm crops, particularly wheat, oats, barley, hay crops such as proso (a millet), and corn. Yields are markedly lower than on such soils as Morton loam. The value of this soil as cropland is about 35 percent of that of the most desirable land, and as grazing land it is about 55 percent of that of the best grazing land.

Bainville loam, smooth phase.—Bainville loam, smooth phase, is the grayish-brown soil that for the most part is in the eastern uplands. The 5-inch surface soil is grayish-brown or dark grayish-brown very fine sandy loam or loam. Below this layer the color grades into brownish yellow. Unlike Morton loam, the material has no well-defined prismatic structure but breaks under slight pressure to firm irregular chunks that crush easily. At a depth ranging from 8 to 12 inches the brown cast is faint, the color being light brownish gray or olive gray. An abundance of salt flecks are present in most places, just below the brown surface layer.

The surface of Bainville loam, smooth phase, is undulating to gently rolling. This soil occupies small irregular tracts, few of which are more than 150 acres in size. In general, the soil occurs on more exposed or rounded knobs than does Morton loam. Both surface and internal drainage are good.

The native vegetation is similar to that on Morton loam, except that niggerwood is more abundant. Blue grama and needlegrass are the principal grasses, and little bluestem is common on the more exposed parts.

Bainville loam, smooth phase, is not extensive. The small irregular tracts are widely distributed over the eastern uplands, especially in the northeastern corner of the county and near Fryburg. Only a part of this soil is tilled, probably about 50 percent of it being used as virgin grazing land. When cropped, it is used principally for wheat, hay crops, and corn. In general, it is farmed like Morton loam, except that a smaller part of it is used for wheat and more of it for hay crops. Crops return lower yields on this soil than on Morton loam. Wheat probably averages about 10 bushels an acre and oats about 21 bushels during better-than-normal years. The value of this soil for crops is about 45 percent of that of the most desirable land, and for grazing about 75 percent of that of the best grazing land.

Bainville clay loam.—This soil is similar to Bainville loam, except that the texture of the surface layer averages clay loam rather than loam and it is developed from clayey material rather than from very fine sand and silt of the Fort Union formation. The color of the surface soil is somewhat lighter grayish brown, its depth is slightly less, and an abundance of carbonates lies nearer the surface than in Bainville loam. As with Bainville loam, the surface is rolling, causing the soil to be more difficult to work, more droughty, and more subject to erosion than those loam and clay loam soils having a smoother surface.

Bainville clay loam is not extensive. Most of the acreage is in small, widely scattered tracts throughout the eastern uplands, although a few areas are in the Badlands.

Possibly 50 percent of the land is tilled, and the rest is used for grazing. The tilled acreage is devoted mostly to small grains and hay, which return comparatively low yields. The value of this soil as tillable land is about 40 percent of that of the best land in the county, and its carrying capacity is about 55 percent of that of the best grazing land.

Bainville clay loam, smooth phase.—Bainville clay loam, smooth phase, is similar to Bainville loam, smooth phase, except that the texture of the soil material is clay loam. In general, it is grayer than that soil. The 4-inch surface layer consists of light grayish-brown friable silt loam or clay loam. This is underlain to a depth of about 8 inches by dark olive-gray clay loam that breaks into irregular fragments, which, on pressure, crush fairly easily. Below this layer the material grades rapidly into olive-gray or yellowish-gray clay. A very few areas of this soil are stony, especially throughout the upper 2 feet, the stones consisting of dark-gray hard angular siliceous rock fragments.

The native vegetation is mostly blue grama, with frequent patches of unpalatable plants, such as little bluestem, triple-awn grass, and broom snakeweed.

The surface of this soil is undulating to gently rolling. Surface drainage is good, and subdrainage, although slow, is sufficient for satisfactory growth of roots.

This soil is not extensive. It occurs as scattered comparatively small bodies throughout much of the eastern uplands. Much of it is tilled and is devoted largely to small grains and hay. Its productivity and value are about equal to those features of Bainville loam, smooth phase. It is a little more difficult than that soil to handle during wet seasons but is probably less subject to soil blowing.

REDDISH-BROWN LOAMS

Reddish-brown loams differ from the Morton soils in the color of the soil layers and in their somewhat more rolling relief. Another distinctive feature is the underlying scoria beds, which consist of red hardened shales together with irregular masses of red and black clinkers. The scoria beds have been formed for the most part by the burning of underlying lignite beds associated with the Fort Union formation prior to the advent of white men, but in a few places coal beds are still burning.

Searing loam.—Searing loam is the reddish-brown soil that occurs over beds of scoria. The 7-inch surface layer of dark reddish-brown loam crumbles easily to soft fragments. It is underlain to a depth of about 16 inches by light reddish-brown friable heavy loam that breaks easily to soft fragments. Below this layer the color fades, splotches of gray appear in many places, and in some places an accumulation of carbonate is present. The soil material below a depth of 20 inches generally has a grayish-brown color with a red tinge, a loam to heavy clay loam texture, and an indefinite structure. Scoria beds lie at a depth ranging from a few inches to 4 feet below

the surface. In many places small patches of scoria outcrop on the surface, and fragments everywhere occur throughout the soil mass. A few areas have a claypan resembling that of the claypan or Solonetz soils described later. These areas are generally underlain by clayey material, and the scoria beds are not so prominent. Areas having this claypan development are indicated on the map by appropriate symbols.

The surface of Searing loam is undulating to somewhat billowy and in general is not so smooth as that of Morton loam. Both surface and subsurface drainage are good.

Practically all of this soil is in the eastern uplands within a few miles east of the eastern edge of the Badlands, especially 6 or 7 miles south and southwest of Fryburg. All the areas are small and are associated with areas of scoria.

As on Morton loam, blue grama predominates in the native vegetation, with some western wheatgrass, needlegrass, and niggerwool intermixed. Those areas with numerous clay or slick spots support little vegetation, as the clay spots are almost bare, although the interspot areas support about the same vegetation as normal Searing loam.

Searing loam is a good agricultural soil, and about 80 percent of it is tilled. Wheat and corn probably are the most common crops, although other small grains and hay crops are common. Because of its favorable tilth, the soil is well adapted to cultivated crops, especially corn. Yields of this crop are equal to those obtained on any of the other soils with the exception of Arnegard silt loam. Yields of wheat probably are a little less than those obtained on Morton clay loam. The untilled areas of Searing loam, which include those areas having the claypan condition, are grazed. The normal grazing value of Searing loam approximates that of Morton loam but areas including claypan spots range in grazing value from 30 to 60 percent of that of the best range land, depending on the number of such spots. The relative value of normal Searing loam for crops is about 80 percent of that of the best cropland of the county.

Searing loam, rolling phase.—Searing loam, rolling phase, differs from typical Searing loam principally in that its surface is more rolling or billowy, knobs or outcrops of scoria are numerous, and the depth of the brown soil material is more variable. The vegetation is similar to that on the typical soil, except that such grasses as little bluestem are common on the steeper and more shallow spots and the knobs of scoria are bare of cover other than a sparse shrubby growth.

Areas of this soil are somewhat more numerous than those of the typical soil, but they are relatively inextensive. They are associated with the typical soil and with areas of scoria. The largest acreage is south and southwest of Fryburg, and a few small areas are in the Badlands.

This soil ordinarily is considered suitable only for grazing, although about 30 percent of it is tilled. The tilled land includes the areas most free of scoria outcrops, and about the same crops are grown as on typical Searing loam. Because of the numerous scoria outcrops and the more billowy surface of most of this soil, however, it is more poorly adapted to tillage and returns much lower yields,

compared with typical Searing loam. The relative value of those areas most suitable for tillage is about 40 percent of that of the best land of the county. As grazing land the average value of Searing loam, rolling phase, is about half that of the best grazing land of the county.

GRAYISH-BROWN TO BROWN FINE SANDY LOAMS AND LOAMY SANDS

Grayish-brown to brown fine sandy loams and loamy sands of the uplands are members of the Flasher series. They vary in topography and in depth, color, and texture of surface layer, but all are sandy. As they are more droughty than the soils of the three previous subgroups, they are better suited to deep-rooted crops, such as corn, than to the shallow-rooted small-grain crops. The sandy porous surface soils, however, allow crops to make more efficient use of the moisture from light summer showers than on soils of the first three subgroups; consequently, during some seasons some crops do better on these soils than on the clay loams. The soils of this group are easily handled but are markedly subject to soil blowing. Flasher fine sandy loam is the most productive and most desirable soil of the group. The rolling relief handicaps the use of Flasher fine sandy loam, rolling phase, for tilled crops; whereas the internal character, together with the rolling relief, still more definitely limits the use and desirability of Flasher loamy fine sand.

Flasher fine sandy loam.—Flasher fine sandy loam is the dark grayish-brown fine sandy loam soil that occurs throughout the eastern uplands.

The surface is undulating to gently rolling and is, on the whole, slightly more undulating than the average areas of Morton loam. In general, Flasher fine sandy loam lies on the higher parts of the uplands in association with Morton loam. Both surface drainage and subdrainage are good.

The surface soil, to a depth of about 5 inches, is dark grayish-brown fine sandy loam. Below this layer the color varies; in places the grayish-brown color continues to a depth of 12 inches, and in other places it begins to fade to a light brown at a depth of about 5 inches. The structure is coarsely prismatic to a depth of about 12 inches, but the material does not break into the firm yet friable finely prismatic structure common to Morton loam. Below a depth of 12 inches the color invariably grades into yellowish brown and the texture becomes more sandy. Below a depth of 16 to 18 inches the material is olive-yellow or brownish-yellow loamy fine sand that has little definite structure. A few areas have a very fine sandy loam rather than a fine sandy loam texture throughout the upper layers, and a few areas have a fairly well developed claypan or Solonetz condition in spots. This condition is indicated on the soil map by appropriate symbols.

Practically all of this soil lies in the eastern uplands. Several areas include from 200 to 350 acres, especially those in the vicinity of Saddle Butte and about 14 miles south of Fryburg.

The native vegetation consists principally of a mixture of blue grama and niggerwool, with a small amount of prairie junegrass and buffalo grass intermixed. Many of the sandier areas are partly occupied by sandgrass.

Probably 75 percent of this soil is tilled. Some wheat is grown, but owing to its more sandy texture, the soil is not so well adapted to wheat, oats, and barley as the Morton soils. Consequently, corn and rye occupy a relatively greater proportion of the acreage of this soil than they do of the heavier textured tillable soils, although wheat probably occupies a larger acreage than does any other crop. Such crops as millet, slender wheatgrass, and sorgo are not commonly grown. In places in some seasons corn on this soil has returned very nearly as high yields as on nearby areas of Arnegard silt loam. Wheat yields average about 8 bushels to the acre. Yields of hay crops are lower than on the heavier textured soils, corn for forage probably yields from 1½ to 3 tons, and corn for grain about 20 bushels an acre.

Flasher fine sandy loam is easily tilled, and crops are ordinarily sown with little preparation of the seedbed. It is on such soils as this that small grains are frequently drilled in without any previous preparation. As with Morton loam, crop rotation is practiced to some extent. Care should be taken not to leave this soil bare of vegetation, as its lack of definite prismatic structure and consequent looseness makes it susceptible to blowing by the wind, and plowed fields invariably drift during periods of strong wind. Experiments indicate that tilled fields should always be maintained in as rough or cloddy a condition as possible, as by so doing wind action is most effectively hampered.

The relative value of this soil is less than that of Morton loam. It is about 50 percent of that of the most desirable land of the county. The value of the soil as grazing land is lower than that of Morton loam, largely because of the less desirable type of grass cover on it.

Flasher fine sandy loam, rolling phase.—Flasher fine sandy loam, rolling phase, includes those areas of Flasher fine sandy loam having a surface that is smooth enough to be tilled but so rolling as to make the operation of heavy farm machinery difficult. The surface is billowy or moderately rolling. It is characterized by smooth narrow crests, slopes, and small valleys. The small tracts of smooth land that are necessarily included in the areas shown on the soil map are identical with Flasher fine sandy loam, but the slopes and knobs have a surface layer of grayish-brown fine sandy loam less than 5 inches thick. In such places, carbonates sufficient to cause effervescence are at or near the surface. A large part of the total area of this soil occupies slopes. Here, the soil is less productive, more subject to blowing and water erosion, and more difficult to handle than it is on the smooth narrow crests or in the drainageways, or draws, as they are called locally. The small elongated areas or strips lying along the small draws or drains are the most fertile. Here the layer of grayish-brown or dark grayish-brown fine sandy loam or loam generally is from 10 to 12 inches thick. Because of their position in the draws, these small areas benefit from the runoff received from the adjoining higher land.

The grass cover in the draws is mostly blue grama with some sedge and big bluestem intermixed. This vegetation furnishes good grazing. The grass cover on the slopes, however, is poorer, as most of it is composed of a mixture of blue grama, sedge, patches of sandgrass,

of the cultivated acreage is devoted to subsistence crops, particularly small grains for both grain and hay, other hay crops such as millet, and corn. Some alfalfa is grown but the acreage is small, and the acreage of wheat and flax is comparatively small.

Yields are fairly good. Oats in normally good years yield from 15 to 30 bushels an acre; small grains cut green for hay about 1 ton; and wild hay, most of which is western wheatgrass, from $\frac{1}{2}$ to 1 ton. As cropland, the general productivity of this soil is about 65 percent of that of Arnegard silt loam.

Have silty clay.—Have silty clay is the brownish-gray well-drained silty clay soil on the first bottoms along the rivers. The 6-inch surface layer of this soil is brownish-gray or light grayish-brown friable silty clay, which breaks easily into fine granular fragments that are easily crushed. Below this layer the material has a well-defined laminated structure. When removed with a spade the material breaks readily into small flat angular fragments that are very resistant to crushing. The material in some areas where the surface soil has not been disturbed shows this structure within a very few inches of the surface. The color of the material in this layer ranges from dark grayish brown to olive gray and the texture from silty clay loam to silty clay. When the soil is crushed and moistened the color becomes medium gray. Varves, or very thin laminations, of lighter colored very fine sand occur in a few places in this layer. Below a depth of approximately 24 inches the material consists of alternate layers of silty clay loam and yellowish-gray very fine sand. This soil, throughout its entire depth, contains sufficient carbonates to cause effervescence when the soil is treated with acid.

In a few areas included with this soil, the surface soil material is silt loam in texture rather than silty clay, and in such areas the lenses and laminations of sandy material are more prominent and occur nearer the surface.

Have silty clay occupies areas on the first bottoms of the Yellowstone, Missouri, and Little Missouri Rivers, being most extensive along the Yellowstone and Missouri Rivers. The land surface of most areas is nearly level, and surface drainage is slow. Because of the friable character of the soil material and general presence of coarser laminations below a depth of 24 inches, internal drainage is sufficient to maintain good conditions for plant growth.

The native vegetation on part of this soil evidently was cottonwood trees that ranged in size from about 20 to about 36 inches in diameter, but many open patches, or prairies, were occupied mostly by grasses and shrubby growth. At present the greater part of the untilled land is occupied by a dense growth of brush composed of ash and elm saplings, buckbrush, wild rose, some buffaloberry, and other shrubby growth. Probably 25 percent of the uncleared land supports a medium to fairly dense stand of cottonwood ranging in diameter from 9 to 24 inches, and a few areas support a fair stand of elm and ash ranging in diameter from 2 to 20 inches. Uncultivated land grows up readily to forest and brush.

Probably 90 percent of this soil in the Yellowstone Valley is cultivated and irrigated, and about 35 percent of the acreage in the Missouri Valley and possibly 10 percent of the acreage in Little Missouri Valley are tilled. Dry-farmed areas are productive and yield

spots consist of a dense intractable clay. The less strongly developed areas of claypan spots are covered by grass and have a grayish-brown friable surface layer, about 5 inches thick, over the dark-gray or grayish-brown claypan. The claypan areas represent a special soil condition that is known as Solonetz, although, technically considered, it is to be understood that modifications of the true Solonetz condition exist. Soils of this special condition associated with the Morton and Bainville soils are classified in the Rhoades series, and the complex condition is mapped and named as a Morton-Rhoades complex or a Bainville-Rhoades complex, the dominant soil being named first.

The claypan characteristics detract from the value of these soils because of the interference they offer to tillage, growth of plant roots, and movement of soil moisture. A greater proportionate acreage of these soils is used as grazing land than of the related claypan-free soils. The acreage cropped is used chiefly for the production of small grains, particularly wheat, and yields of all crops are lower than on the corresponding claypan-free soils. Crop rotation, even though it includes only two or three small grains, is practiced, and its desirability is recognized. A few farmers rotate corn or other row crops with the small-grain and hay crops.

Because of the texture and structure of the claypan, these soils are frequently prepared for sowing by fall plowing whenever the moisture condition of the soil is favorable, as the hard clods are broken to a more friable condition by subsequent freezing and thawing during the winter. It is the common opinion of the farmers that persistent tillage, together with the effects of freezing and thawing, improves the tilth and productiveness of these soils from year to year.

Morton-Rhoades loams.—This complex represents areas of Morton loam in which spots of Rhoades loam are moderately developed either in areal extent or in the degree of the development of the alkali claypan or Solonetz condition. Such areas are less spotted by bare clay and consequently are more productive than the areas designated as Rhoades loam complex.

Morton-Rhoades loams occupy undulating to gently rolling areas in the eastern uplands. This soil complex is widely distributed throughout this part of the county, but the individual areas are smaller and less numerous than those of Patent-Moline clay loams. Surface drainage is good, but internal drainage is slow.

The native vegetation on the larger or interspot areas is predominantly blue grama with some western wheatgrass and western needlegrass intermixed. Little clubmoss commonly occupies much of the ground not covered by these grasses. The vegetation on the clay spots varies considerably. A very few of these spots are unproductive and support only a scant growth of such plants as small pricklypear, gumweed, and saltgrass; a great many are occupied by a fair or patchy cover of buffalo grass and western wheatgrass; and a few are completely covered with a growth chiefly of buffalo grass and, to smaller extent, of western wheatgrass and blue grama.

Approximately 50 percent of the acreage is tilled, and most of the cultivated land is devoted to small grains and hay. Wheat is the most common crop, and during good years the yields average about 11 bushels an acre. Small grains cut green for hay yield about 1 ton to

the acre. As cropland the value of this soil complex is about 55 percent of that of the most desirable land in the county, and as grazing land its value is about 70 percent of that of the best grazing land.

Morton-Rhoades loams, rolling phases.—This soil complex resembles Morton-Rhoades loams except that it has a more rolling surface, the gradient ranging from $7\frac{1}{2}$ to 15 percent. As a consequence, the character of the soil, particularly the depth to which the grayish-brown surface soil extends, is more variable, and probably a greater proportion of the complex is entirely free of the claypan than is true of Morton-Rhoades loams.

The total area of this soil is small. The individual areas are very small and are widely scattered over the eastern uplands. Although commonly considered suitable for tillage, this soil complex is comparatively low in productivity for grains, is relatively more subject to water erosion, and is more difficult to handle than the smoother lying areas of the same type of complex. Approximately 50 percent of the land is tilled and used primarily for small-grain and hay crops. Its values as cropland and grazing land are about 35 and 55 percent, respectively, of those of the best land in the county.

Morton-Rhoades clay loams.—This soil complex, as indicated by its name, is one of Morton and Rhoades clay loams and resembles Morton-Rhoades loams, except that the surface soil of the interspot areas averages clay loam rather than loam. Otherwise the internal soil characteristics, relief, and drainage are similar to those of the loams complex.

This soil is more extensive than the loams complex but not so extensive as Patent-Moline clay loams. Areas of this complex are widely distributed throughout the eastern uplands, particularly east and northeast of Saddle Butte.

Approximately 50 percent of the land is tilled, and most of the cultivated acreage is used for small grains and hay. Wheat is the most common crop, and during the better years yields average about 11 bushels an acre. Small grains cut green for hay yield about 1 ton an acre. As cropland, this complex is estimated to be about 50 percent as valuable and for grazing about 75 percent as desirable as the most desirable land for these respective purposes.

Morton-Rhoades clay loams, rolling phases.—This soil complex is rather similar in characteristics to Morton-Rhoades loams, rolling phases, complex, except that the textures of the surface soils are clay loams instead of loams. Variations in the depth and coloring of the surface soil are slightly more common in this complex than in the Morton-Rhoades loams complex, and the difficulties of tillage, unsatisfactory moisture relationships, and hazards of water erosion are probably slightly greater because of the higher content of clay.

This is not an extensive soil condition. A greater proportion of the total area is used for grazing than of Morton-Rhoades loams, rolling phases, because of its less desirability for cropping purposes, and also in part because of its occurrence in places as small areas in association with more extensive areas of Bainville loam and Bainville loam, hilly phase. The tilled areas are used largely for wheat and oats, and the untilled areas for wild hay as well as for grazing.

As is true of other clay loams in this county, tilth is improved by fall plowing. The relative values for cropland and grazing land are 30 and 50 percent, respectively.

Bainville-Rhoades loams.—This complex represents areas of Bainville loam, smooth phase, intermixed with smaller areas of Rhoades loam, which generally occur as circular or elliptical bare clay spots. In common with the other complexes of this character, the claypan development is not uniform either in extent or in degree of development. As mentioned previously, the bare clay spots are the result of erosion of the surface soil, which overlies the claypan. The claypan development itself is a result of the influence of excess sodium in the soil and is discussed in the section on Morphology and Genesis of Soils, in the latter part of this report. As in other soils of this subgroup, the number of claypan areas in the complex is less than in the complexes included in the group with numerous claypan (Solonetz) areas.

This complex is of relatively small extent and importance in Billings County, and it is used more for grazing and wild hay than the corresponding complex of Morton-Rhoades loams, largely because of the lower productivity and suitability of Bainville loam as compared with Morton loam. The cropped areas are used largely for small grains, as is true of most of these complexes of a comparatively moderate degree of claypan development. The values of the complex for cropping and grazing are approximately 45 and 60 percent, respectively, of the most desirable land in the county.

Bainville-Rhoades loams, rolling phases.—This complex consists of Bainville loam in which are intermittent areas of Rhoades loam or in which the claypan characteristics of Rhoades loam are developed to only a slight degree. The rolling relief, ranging from $7\frac{1}{2}$ to 15 percent gradient, results in a less uniform distribution of the claypan areas, inasmuch as the spots more commonly occur in the depressions where drainage has not been adequate to carry off the excess sodium to which the claypan or Solonetz development is largely attributed.

In comparison with Bainville loam, smooth phase, the Bainville areas of this complex are less productive of the small grains, largely because of the rolling relief and the undesirable effect such relief has on soil development, moisture relationships, use of farm machinery, and susceptibility to erosion. These relationships have been brought out in the earlier description of Bainville loam. Moreover, the presence of areas of Rhoades loam lessens the productivity of areas of Bainville loam in the same way that their presence detracts from the productivity of any other soil otherwise free of claypan development. This means that the areas of this complex are less well suited for either crops or pasture than are Morton-Rhoades loams, rolling phases, Bainville loam, or Bainville-Rhoades loams.

The total area of this soil complex is very small. Widely scattered bodies are in the eastern uplands, especially in the extreme northeastern part of the county. Some of this soil is considered suitable for tillage, although more than 50 percent of its total area is used for grazing. Many of the bodies are included or associated with land

sued only to grazing and consequently are used for the same purpose. The crops most commonly grown are small grains, particularly wheat, and hay crops. Yields are low and uncertain. The value of this land for crops and grazing is about 30 and 50 percent, respectively, of that of the best land in the county.

Bainville-Rhoades clay loams.—This complex represents areas of Bainville clay loam in which the claypan spots are irregularly distributed or in which, even though the claypan is rather uniformly developed, the bare spots are not so numerous, so intractable, or so unproductive as those of the soils with numerous claypan (Solonetz) areas. It should be understood that in this soil separation, as in the other separations of this kind, certain small areas approach the character of areas shown on the map as Rhoades clay loam complex. The mechanical difficulties of showing the extremely small areas on a map of the scale published with this report account for these minor inclusions.

Small areas of this soil complex are scattered over the eastern uplands. The surface for the most part is gently rolling, and the areas are well drained, although internal drainage is inclined to be slow.

The native vegetation is similar to that on Morton-Rhoades loams, although the interspot areas support a somewhat less uniformly good stand of grasses.

This soil complex, on the average, is fairly suitable for crops requiring tillage of the soil, although not more than 50 percent of the acreage is tilled at present. Included small areas with strongly developed clay spots and a well-developed claypan are unsuitable for tillage. Moreover, many of the areas are closely associated with hilly land suitable only for grazing; consequently such areas are more economically used for that purpose. The cropped areas are devoted primarily to small grains and hay crops. Yields are lower than those obtained on Morton-Rhoades clay loams, and the values of this complex as cropland and grazing land are about 40 and 60 percent, respectively, of the most desirable land of the county.

Bainville-Rhoades clay loams, rolling phases.—This complex resembles Bainville-Rhoades loams, rolling phases, except that the texture of the surface soil of the interspots is clay loam instead of loam. The greater clay content makes this complex slightly less desirable for tillage than the loam complex, because of the increased difficulty of tillage, the slower rate of infiltration of rain water, and the consequent increased loss by evaporation. These effects of the increased clay content are not so noticeable in areas that still maintain their native-grass cover, and the relative suitability of the two soils for grazing is approximately the same.

The relationships between this complex and the smoother lying complex of Bainville-Rhoades clay loams are similar to those between Bainville-Rhoades loams, rolling phases, and Bainville-Rhoades loams, described under Bainville-Rhoades loams, rolling phases.

This complex has approximately the same extent as Bainville-Rhoades clay loams. It is distributed rather widely throughout the eastern part of the county. Some areas are tilled, but most of the acreage is used for grazing or wild hay, partly because of the relatively low productivity for small grains and partly because of the

occurrence of the complex with soils more definitely limited in their use to grazing. The values for crops and grazing are approximately 30 and 50 percent, respectively, of the best land in the county.

GRAYISH-BROWN LOAMS AND CLAY LOAMS WITH NUMEROUS CLAYPAN (SOLONETZ) AREAS

The grayish-brown loams and clay loams with numerous claypan (Solonetz) areas differ from the soils of the preceding subgroup in having more numerous claypan and clay spot areas. As a result, the most important and outstanding characteristics of the soils of this group are combined in the claypan that lies at a depth ranging from 5 to 10 inches below the surface (pl. 7, *B*) and the slick, or clay, spots that show on the surface as bare or semibare pocklike spots (pl. 8). The surface of these areas has a choppy or somewhat rippled appearance. The clay spots are irregularly rounded in outline and range from 3 to 20 feet in diameter. They occupy the low positions or depressions that lie from 4 to 12 inches lower than the surrounding land. These depressions represent from 15 to 40 percent of the area of the soil bodies. Vegetation, especially grass, is generally sparse or entirely lacking. The interspot areas, or higher part, making up the remaining 60 to 85 percent of the soil bodies, represent that part in which the claypan has not been exposed by differential erosion. The claypan in the interspot areas varies both in degree of development and in extent, as some of the interspot areas lack the claypan and are representative of the associated claypan-free soils of the uplands. Almost all of the interspot areas support a good cover of vegetation consisting principally of grasses desirable for grazing.

Because of the impossibility of showing on the published soil map all the various soil conditions, these areas are recognized as complexes. Thus, the soil of any particular interspot area is Rhoades loam, Morton loam, Bainville loam, or some intermediate soil condition. The most common variations are in the thickness and color of the surface layer, the thickness of the claypan layer, and the abruptness of the change from the comparatively friable surface layer to the hard, intractable claypan.

A generalized description of the interspot areas representative of the uneroded Rhoades soils follows: (1) A friable 6-inch surface layer ranging in texture from very fine sandy loam to silty clay loam, underlain abruptly by (2) a comparatively dark hard dense claypan ranging from 3 to 7 inches in thickness. Below this, the material gradually becomes less hard and lighter colored, and (3) at a depth of about 16 inches, olive-drab fairly hard but somewhat friable clayey material is reached. Carbonates sufficient to cause effervescence when the soil material is treated with an acid are reached in most places 2 or 3 inches below the lower surface of the claypan. A generalized description of the eroded Rhoades soil, or clay spots, follows: A 2- or 3-inch surface layer of comparatively dark clay having a hard resistant consistence and structure. This clay is hard when dry and slick and plastic when wet. Moisture penetrates slowly. This is underlain by soil similar to that below the claypan layer of the interspot areas.

These soils with numerous claypan (Solonetz) areas are widely distributed over the uplands in the eastern part of the county, but their acreage within the Badlands is very small. It is not uncommon in the eastern part for areas of these alkali claypan soils to extend over several hundred acres. Surface drainage is good, but internal drainage is impeded by the claypan and generally clayey character of the underlying layers. None of these soils is considered suitable for crops requiring tillage.

Rhoades loam (complex with Morton or Bainville loams).—This soil complex is in the eastern uplands. As indicated in the general description of this group of soils, the areas of this soil complex appear to comprise two distinct but intricately mixed components—the interspot areas and the clay spots. The former occupy from 50 to 85 percent of the soil area and, consequently, represent the main body of this soil. Neither the clay spots nor the interspot areas are uniform in respect to soil conditions. This soil complex is characterized by areas underlain by claypan, a part of which has been exposed by differential erosion of the surface soil layers. It also includes small areas of claypan-free soils of the Morton and Bainville series.

This complex differs from the Morton-Rhoades loams complex mainly in two particulars: The claypan or Solonetz areas—parts of which are exposed to form the circular or elliptical bare spots—are more numerous; and the areas shown on the map are complexes of the claypan condition in areas of Bainville loam as well as in areas of Morton loam.

In general, the surface is undulating, although a few rolling areas are included in the Bainville parts of the complex. Surface drainage is good, whereas internal drainage is slow, except in the claypan-free areas.

As has been emphasized throughout the previous discussion of these complex areas, soil conditions vary greatly within short distances, and they are impossible to show separately on the published soil map of the scale used. The following descriptions apply to the Rhoades members of this complex—one in the interspot areas and one in the bare or clay spots. There is no need to describe the Morton or Bainville parts of the interspot areas, as descriptions of the profiles of these soils have been given; but it must be remembered that in a particular area the soil profile may be transitional between those of the Morton, Bainville, or Rhoades soils as described in this report.

The 5-inch surface layer of an interspot area representative of Rhoades loam is dark grayish-brown very fine sandy loam or silt loam that crumbles easily to a fine crumbly mass. Abruptly below this is a hard, dense layer of very dark grayish-brown sandy clay or clay. When removed from place, the material in this layer breaks into hard angular fragments that are very resistant to further crushing. At a depth of about 10 inches the color becomes lighter and the hardness becomes less pronounced, and at a depth of about 15 inches the material is olive-drab or olive-gray clay with numerous flecks of white carbonate. Carbonates sufficient to cause effervescence with an acid are generally present within 2 or 3 inches below the claypan layer.

The clay spots of Rhoades loam complex, which lie from 4 to 12 inches below the surrounding interspot areas, have a gray semicrust of very fine sand a fraction of an inch thick. Beneath this crust and extending to a depth of about 1½ inches is grayish-brown or dark grayish-brown fairly friable silty clay loam, and below this is a 2-inch layer of very dark grayish-brown fairly hard dense clay, which resembles somewhat the claypan layer as described. In many places this material lies somewhat nearer the surface. Below a depth of about 4 inches the material grades rapidly into olive-drab silty clay, which below a depth of 6 or 8 inches contains an abundance of white salt flecks, most of them carbonates. This material is hard in place but crushes fairly easily when subjected to firm pressure.

The native vegetation on the clay spots differs markedly from that on the interspot areas. Where the clay spots are most numerous and the claypan well developed, the clay spots are very nearly bare except for a scattered growth of saltgrass, western wheatgrass, and small pricklypear. Where the clay spots are less developed and have a somewhat more fertile surface layer, the soil supports a fair to good stand of buffalo grass and blue grama. The native vegetation on the interspot areas is similar to that on Morton loam, and here blue grama dominates, with such grasses as western needlegrass, western wheatgrass, and junegrass intermixed. Little clubmoss is common on the interspot areas, where it occupies that part of the ground not covered by grasses. The carrying capacity of this soil naturally differs according to the number and productivity of the clay spots. Those areas where the bare clay spots are most numerous are of low value as grazing land and will support only 15 to 30 percent of the number of cattle that Arnegard silt loam will carry; but, where the clay spots are least numerous and are partly covered with grass, the carrying capacity is from 40 to 60 percent of that of Arnegard silt loam.

Rhoades loam, rolling phase (complex with Morton or Bainville loams, rolling phases).—This complex differs from the Rhoades loam complex just described in that the surface is decidedly more rolling or sloping. Otherwise, the general characteristics of the two complexes are similar, and reference to the preceding description should give the essential information regarding this mapping unit.

The areas of this soil are few and small, totaling only 192 acres. One of these areas is in sec. 16, T. 141 N., R. 98 W. As grazing land, this soil is slightly inferior to the Rhoades loam complex just described, as the steeper slopes and the occasional knobs do not support so good a grass cover. The relative value of this land for grazing is estimated to be about 25 percent of that of the best grazing land.

Rhoades clay loam (complex with Morton or Bainville clay loams).—Rhoades clay loam complex is similar to Rhoades loam complex, except that the texture of the surface layer of the interspot areas averages clay loam rather than loam. As is true of the other complexes of this subgroup, the interspot areas vary from soils of the Morton and Bainville series to the claypans of the Rhoades series. The 4- or 5-inch surface layer of the Rhoades clay loam part of the interspot areas is grayish-brown or dark grayish-brown friable clay loam that is easily crushed to a crumbly mass. Below this is the dark grayish-brown or very dark grayish-brown claypan. As in

Rhoades loam complex, the clay spots differ considerably in size, number, and vegetative cover.

The surface is undulating, and surface drainage is good, but, because of the clayey character of the subsurface layers, internal drainage is slow. This soil is not extensive, as it occupies a total area of only about 3 square miles. The grass cover, relative position in the uplands, use, and comparative value are approximately the same as for Rhoades loam complex, although the development of the claypan is probably slightly greater because of the influence of the clay parent material.

Rhoades clay loam, rolling phase (complex with Morton or Bainville clay loams, rolling phases).—The Rhoades clay loam, rolling phase, complex differs from areas of Rhoades clay loam complex in the rolling rather than undulating surface, the slopes ranging from about 7 to 15 percent gradient. As a result of the increased slope, this soil complex is more variable, and in a few places, especially on the steeper slopes and exposed knobs, the extent of the Bainville component is somewhat greater than over the rest of the areas.

Only a few small areas of this soil are mapped, chiefly in the northeastern and northwestern parts of the county. The native vegetation is similar to that growing on the smoother complex, except that in the more rolling Bainville areas little bluestem is more common. The carrying capacity of grazing land is estimated to be from 20 to 25 percent of that of Arnegard silt loam.

SOILS AND LAND TYPES OF THE HILLY UPLANDS AND BADLANDS

The extensive soils and land types of the hilly uplands and Badlands cover 47 percent of the total area of the county. They form a rather definite and natural unit because of their common external soil characteristic—hilly and steep relief. They are associated with definite topographic forms—the hills, the breaks, and the Badlands. These areas remain the land of the cowboy. Here it is that most of the cattle graze and the newly formed grazing associations are active. Here, too, comes the tourist for vistas overlooking canyons, some of which have been included in the newly established Roosevelt State Park and Roosevelt Recreational Demonstration Area.

The soils and land types are placed in three subgroups on the bases of soil texture and comparative extent of rough broken land.

GRAYISH-BROWN LOAMS AND CLAY LOAMS

The grayish-brown loams and clay loams of this group have so steep a relief as to make tillage impracticable. The surface layer generally is thin, the depth to the underlying gray parent material is variable, carbonates are abundant at or very near the surface, and the native vegetation is less desirable and less uniform than on the smoother soil types of the same series. Except for the steep phase of Cheyenne gravelly loam, all the soils of this subgroup are hilly and steep phases of the Bainville soils. Mixtures of sedge, blue grama, and little bluestem are the principal components of the grazing vegetation. Practically all of this land is used for grazing, and, except for the effects of overgrazing, most of it remains in its virgin condition.

Bainville loam, hilly phase.—Bainville loam, hilly phase, includes all loam soils of the dissected uplands having a surface slope so steep as to make tillage inadvisable and yet not so precipitous as to have a strikingly thin grass cover or occasional barren areas on it (pl. 4, A). The gradient in general ranges from 15 to 30 percent. Owing to the range in slope, the soil characteristics vary considerably. Some of the smoother parts are similar to Morton loam, although most of them are more like Bainville loam. The steeper parts are even grayer than the average Bainville loam and are shallower to the underlying undisturbed gray soil material.

Bainville loam, hilly phase, is extensive. It occurs throughout practically all of the Badlands, and numerous small areas, ranging from 10 to 100 acres in size, occur throughout the smoother parts of the county.

Because of the variation in this soil and its position, the vegetation is widely varied. The native vegetation on the steep grassed slopes is niggerwool and blue grama. Little bluestem, plains muhly, triple-awn grass, and similar vegetation predominate on the steeper slopes. The sandier areas commonly support a mixture of niggerwool, blue grama, and patches of sandgrass. Creeping juniper is a common plant that grows in thin stands, generally near the top and on the north side of steep knolls and knobs. The narrow valleys that occur within areas of hilly relief are occupied generally by a mixture of blue grama and western wheatgrass and in places by big bluestem. Some of them support a fairly dense stand of ash and elm trees about 6 or 8 inches in diameter. The ridge tops are occupied generally by blue grama and niggerwool with some western wheatgrass and needlegrass intermixed.

Bainville loam, hilly phase, is used only for grazing. It is rated at about one-third the value of the most desirable grazing land. The best grazing is in the draws, and the poorest is on the steep slopes, especially those facing south.

Bainville loam, steep phase.—Bainville loam, steep phase, includes all the loam soils in Billings County having a surface slope of more than 30 percent. In general, the land is so steep as to have a thinner cover of grass on it than does the average hilly or sharply rolling phase, and scattered barren slopes are common. The grass mixture is composed of about the same species as those growing on Bainville loam, hilly phase. In addition to the fact that the grass cover is thinner, much of the area of the steep slopes is occupied by such shrubby growth as creeping juniper, buckbrush, silverberry, and buffaloberry. Thickets of ash, elm, quaking aspen, chokecherry, and cedar commonly occur on the north-facing slopes. As with the hilly phase, the narrow included valleys are generally occupied by a mixture of blue grama and western wheatgrass. Some of the draws have a fairly dense stand of ash and elm trees.

Bainville loam, steep phase, is used only for grazing. As such, it is valued at about one-fifth of the value of the most desirable grazing land. Most of this land, especially areas in which the coulees support a fairly good growth of trees, is desirable for winter grazing because of the protection afforded from the cold winds and storms.

Bainville clay loam, hilly phase.—Bainville clay loam, hilly phase, includes all clay loam soils having a surface slope so steep as to make tillage inadvisable and yet not so precipitous as to be incapable of

supporting a fairly uniform grass cover. Owing to the range in slope—from 15 to 30 percent—soil characteristics vary considerably within short distances. Some of the smoother spots are similar to Morton clay loam, although most of them are more like Bainville clay loam. The steeper areas are even grayer and are shallower to the underlying undisturbed gray soil material than is the average Bainville clay loam.

This soil is extensive. It occurs throughout practically all of the Badlands, and numerous small areas ranging from 10 to 100 acres in size occur throughout the smoother parts of the county. The aggregate area is considerably greater than that of Bainville loam, hilly phase.

The type of vegetation varies according to the position of the soil. The cover on the less steep slopes is a mixture of niggerwool and blue grama. On the steeper slopes little bluestem, plains muhly, triple-awn grass, and similar vegetation predominate. Here and there patches of creeping juniper and other bushy growth occur on these slopes. Most of the narrow valleys that have accumulated some brown friable soil material support a fair to good stand of blue grama and western wheatgrass, and, in some locations, big bluestem is prominent. Some of the draws support a fairly dense stand of ash and elm trees about 6 or 8 inches in diameter. The narrow ridge tops generally support a grass cover, in which blue grama is more prominent than it is on the steep slopes.

Bainville clay loam, hilly phase, is adapted only to grazing. As such, it is valued at about one-third of the value of the most desirable grazing land. As on the hilly phase of Bainville loam, the best grazing is obtained in the draws or valleys and the poorest on the steep slopes, especially those facing south.

Bainville clay loam, steep phase.—Bainville clay loam, steep phase, includes all clay loam soils having a surface slope of more than 25 percent. In general, it is so steep that the grass cover is noticeably thinner than that on the rolling or hilly phases. Here and there are some barren slopes. About the same species of grasses grow as on Bainville clay loam, hilly phase. In addition to the fact that the grass cover is thinner, much of the area is occupied by such shrub growth as creeping juniper, buckbrush, silverberry, and buffaloberry. Occasional thickets of ash, elm, quaking aspen, chokecherry, and cedar occur on the north-facing slopes. As with the hilly phase, most of the narrow included valleys are occupied by a mixture of blue grama and western wheatgrass. Some of the draws have a fairly dense stand of ash and elm trees.

Bainville clay loam, steep phase, is used only for grazing. As such, its value is at about one-fifth of that of the most desirable grazing land. Most of this land, especially those areas in which the coulees have a fairly good growth of trees, is desirable for winter grazing because of the protection from the cold winds and storms afforded by the steep slopes and trees.

Cheyenne gravelly loam, steep phase.—Cheyenne gravelly loam, steep phase, includes extremely steep nontillable gravelly areas on the border or front of old alluvial benches or terraces that have been subjected to geologic erosion. The few small areas of this soil occur

chiefly along the outer edges of the high benches bordering the Little Missouri River Valley, especially in the northwestern part of the county.

The upper few inches of the soil consist of gravel intermixed with a small quantity of brown loam. The underlying material is light-colored sand and gravel. All the material is so gravelly that it is removed from place with a spade only with great difficulty. This land is extremely droughty and supports only a thin cover of vegetation consisting principally of blue grama, niggerwool, and several other plants that have little or no grazing value. All this soil is used as grazing land, and its value as such is about one-eighth of that of the best grazing land. Many of the underlying gravel beds are potential sources of material for road and other construction uses.

GRAYISH-BROWN LOAMY FINE SANDS

Grayish-brown loamy fine sands of the hilly uplands and Badlands include the hilly and steep phases of Flasher loamy fine sand. Steepness of slope prohibits their use for tilled crops, and their loamy fine sand texture makes them too droughty to support the more desirable grasses. They overlie the distinctly sandy beds and sandstone strata of the Fort Union formation, and, because of the relative resistance of sandstone to geologic erosion, they occupy some of the highest areas in the county.

Flasher loamy fine sand, hilly phase.—Flasher loamy fine sand, hilly phase, is similar to typical Flasher loamy fine sand previously described (p. 46), except that it has a sharply rolling or hilly surface. The slope ranges from 15 to 30 percent. The brown surface soil varies more than in the typical loamy fine sand; it is very thin or entirely lacking on the steeper parts of many slopes. This is not an extensive soil, and it occurs mainly along the eastern edge of the Badlands. It is adapted only to grazing. The vegetation is comprised principally of niggerwool with a small amount of blue grama intermixed. Dense patches of sandgrass are common, and some little bluestem grows on the steeper slopes. The grass cover is thinner and more uneven than that on the smoother typical soil; consequently the carrying capacity of the range is less. The value of this soil for grazing is about 20 percent of that of the most desirable grazing soil.

Flasher loamy fine sand, steep phase.—Flasher loamy fine sand, steep phase, differs from the typical soil primarily in having a steep slope, the gradient of which is more than 30 percent. The brown surface layer is everywhere shallow and is lacking in those areas where soft sandstone outcrops or those sandy areas made bare by the soil slipping down the slope. Because of its steeper, drier situation, the vegetation on this soil does not provide such good grazing as that on the smoother soils of this series; the stand is thinner; and more of the cover is composed of nonedible plants. Niggerwool is the most common plant, and patches of sandgrass are abundant. Little bluestem is more common on this soil than it is on the smoother soils, and a scant shrubby growth occupies some of the north-facing slopes.

Although its total area is not large, this soil is widely distributed throughout much of the Badlands. It is devoted entirely to graz-

moderately dark or is absent, and light grayish-yellow or light-brown material is exposed. The general effect in looking across these areas is that the soils are markedly light colored.

Because of their comparatively droughty character, low natural fertility, susceptibility to both wind and water erosion, and the difficulty they offer to the use of farm machinery, a large proportion of the area of these soils is not suitable for crops requiring tillage, and it is commonly conceded that a large part of the tilled acreage, as evidenced by low yields and soil deterioration, would be more profitably utilized as grazing land. A large proportion of the grazing land of the county is included in the soils of this subgroup, but their carrying capacity is considerably less than that of the more level dark-brown soils, such as Grail silty clay loam and Morton loam.

Patent clay loam, slope phase.—Patent clay loam, slope phase, differs from typical Patent clay loam essentially in having a greater slope, the gradient ranging from 7 to about 18 percent. Because of this greater slope, the soil is more variable and the depth to the underlying olive-gray clay is less, but the variation in the character of the soil on the slopes, in general, is not so great as that of soils of the rolling land.

The surface layer of Patent clay loam, slope phase, is brownish-gray clay loam, very thin or lacking on the more exposed knobs and slopes. The underlying material grades into light brownish-gray or olive-gray material, the topmost 5- or 6-inch layer breaking easily, if disturbed, into nut-sized mellow fragments. Below this is olive-gray clay similar to that underlying typical Patent clay loam. Carbonates sufficient to cause effervescence when the soil is treated with acid are within a depth of 12 inches from the surface.

This soil is less extensive than typical Patent clay loam. It is associated with the typical soil distributed widely over the county. The largest areas are in T. 146 N., R. 102 W.; T. 147 N., R. 102 W.; and T. 146 N., R. 104 W. Many smaller areas are in Blue Butte Township and the immediately surrounding townships and in the southwestern part of the county.

The grass cover is similar to that on typical Patent clay loam, the dominant species being blue grama, with smaller quantities of western wheatgrass. Less desirable species and a thinner stand are on the most exposed patches or knobs.

Probably 30 percent of this soil is tilled. Wheat is by far the dominant crop, with other small grains and hay crops occupying most of the remaining tilled acreage. Yields are markedly less and are more variable than those obtained on typical Patent clay loam and range from 35 to 50 percent of the yields on Williams loam. Because of its greater susceptibility to erosion and lower natural fertility, only the smoothest areas of this soil are suitable for tillage, and the rest of the land is best utilized as grazing land. Although the carrying capacity of this soil is only about 60 percent of that of Arnegard silt loam, it is considered desirable grazing land, principally because of the good type of grasses forming the cover.

Bainville loam.—Bainville loam is a rolling light-colored loam soil of the upland part of the county. The more level areas are similar to Bainville loam, smooth phase, but, as a large proportion of the land is more sloping, the thickness of the grayish-brown surface layer

Most of the areas of this rough land have a rolling to steeply rolling moundlike surface. An exception is the belt or zone comprising the escarpment of Bullion Butte, much of which has a very steep to precipitous slope.

Vegetation is comparatively sparse, although practically all of the soil material in the crevices and openings between the rocks is occupied by vegetation, much of which is edible for livestock. Little bluestem, a small quantity of niggerwool, and blue grama are the most common edible plants.

This is not a very extensive land type, and most of it occurs in the vicinity of Fairfield, near Bullion Butte, and in the southeastern corner of the county adjacent to Slope County.

Because of the large part of the surface occupied by the rocks and because of the less palatable character of the grasses, this land has a low grazing value, only slightly better than that of rough broken land.

Scoria.—This land type includes all exposed scoria beds and steep areas in which scoria forms most of the surface material. Scoria is composed mostly of angular fragments, from 1 to 4 inches in diameter, of light-red shale that presumably have been formed by the baking of the clay overlying burning lignite beds. A small part of this material is composed of very dark reddish-brown hard clinker-like masses, ranging from 6 inches to several feet in diameter. Practically all of the areas of this land type have a hilly or rough surface, the relief ranging from 50 to 150 feet. The largest areas are east of the Little Missouri River from Franks Creek southward.

The vegetation, except creeping cedar, is sparse and is composed mostly of plants of low palatability. Creeping cedar, in many places, particularly on the north-facing slopes, forms dense matlike patches. A thin cover of grass, including some niggerwool and blue grama grows in places. The draws or drainageways, where moisture conditions are better and some soil material has accumulated, have a good grass cover composed principally of blue grama in some places and of big bluestem in others. The proportion of the land that supports a good grass cover is small, probably not more than 20 percent. None of this land is tillable, and its grazing value is about equal to that of rough broken land. The scoria itself is commonly used as road-surfacing material, and a bountiful supply of it is available for this purpose.

SOILS OF THE DEPRESSIONS AND LOWER (CONCAVE) SLOPES

The soils of the depressions and lower (concave) slopes occupy depressions, such as narrow slightly sloping drainageways, and sites of former ponds in the uplands and the lower (concave) slopes spread as aprons at the bases of buttes and higher uplands. These topographic positions are the most favorable situations for an adequate supply of moisture, as they receive runoff from nearby higher land, and as a result they support the most abundant growth of native grasses. The soils of some of these areas therefore contain more organic matter than any other soil in the county and are therefore the darkest. They are also the thickest over the underlying carbonates. These are the Arnegard and Grail soils. Some areas are

subject to recent deposition of local alluvium, and the soils are young and light colored. These are Patent soils. Some areas in the depressions and on the slopes are subject to the accumulation of soluble salts and the influence of excess sodium. These are the Sage, McKenzie, and Moline soils.

VERY DARK GRAYISH-BROWN SILT LOAMS

The subgroup of very dark grayish-brown silt loams is represented by only one soil, Arnegard silt loam, which occurs along the drainage-ways in the uplands. This is the darkest and deepest soil in the county and the most productive for general crops and grasses.

Arnegard silt loam.—Arnegard silt loam is the very dark grayish-brown friable soil that occurs along the shallow upland draws within areas of such soils as the Morton and Bainville. The 3- or 4-inch surface soil is dark grayish-brown silt loam. Below this layer the color is generally darker—very dark grayish brown—although in many areas it is dark grayish brown throughout the soil. This layer has a well-developed prismatic structure. The dark color and well-defined structure extend to a depth ranging from 12 to 24 inches. Below this depth the color gradually becomes lighter, and at a depth of 32 inches it is olive drab in most places. At this depth the prismatic structure is lacking, although the material generally is friable. Carbonates sufficient to cause effervescence when the soil is treated with acid occur at a depth of about 22 inches.

The surface is very gently sloping, and the soil occurs as strips along drains or gentle depressions. It is sufficiently drained to prevent the accumulation of salts and to allow normal root development. The soil mass for the most part is composed of material transported by runoff from the immediately surrounding soils of the uplands. Blue grama and western wheatgrass make up most of the native vegetation, and in a few places big bluestem is prominent. The grass cover generally is dense. Such vegetation as niggerwool, sandgrass, and little bluestem grows in very few places.

Arnegard silt loam is not an extensive soil. The narrow strips of this soil are generally associated with areas of the Morton soils and are scattered throughout the eastern uplands. About 80 percent of the land is tilled. Wheat is the most common crop, but practically all crops are grown on it, especially as much of it is farmed in rotation. Farmers frequently choose tracts of this soil for gardens and other comparatively intensive crops, because of its high fertility, favorable moisture conditions, and ease of cultivation. Because of its greater fertility and better moisture relationships, it is the best adapted soil of the uplands for the production of alfalfa and sweetclover.

Yields of all crops grown on this soil are comparatively high. During years of sufficient rainfall for good growth of crops, wheat yields from 18 to 30 bushels an acre. The average yield, over a period of several years, is probably about 16 bushels. Yields of other grains are correspondingly high. Hay and forage crops, including corn, yield better on this soil than on any other.

Arnegard silt loam has a relative value ranging from 90 to 100 percent for crops or grazing because, as previously stated, it is considered the best soil in the county as either tilled or grazing land.

DARK GRAYISH-BROWN SILTY CLAY LOAMS

The subgroup of dark grayish-brown silty clay loams is represented by one soil—Grail silty clay loam. This is the dark and comparatively deep soil that has developed from local alluvium on the lower slopes of hills or on the upper slopes of valleys.

Grail silty clay loam.—Grail silty clay loam is the dark-colored heavy-textured fertile soil that occurs on gentle valley slopes immediately below more rolling land. The surface layer, which extends to a depth of about 5 inches, consists of dark grayish-brown heavy silt loam or silty clay loam. The material is friable and breaks easily into fragments that are readily crushed to a mealy mass. Below this layer the material is either dark grayish-brown or very dark grayish-brown silty clay loam. This layer has a fairly well defined prismatic structure. At a depth of about 12 inches the color begins to fade, the prismatic structure gradually disappears, and white carbonate flecks become abundant. At a depth of about 30 inches the color is olive drab with some white carbonate flecks, and the material shows no indication of a prismatic structure, but, when dug, comes out as friable pieces or chunks. The few areas of this soil that have a claypan are indicated on the map by appropriate symbols.

The most common position of this soil is on gentle alluvial slopes of valleys and on the gently sloping areas that have been developed as a result of local deposition of soil material by runoff from the immediately surrounding higher land. A very few areas have slopes sufficient to make them susceptible to rill and gully erosion, if cultivated, and to offer some difficulty to the operation of farm machinery. Surface drainage is good, and subsurface drainage, although slow, is sufficient to allow good plant growth. The native vegetation is composed principally of blue grama with considerable western wheatgrass intermixed where grazing has not suppressed it. Buffalo grass grows on some areas. Very few of the less palatable grasses grow on this soil, but little clubmoss very commonly occupies that part of the surface not covered by grass. Some of the clay spots in the claypan variation have a scant vegetative cover, although many of them support a fair to good cover of buffalo grass and some western wheatgrass.

Grail silty clay loam is widely distributed over the eastern uplands, where it is associated with the Morton and Patent soils. The areas range in size from 10 to 200 acres. About 65 percent of the acreage of this soil is tilled. It is one of the most desirable soils of the county, and all the important crops are grown successfully on it. It is a fertile soil, and its water-holding capacity, owing to its relatively high content of organic matter and its position, is high. Farmers frequently remark that they are much more certain of producing a crop on this soil than on most of the other tilled soils. Wheat is the dominant crop; and other small grains, especially barley and oats, are next in importance. Farmers practicing livestock farming devote part of this soil to corn and hay. Slender wheatgrass and sorgo are common forage crops. During years of sufficient rainfall wheat yields about 20 bushels an acre, and other crops give correspondingly high yields. Because of its large store of plant nutrients, this soil, like Arngard silt loam, can stand

continuous cropping longer than the other tillable soils. Crop rotation is followed on much of the land. Wheat occupies a relatively larger part in the rotation than it does on most other soils. Fall plowing is commonly practiced, and ordinarily it is to be preferred as the most satisfactory way of preparing the ground for the seeding of spring-sown grains. The relative value of this soil is from 85 to 90 percent of that of the best cropland. As grazing land this soil is equal to the most desirable soils. The areas having a claypan are somewhat less productive as either crop or grazing land, and consequently are of somewhat lower value, depending on the degree of development of the claypan and the frequency and intractability of the clay spots.

BROWNISH-GRAY SILT LOAMS, CLAY LOAMS, AND CLAYS

Brownish-gray silt loams, clay loams, and clays are members of the Patent series. The Patent soils are the rather gray soils developed in positions similar to those occupied by the Grail soils. The color differences between soils of the two series are indicative of the relative time during which soil-forming processes have been operative on the local alluvium underlying the soils of the two series. In fact, the Patent soils are still subject to deposition and active erosion, especially in areas particularly subject to the accumulated runoff from the higher lands in the background. As mapped these soils necessarily represent a range in conditions as regards stability of the environment measured by amounts of runoff, siltation, erosion, vegetative cover, and stage of soil development, and the several members of the series have individual significance as regards land use. Patent silt loam and Patent clay loam are very desirable for grazing and the production of wild hay and are fairly satisfactory for crops, whereas Patent silt loam, eroded phase, and Patent clay do not rank high even for grazing.

Patent silt loam.—Patent silt loam includes those areas that have a very fine sandy loam or silt loam texture to a depth of at least 6 inches. The color varies from brownish gray to brown to a depth ranging from 6 to 10 inches. The material is friable and crumbles easily to a fine-grained mass. The material below the surface layer in most places is grayer, and it grades into clay loam. In some areas it has a fairly well developed prismatic structure. Below a depth of approximately 18 inches is laminated olive-drab silt or clay. Generally, this soil shows effervescence throughout its entire depth when it is treated with acid. Flecks of white carbonate occur below a depth of 16 inches and, in places, are somewhat nearer the surface.

Patent silt loam occurs on gentle alluvial slopes of valleys or on the lower gently sloping hillsides that have been developed by deposition of local alluvium through runoff from the surrounding higher land or buttes (pl. 5). Surface drainage is good. The native vegetation is composed principally of blue grama with considerable western wheatgrass intermixed where excessive grazing has not suppressed it, and patches of buffalo grass are common. The grass cover on the areas of coarser textured soil is generally more uneven and thinner than on the heavier textured parts.

Patent silt loam is not an extensive soil. Little or none occurs on the eastern uplands, and practically all of it lies in the valleys of

streams tributary to the Little Missouri River, especially Government Creek. Because of its location in the Badlands, probably not more than 30 percent of this soil is tilled.

Oats, millet, slender wheatgrass, and corn are common crops grown for hay and forage; and native grasses, especially western wheatgrass, are cut from a few areas for hay. The acreage of corn is small, but this crop is commonly grown in rotation with the hay crops. Only a small acreage is devoted to wheat. Yields of the commonly grown crops are about 20 percent lower than those obtained on Morton loam, and the natural fertility is noticeably less.

Because of its coarser texture and consequent weaker structure, this soil is better adapted to cultivated crops, such as corn, than is Patent clay loam; however, it is more subject to blowing. The value of this soil ranges from 45 to 65 percent of that of the best land in the county.

Patent silt loam, eroded phase.—Patent silt loam, eroded phase, includes areas that have been seriously affected by the development of numerous shallow surface ditches or by sheet deposition of alluvium on the surface to such an extent as to affect seriously the character of the profile and the productivity of the soil. The surface material ranges in texture from very fine sandy loam to silt loam and is generally brownish-yellow or yellowish-gray laminated material, as little or no soil structure or brown color has been developed. Its surface slope is similar to that of the Patent soils, but its location is in general closer to the higher lying upland, from which runoff water floods onto it.

Soil of this eroded phase is associated with other areas of Patent soils throughout much of the Badlands. Probably the most extensive areas are a few miles southeast of Medora. Although most of this soil occurs as strips immediately below steep upland areas, in some places it occupies entire coulees or valleys.

Because of its susceptibility to erosion and its general low state of fertility, this soil is not adapted to tillage, and practically all of it is devoted to grazing. The vegetation for the most part is blue grama, which varies considerably in density of stand according to the effect of the deposition of the alluvium. Western wheatgrass is associated with grama on the areas of heavier soil, and niggerwool is associated with grama on some of the areas of coarser textured soil. Its value as grazing land is about one-third of that of Patent clay loam.

Patent clay loam.—Patent clay loam occurs on gentle valley slopes immediately below more rolling areas. The 6- or 7-inch surface soil is dark-gray or brownish-gray friable clay loam. The material breaks easily into small readily crushed fragments. It is underlain to a depth of about 10 inches by material that is somewhat grayer but has a weak to fairly definite prismatic structure. At a depth of about 12 inches the color becomes olive drab and the prismatic structure becomes less prominent. The structure becomes less prominent and the color lighter with depth to about 30 inches below the surface, where the material is laminated almost structureless yellowish-gray and olive-drab silt or clay. In most places, carbonates plentiful enough to cause effervescence when the soil is treated with acid occur throughout the entire soil mass.

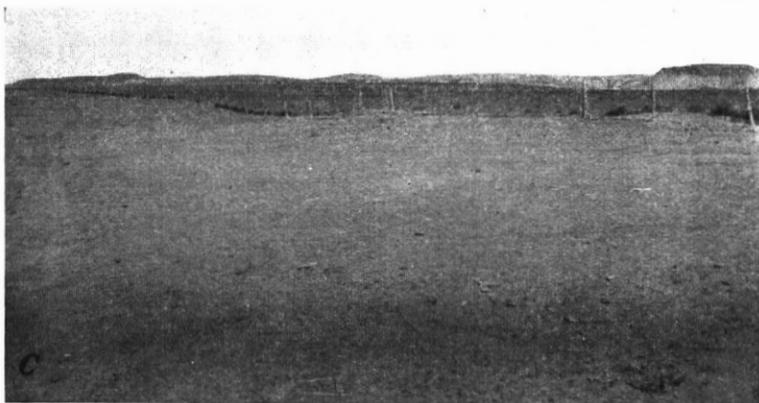
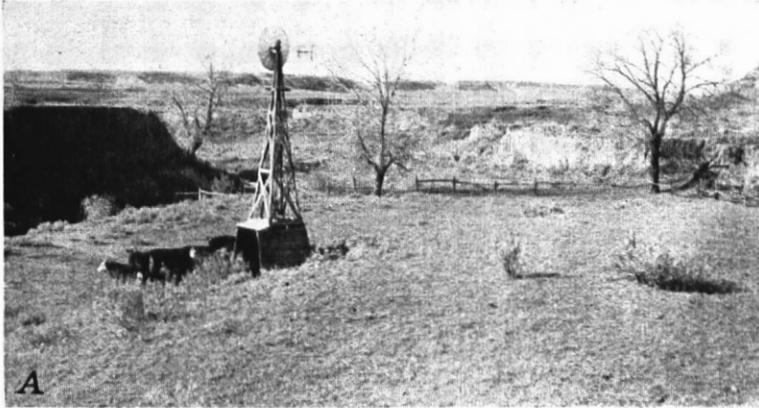
Patent clay loam occurs on gentle alluvial slopes of valleys and on the gently sloping hillsides that have been developed by deposition of local alluvium through runoff from the surrounding higher land. The native vegetation is composed principally of blue grama with considerable western wheatgrass intermixed where grazing has not suppressed it, and patches of buffalo grass are common. Sagebrush grows on some areas, especially where the land is overgrazed.

This soil is widely distributed over the county, although its aggregate area is only 16.7 square miles. Its most common occurrence is in the broad coulees and valleys of the Badlands (pl. 4, *B*), and a few areas occur throughout the eastern uplands.

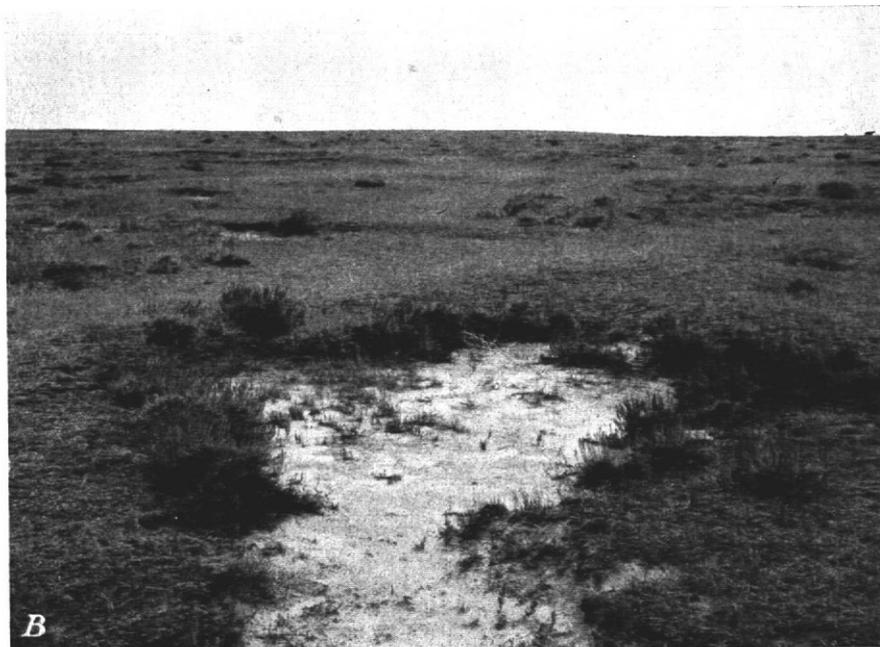
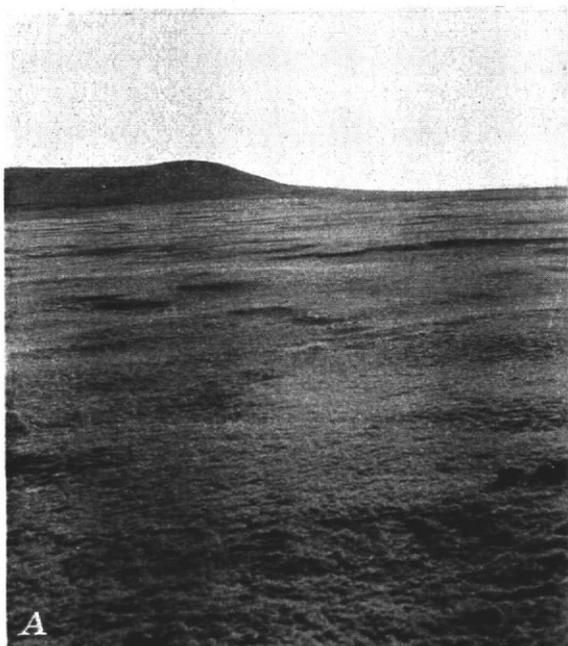
Because a large part of this soil is rather isolated within the Badlands, probably not more than 20 percent of its total acreage is tilled. Wheat is the predominant crop on those areas in the eastern uplands, but throughout the Badlands forage crops predominate. Native grasses, especially western wheatgrass, are cut for hay from some virgin areas. The most common forage crops are small grains, especially oats, and such crops as millet, slender wheatgrass, and sorgo. The heavier textured soils, such as Patent clay loam and Grail silty clay loam, are preferred for such crops as the last three mentioned. The acreage of corn is small, but corn is commonly grown in rotation with small-grain and hay crops. The small-grain crops are grown for grain to some extent.

Patent clay loam is a desirable soil for grazing. The grass cover is of high quality and ordinarily attains a good growth. Because of their location in deep, well-protected valleys, many areas are desirable for winter grazing. Yields of tilled crops are, on the average, lower than those obtained on such soils as Morton loam. In years of sufficient rainfall wheat yields 10 to 15 bushels an acre. Hay crops, such as slender wheatgrass, yield from 1 to 1½ tons an acre under favorable conditions. The value of Patent clay loam as cropland is from 45 to 65 percent of that of the most desirable soil of the county, and as grazing land about 90 percent of that of the most desirable grazing land.

Patent clay loam, slope phase.—Patent clay loam, slope phase, includes those areas of Patent clay loam and Patent silt loam with sufficient slope to make the operation of heavy farm machinery difficult, and yet they are not too steep to be commonly used as tillable land. The gradient ranges from 7½ to 15 percent. Because of its steeper slopes, this soil is more variable than Patent clay loam. In the lower lying areas and narrow strips along drainageways the soil resembles the typical soil, but on the slopes that make up the greater part of the areas the soil is not so well developed. Generally, the surface soil is 3 or 4 inches thick and is similar in character to the typical soil. Below this layer the material is gray or yellowish-gray clay loam with little of the prismatic structure that ordinarily occurs in the typical soil. The material is laminated in many places and is identical with the material occurring in the typical soil below a depth of 30 inches. Carbonates sufficient to cause effervescence when the soil is treated with an acid are generally distributed throughout the entire depth of this soil. Drainage is good, even excessive on the steepest parts.



Adjoining views of Patent silt loam A, Upper valley of Government Creek; B, butte, remnant of upland from which the parent materials of Patent silt loam were washed; C, smooth areas adapted to the production of feed crops.



A, Clay spots on Patent-Moline clay loams, originally bare, now covered with grass. *B*, Moline clay loam complex showing numerous bare clay spots

This soil is widely distributed throughout the Badlands. Its aggregate acreage is more than twice that of the typical soil. The areas generally occur as narrow belts occupying valley slopes, and most of them range in size from 30 to 120 acres.

A large part of this soil is devoted to grazing, probably owing in part to its common occurrence in rather isolated sections of the Badlands. The cropped acreage is occupied mostly by subsistence crops, principally hay. The type of native grasses is identical with that on the typical soil, except that the growth is thinner on the steeper part and some unpalatable plants occur on these poorer sites. As cropland, this slope phase is valued at about 40 percent of the value of the most desirable soil; as grazing land, it is valued at 60 to 70 percent of the value of the best grazing land.

Patent clay.—Patent clay includes areas of practically bare clay and silt occurring either as freshly eroded gentle slopes or bare alluvium along drains or alluvial fans that extend out from rapidly eroding hills and buttes of the uplands. Many of the few small areas are along Davis Creek. This soil consists principally of clay from which the surface soil has been eroded and, to less extent, of recent alluvial deposits of silt and clay. Most of the areas actually consist of an intricate mixture of these two conditions of erosion and deposition, although the eroded condition is dominant.

The land supports very little or no vegetation. Most areas of this soil are associated with other Patent soils. The bodies are not numerous, and few of them cover more than 10 acres each. This land is worthless for either tillage or grazing.

BROWNISH-GRAY CLAY LOAMS WITH CLAYPAN (SOLONETZ) AREAS

The subgroup of brownish-gray clay loams with claypan (Solonetz) areas consists of the soil complexes formed by the occurrence of clay spots and claypan development in areas of Patent soils. The claypan development or Solonetz type of soil is similar to that designated by the Rhoades series, except that in these areas the claypan condition has developed on a different type of parent soil material; namely, gray or brownish-gray clays deposited as local alluvium. Such soils are classified in the Moline series. The Patent-Moline complexes do not contain so many bare clay spots and claypan areas as do the Moline complexes in the next subgroup discussed.

Patent-Moline clay loams.—This complex represents areas of Patent clay loam associated with smaller areas of Moline clay loam or modifications of its strongly developed claypan or Solonetz type of profile. The bare areas are not so numerous as in the areas designated as Moline clay loam (complex with Patent or Grail clay loams). Some of the spots originally bare are now grown up to grass (pl. 6, A'). This complex covers a far larger area than its slope phase, and it is also the fourth most extensive unit in the county. Fairly large areas occur throughout the eastern uplands. These soils occupy gentle alluvial slopes of the drainageways and valleys and have good surface drainage. Internal drainage, however, is slow.

The native vegetation on the main or interspot portions is predominantly blue grama with some western wheatgrass and other

desirable grasses intermixed. Little clubmoss also is common. The vegetation on the clay spots varies considerably. A very few of these spots are very unproductive and support only a scant growth of such plants as small pricklypear, gumweed, and saltgrass. A large part of them, however, is occupied by a fair or patchy cover of buffalo grass and western wheatgrass, and a few spots are completely occupied by buffalo grass and, to less extent, by western wheatgrass and blue grama.

Approximately 50 percent of the acreage of this complex is tilled, and most of that is devoted to small grains and hay. Wheat is the most common crop and in years of sufficient rainfall it yields about 11 bushels an acre. Small grains cut green for hay yield about 1 ton. As cropland, the value of this soil is about 50 percent of that of the most desirable land, and for grazing it is worth about 75 percent of the value of the most desirable grazing land.

Patent-Moline clay loams, slope phases.—This complex resembles Patent-Moline clay loams just described except for the more sloping surfaces, the gradients of which range from about $7\frac{1}{2}$ to 15 percent. As a consequence the character of the soil, particularly the thickness of the darker colored material, is more variable, and more of the area, especially the occasional knobs, is free of claypan. Surface drainage is somewhat excessive.

Small areas of this complex are widely scattered over the eastern uplands. Many of them are utilized for grazing because they are included or closely associated with extensive areas of land that are suitable only for this use. The tilled areas are devoted principally to small-grain and hay crops, the latter consisting principally of such crops as small grains cut green and millet. The relative values of the land for crops and grazing are about 30 and 60 percent, respectively, of those of the best land of the county.

BROWNISH-GRAY CLAY LOAMS WITH NUMEROUS CLAYPAN (SOLONETZ) AREAS

The brownish-gray clay loams with numerous claypan (Solonetz) areas differ from the members of the preceding subgroup essentially in the number of bare clay spots and the relative proportion of the total area affected by development of a claypan. Another distinction is that these areas include also the strongly solonized areas of the Grail soils. This grouping of the strongly affected or scabby areas of both the Grail and the Patent soils in one complex was made in order to reduce the number of individual soil separations shown on the map, because the important characteristic affecting land use here is the number of clay spots rather than the color of the soil of the inter-spot areas. This principle of combination also applies to the Rhoades loam complex and others.

Still another feature of the Moline complexes is that certain areas contain puff spots, or Solonchak soils. As previously described (p. 29), the Solonchak soils are affected adversely by soluble salts. The description of the Wade-Farland silty clay loams and the section on Morphology and Genesis of Soils contain added information.

Moline clay loam (complex with Patent or Grail clay loams).—Moline clay loam complex is the claypan soil complex that occupies the gentle alluvial slopes, particularly of the eastern uplands. Bare

clay spots are numerous (pl. 6, *B*). The largest areas are around Saddle Butte School, near Strauch School northeast of Fryburg, and south of Gorham. The surface is gently sloping, and surface drainage is good. Internal drainage, however, is slow because of the claypan and the generally clayey character of the entire soil.

Like the other complexes, this complex has a soil profile that varies in detail. The interspot areas range from typical Moline soils to slightly developed Moline soils, or they may represent a more advanced stage of reclamation. Again, parts of the interspot areas are representative Patent or Grail soils or slight modifications of them. Also a few areas are affected by an accumulation of soluble salts. These have characteristic bare puff spots (Solonchak) instead of bare clay spots (Solonetz). See the description of Wade-Farland silty clay loams for more detailed information. In the interspot areas representative of Moline clay loam the surface soil above the claypan ranges from 5 to 8 inches in thickness and consists of grayish-brown or brownish-gray friable clay loam or silt loam. The claypan layer is very dark grayish-brown hard dense clay, which when dug comes out in hard angular pieces about $1\frac{1}{4}$ inches in diameter. This layer is from 3 to 6 inches thick. Below it the material gradually becomes less hard and lighter colored, and at a depth of about 14 inches it is dark olive-gray clay containing an abundance of white salt flecks. The soil at a depth of 1 to 2 inches below the claypan layer effervesces when treated with acid. The clay or slick spots are similar to the other clay spots previously described.

The native vegetation on most of the interspot areas is a good stand of blue grama with some western wheatgrass and a smaller proportion of such grasses as western needlegrass and prairie junegrass. Little clubmoss also is common. As mentioned before, the cover, if any exists on the clay spots, is sparse and has little or no grazing value. It consists for the most part of saltgrass, cacti (principally small pricklypear), gumweed, and a few stalks of western wheatgrass.

Very little of this soil is tillable. It is best used as grassland, and as such it has a value of about 30 percent of that of the most desirable grazing land.

Moline clay loam, slope phase (complex with Patent or Grail clay loams, slope phases).—This soil complex is similar to the more extensive Moline clay loam complex, except that the surface is more sloping, the gradient ranging from $7\frac{1}{2}$ to 15 percent. It is far less extensive, and because of its greater slope it is somewhat more droughty and supports a somewhat poorer grass cover. Like that soil, it is suitable only for grazing and has even less value for grazing—about 25 percent of the value of the most desirable land.

DARK-GRAY INTRACTABLE CLAYS

Only one soil type—McKenzie clay—is classified in the subgroup of dark-gray intractable clays. This dense clay is similar to the dense clays of the claypan group of soils but differs greatly in the uniform character of its extent and development. Soil-forming processes have operated somewhat differently on this soil, and the areas as sites of former ponds have had a different geological history from those of the claypan soils.

McKenzie clay.—The striking and important characteristics of McKenzie clay are its dark and dense clay layers. The 14- to 18-inch surface soil is very dark gray or nearly black hard clay. The material to this depth has well-defined vertical cracks. Below this layer the cracks are not so prominent and a few salt flecks are evident. At a depth ranging from 18 to 25 inches the color begins to fade, salt flecks are more numerous, and the mass effervesces when treated with an acid, indicating the presence of carbonates. Below a depth of 40 inches the material is dark olive-drab clay containing an abundance of carbonates. This material is generally less hard than the layers above.

McKenzie clay occurs chiefly in one fair-sized body and several very small ones southwest of Gorham. The surface is nearly level, and, unlike the soils with claypan or Solonetz areas, it has no bare spots. Because of the nearly level surface and the imperviousness of the soil material, drainage is very slow.

The native vegetation differs markedly according to moisture conditions. The most poorly drained areas support a growth composed mostly of sedges, foxtail, and smartweed. The less wet areas support a good growth of western wheatgrass. During favorable years this vegetation furnishes good grazing or hay, whereas during dry years little or no growth is made.

Because of its intractable character and the frequent inability of plants to grow on it because of unsuitable moisture conditions, this soil is not adapted to tillage. Practically all of it is devoted either to wild meadow or to grazing. Yields of hay and the carrying capacity of the grazing land differ considerably from year to year according to the moisture supply. When the moisture is sufficient, the growth of grass is luxuriant on the better areas, as this soil contains a large supply of plant nutrients. During dry seasons vegetation practically stops growing. The average grazing value of this soil is about 40 percent of that of the most desirable grazing land.

BROWNISH-GRAY CLAYS WITH RELATIVELY HIGH SALT CONTENT

Only one soil type—Sage clay—is recognized in the subgroup of brownish-gray clays with relatively high salt content, although other small areas affected by an excess of soluble salts are shown on the soil map by appropriate symbols.

Sage clay.—Sage clay is the least extensive soil mapped in Billings County. The largest body lies east of the Little Missouri River between Mikes and Ash Creeks. This soil occurs in positions favoring the accumulation of salts, mainly in slight depressions where drainage is inadequate to remove the salts that accumulate through the evaporation either of capillary water rising to the surface or of ponded water from the surrounding higher land. Its most common occurrence in McKenzie County, where it has a slightly larger acreage than here, is in the depressions and flats associated with alluvial bottoms and terraces, principally of the Little Missouri River Valley.

The surface soil of Sage clay is dark olive-gray clay. Over the greater part of the area the soil is firm and hard to penetrate with a spade. In some places a thin gray siliceous crust covers the

surface during dry periods and salt crusts form in patches. White specks or flecks of carbonates and other salts are distributed throughout the soil below the thin surface crust. The soil does not crumble easily but breaks under pressure into angular fragments, and in some places the soil mass is moist within a very few inches of the surface at all times.

The native vegetation is sparse, and parts of the areas are nearly barren. Some support a fair growth of sagebrush, and others have a fair cover of broom snakeweed and some saltgrass. In places a thin patchy cover of blue grama and western wheatgrass has established itself. None of this soil is tilled, as it is very difficult to plow and has very low productivity for crop plants. Its grazing value is extremely low; in fact, most areas are practically worthless.

SOILS OF THE TERRACES

The group of soils of the terraces occurs on the alluvial terraces, which formerly were old flood plains and which now lie from less than 10 feet to more than 200 feet above the present bottom lands. The high terraces, or mesalike benches, stand out in sharp relief along the present valley of the Little Missouri River, and from the valley floor they appear to be isolated projections of the uplands, as the terrace fronts are composed of precipitous walls of bare clay, such as characterize the Badlands.

The smooth topography, the favorable positions relative to runoff from the surrounding uplands, the rather uniform character of individual strata of the parent alluvial materials, and the length of time the soils have been undisturbed by geologic processes have all been factors to make these terraces favorable sites for the development of zonal soils. (Zonal soils are those that carry the imprint of the climatic and vegetative influences operative in soil formation.) Some of these soils are, therefore, representative of the Chestnut great soil group; and the two outstanding series in this respect are the Farland and the Cheyenne. The soils developed from relatively fine textured parent material are classified in the Farland series; those overlying gravel and sands, in the Cheyenne series. Less well developed zonal soils, that is, those with a less dark brown color, less prismatic structure, or greater variability in depth to carbonates, include the Cherry series and the high-terrace phase of the Huff soils. The Wade soils are intrazonal because they owe their characteristics largely to a local condition of impeded drainage.

DARK GRAYISH-BROWN AND BROWN LOAMS TO SILTY CLAY LOAMS

The subgroup of dark grayish-brown and brown loams to silty clay loams includes mainly the Farland and Cheyenne soils, and these are the soils that express more completely than any other soils on the terraces the characteristics of the Chestnut zonal group. They are dark grayish brown or brown, have a pronounced prismatic structure, are well drained, and have a comparatively favorable moisture-holding capacity. As they have smooth surfaces, they are easily tilled. They are comparatively deep over the underlying carbonates and have developed largely under a short-grass vegetation. These characteristics make them desirable for tilled crops. Briefly stated, the

Farland soils are the terrace equivalents of the Morton soils of the uplands.

Huff very fine sandy loam, high-terrace phase, is included in this group, although the Huff soils are not strictly soils of the terraces. The close geographic association of this soil with Farland silt loam, high-terrace phase, makes it almost imperative that the two be considered together in the discussion and be shown by the same color on the map.¹⁸

Farland silt loam.—Farland silt loam is the dark grayish-brown loam or silt loam soil occurring on well-drained alluvial benches or terraces. The surface is gently undulating, although a few areas are approximately as undulating as the smoother areas of Morton loam. This soil occupies benches along the larger streams, and most of it occurs in numerous irregular tracts interrupted by stream channels and first bottoms. Practically all of it lies well above the flood plains of the creeks. For the most part, it occurs on the eastern uplands, although a very few areas are in the Little Missouri River Valley. The largest acreage of this soil is along the Green River. Although surface drainage is not well developed, subdrainage is sufficient to maintain entirely satisfactory drainage conditions for plant growth. The native vegetation is practically the same as on Morton loam.

The surface soil, to a depth of about 7 inches, is dark grayish-brown loam or silt loam. The material is friable and easily crushed into a mealy mass. Below this layer and extending to a depth of about 16 inches, the material is dark grayish-brown heavy silt loam having a prismatic structure that breaks readily into nut-sized fragments. These pieces are firm but are easily crushed under a little pressure. Below this layer the color becomes lighter, grading into olive gray at a depth of about 25 inches. The texture of this underlying material ranges from sandy loam to clay loam, the latter predominating. In most places white flecks of carbonates are in evidence below a depth of about 18 inches. A claypan has developed in a very few areas, which are shown by symbol. This claypan is identical with that occurring in Farland-Wade silty clay loams, a complex that is described later in this report.

Farland silt loam is a desirable soil for tilled crops, as it is productive of practically all of the crops commonly grown and is easily managed. Probably 80 percent of this soil is tilled. A small part is farmed under a rotation including a cultivated crop, and some summer fallowing is practiced. Wheat occupies the greatest acreage of any one crop, and in good seasons it yields about 15 bushels an acre. Other small grains do equally well. Yields of corn are equal to or greater than those obtained on Morton loam. Because of its position, this soil is fairly well adapted to the production of alfalfa and sweetclover. Its relative value for cropping is about 90 percent of that of the best soil of the county. It is also one of the most desirable soils for grazing, although it affords natural protection for winter grazing in but few places and is too valuable as cropland to be devoted to this purpose.

¹⁸ Actually, there may be some question of the correlation of the high-terrace phase as Huff soil; but as the physical characteristics of the profile are very similar to those of the Huff soils, it did not seem practicable to introduce a new series name for this special condition.

Farland silt loam, high-terrace phase.—Farland silt loam, high-terrace phase, occupies the isolated high plateau-like benches that lie from 100 to 200 feet above the Little Missouri River Valley. The character of the soil is similar to that of the typical soil except that it is almost everywhere underlain by silt and clay. Generally a thin layer of gravelly or sandy material lies at a depth of about 30 inches. The native vegetation is similar to that of Morton loam—predominantly blue grama with a considerable intermixture of western needlegrass and other grasses.

This soil appears to be developed from considerably older alluvium than that from which typical Farland silt loam is developed. The surface is undulating, being slightly more uneven than that of the typical soil but noticeably smoother than that of Morton loam. Most of the areas are uniform and unbroken by difficultly tillable tracts and both surface drainage and subdrainage are good. It lies on high comparatively isolated benches bordering the Little Missouri River Valley. These benches are remnants of an ancient alluvial valley floor through which, during geologic time, the Little Missouri River has cut to its present position. They are distributed along the valley throughout the entire length of the county and range in size from 10 to several hundred acres, the largest area lying about 2 miles east of Bullion Butte. Most areas are partly or wholly surrounded by rough land, most of which slopes steeply to the lower lying Little Missouri River and tributary valleys.

Farland silt loam, high-terrace phase, is nearly as desirable and productive as typical Farland silt loam. Because of its higher position, it is not so suitable for such crops as alfalfa and sweet-clover, but it is very productive of the commonly grown grain and hay crops. Comparatively good yields of wheat on it have been reported, and other crops, such as corn, small grains for hay, and millet, yield well. Because of its generally isolated position and close proximity to extensive areas of grazing land, a large part of it is devoted to the production of forage and grain crops for feed.

Its relative value as either tillable land or grazing land is about 85 percent of that of the most desirable soil in the county.

Farland silty clay loam.—Farland silty clay loam is the dark grayish-brown clay loam, free of claypan development, that occupies the flats or benches along the larger stream valleys of the eastern uplands. It occurs on the older comparatively well-drained benches along the larger streams of this part of the county. The most extensive areas are along the Green River, where they lie from 10 to 20 feet above the bed of the stream. The surface of this soil, in general, is nearly level. Those parts of the areas lying near the stream channels are well drained, but those lying several rods from the stream channels have slow surface and subsurface drainage. During normal seasons, however, drainage is sufficient for good growth of plants.

The surface soil, which extends to a depth of about 6 inches, is dark grayish-brown to very dark grayish-brown friable silty clay loam. Below this and extending to a depth of about 16 inches, the material is clay loam of about the same color, having a well-defined prismatic structure. Generally the fragments, although friable, are firmer or more resistant to pressure and root penetration

than those of the other Farland soils and the Morton soils. Below a depth of about 16 inches the color becomes more gray and the prismatic structure gradually disappears, and at a depth of about 24 inches the material is olive-drab clay or clay loam having little or none of the structure common to the layer above. White carbonate flecks are generally present, especially in the upper part of this layer, that is, just below a depth of 16 or 18 inches. Small tracts here and there, indicated on the map by appropriate symbols, have a moderately developed alkali claypan.

The native vegetation is predominantly blue grama and western wheatgrass with some other equally palatable grasses intermixed. As on the other dark grayish-brown soils, little clubmoss is common.

This soil is associated with Farland silt loam and Farland-Wade silty clay loams. Probably 60 percent of the land is tilled, and the rest is used as grazing land. It is well adapted to the production of small-grain and hay crops, and the yields approximate those obtained on Farland silt loam. Cultivated crops are less common on this soil than on the more loamy soils, although they are frequently and successfully grown. Wheat occupies a greater acreage than any other crop, and oats and barley probably rank next in order. Some of these crops ordinarily are cut for hay. Such forage crops as millet, slender wheatgrass, and sorgho are grown frequently and yield well. The soil is fairly well adapted to growing alfalfa and sweetclover except where the claypan characteristic is in evidence. The acreage of corn is relatively small, but yields are comparatively reliable and good. Crop rotation, including a cultivated crop, is practiced to some extent, and some fall plowing is done. The relative value of this soil as cropland is about 85 percent of that of the most desirable soil of the county and as grazing land is nearly equal to that of Arnegard silt loam.

Cheyenne loam.—Cheyenne loam is the dark grayish-brown loam soil that overlies gravelly alluvium. It occurs on the alluvial gravelly benches or terraces of the stream valleys of the eastern uplands and the high benches that rise from 150 to 200 feet above the Little Missouri River Valley. This is not an extensive soil. Most of the areas are on the eastern uplands, especially south and southeast of Gorham and along the Middle Fork of the Green River. A large area along the Little Missouri River Valley, however, is about 5 miles northwest of Medora.

The surface of this soil is undulating. It is a little more billowy than that of some of the other well-drained alluvial bench soils, such as Farland silt loam. Surface and internal drainage are good, the latter being excessive where the gravelly material is within 10 or 12 inches of the surface.

The 7-inch surface soil is dark grayish-brown loam. Below this and extending to a depth of about 14 inches, the material is dark grayish-brown gritty loam with a structure sufficiently prismatic to cause the material to break from place as firm irregular fragments, which may be crushed fairly easily. In some areas this layer has a well-defined prismatic structure, the prislime pieces breaking easily to friable nut-sized pieces. Below this, the soil becomes lighter brown or yellowish-brown gritty loam and the structure becomes weaker. At a depth of about 24 inches, light-brown sandy loam occurs, which gives way to sandy gravelly material at a depth of about 30 inches.

Carbonates, plentiful enough to cause effervescence when the material is treated with an acid, occur at a depth of about 20 inches. In a few areas the surface layers are shallower, and the texture of the 5- or 6-inch surface soil is fine sandy loam rather than loam. Gravelly knobs are common in such areas. The gravel beds underlying this soil range in thickness from a trace to 14 feet, and many of the thicker beds are suitable sources from which to obtain gravel for road building.

The native vegetation is a mixture of blue grama, niggerwool, and needlegrass. The grass cover is thinner and less palatable on the more gravelly spots. With the exception of the large area 5 miles north of Medora, which is rather inaccessible, a large part of this soil is tilled. The area north of Medora is devoted entirely to grazing and is desirable land for this purpose.

All the small-grain crops commonly grown, corn, and hay are produced on this soil. Because of its rather droughty substratum of gravelly material, the soil, especially those areas where the gravel lies near the surface, is better adapted to corn and rye than to other small-grain crops. Wheat and corn are the predominating crops. Wheat yields average about 10 bushels an acre and corn about 20 bushels. The yield of forage crops is less than on such soils as Morton loam and Grail silty clay loam. Crop rotation, including corn as a cultivated crop, is commonly practiced. The relative value of Cheyenne loam as either tilled or grazing land is somewhat less than that of Morton loam.

Cheyenne gravelly loam.—Cheyenne gravelly loam is the brown to dark grayish-brown gravelly loam soil occupying gravelly alluvial benches. The relief of this soil ranges from a little more billowy than Cheyenne loam to rolling. The higher and more rolling parts are more gravelly, whereas the smoother and lower lying parts or troughs approach Cheyenne loam in thickness of surface soil. Drainage is excessive, especially in the more rolling areas.

The surface soil is variable. In places the 5-inch surface layer is dark grayish-brown loam containing a few pieces of gravel. This loam surface layer is lacking in many places, especially on the more exposed knobs and slopes. Below this layer and extending to a depth of about 12 inches, the material is grayish-brown distinctly gravelly loam or gravelly sandy loam. The material in many places has a noticeable prismatic structure; that is, the soil mass breaks easily into angular fragments, about 1 inch in diameter, that are fairly easily crushed to a crumbly mass. Below this layer the color fades rapidly and the material becomes either light-brown sand or gravel. At a depth of 28 inches, distinctly gravelly material is reached.

The native vegetation is a mixture composed principally of blue grama and niggerwool. In places the vegetation is thin and made up in part of such plants as skeletonweed and snakeweed. The more rolling parts have the poorer type of vegetation.

This soil is very inextensive. It is associated with Cheyenne loam and Cheyenne gravelly loam, steep phase. About 40 percent of it is tilled. The sandier or more gravelly areas are droughty, as are also the rolling parts, and are not adapted to tillage. The better parts, although more droughty than Cheyenne loam, are fairly productive. Corn and rye probably are the crops best adapted to this soil. Small

grains other than rye are grown, but their yields are low and unreliable. Corn and rye also return low yields but more remunerative yields than any other crop. Corn yields from 10 to 15 bushels and rye about 9 bushels to the acre. The relative value of the tillable areas ranges from 30 to 40 percent of that of the most desirable land. The more rolling tracts are not adapted to tillage and have a grazing value equal to about one-half of that of the best grazing land.

Huff very fine sandy loam, high-terrace phase.—Huff very fine sandy loam, high-terrace phase, is not an extensive soil. It occurs only on the high terraces along the valley of the Little Missouri River, where it is associated with Farland silt loam, high-terrace phase, as narrow strips on the outside borders of the terraces. The surface generally is undulating to rolling, and both external and internal drainage are good. The native vegetation is largely blue grama and needlegrass, with some niggerwool and patches of sandgrass.

The soil of these areas is not altogether typical of the Huff soils, inasmuch as the color of the surface soil is dark grayish brown instead of light grayish brown and their prismatic structure is more strongly developed than is characteristic of the Huff soils. Soil of this phase may be considered transitional between the Farland and Huff soils.

The 6- to 8-inch surface layer of this soil is dark grayish-brown very fine sandy loam with a weak prismatic structure that breaks readily and crushes easily. Between depths of 8 and 14 inches the color grades into light brown and the prismatic structure becomes less evident; and between this depth and about 20 inches the color fades from light brown to olive gray and effervescence is produced when the soil is treated with an acid. The soil material below this depth is generally sandy, and white flecks of carbonate are present.

The larger part of these areas is cultivated with the larger nearby areas of Farland silt loam, high-terrace phase. Their position near the edge of the high terraces, their more undulating to rolling surface, and their lighter texture and looser structure make them more subject to soil blowing than is the Farland soil. These more unfavorable characteristics or conditions tend to throw these areas out of tillage sooner than the more desirable areas of the associated Farland soil. Corn is a comparatively better crop than the small grains, but the soil does give up a greater percentage of its moisture to the growing plants than do the heavier soils. Because of its character and, in some areas, because of its isolated position on high benches in the Badlands, it is used more for forage crops than for small grains. Its relative crop value is about 55 percent and its grazing value about one-half of that of Arnegard silt loam.

BROWNISH-GRAY SILTY CLAY LOAMS

Brownish-gray silty clay loams of the terraces are represented in this county by one soil type—Cherry silty clay loam. This soil occurs principally on the low terraces of the Little Missouri River and has developed from fine-textured alluvial material. Its considerably lighter brown and gray color in comparison with the Farland

and Cheyenne soils suggests its youth and younger stage of development.

Cherry silty clay loam.—Cherry silty clay loam is the brownish-gray heavy-textured soil that occupies the benches along the Little Missouri River and the larger streams of the Badlands. Most of it lies from 10 to 20 feet above the first bottoms. Along the few tributary streams, it occupies the entire valley floor, and in such places it is generally cut by deep steep-sided meandering drains. Such areas generally are so severely dissected that tillage is impracticable.

The surface of this soil ranges from nearly level to very gently sloping, and drainage is invariably good. Although many soils exceed it in total area, it is one of the more important tillable soils, and fairly large areas occur throughout the entire length of the Little Missouri Valley.

The color and texture of this soil are similar to those features of Patent clay loam. The 5-inch surface soil is friable brownish-gray silt loam or silty clay loam that breaks easily into a crumbly mass. The surface soil of the silty areas averages a little browner than that of the silty clay loam areas. Below this layer the color becomes slightly grayer, but the material has a fair to good prismatic structure, the mass breaking into nutlike fragments, which are crushed under a little pressure into a crumbly mass. Below a depth of 15 inches is a variable material, predominantly olive drab in color. The prismatic structure gradually gives way to faint laminations or bands of various shades of gray and yellowish-gray silt and clay. This material is friable and fairly easily crushed into a crumbly mass. In most places carbonates are plentiful enough throughout to effervesce when the soil is treated with an acid.

The native vegetation is mostly blue grama with some western wheatgrass intermixed where overgrazing has not suppressed it. Probably 35 percent of the area of this soil is tilled, and, owing to its occurrence in the Badlands, it is used largely for the production of subsistence crops. Hay crops, especially oats, millet, and slender wheatgrass, are commonly grown, and some corn is produced, especially on the more silty areas. Yields equal or slightly exceed those obtained on Patent clay loam. Much of the area not tilled is used for native-grass meadow. Western wheatgrass is the dominant native grass used for this purpose. Where it is protected from grazing it invariably dominates the blue grama. Yields range from $\frac{1}{3}$ to $1\frac{1}{4}$ tons per acre. Owing to the scarcity of productive tillable land or good wild meadowland in the Badlands, this soil is prized by ranchers for these purposes. Its value is about 65 percent of that of the most desirable soil of the county. Because of its ability to support a good grass cover, it is considered very desirable grazing land.

DARK GRAYISH-BROWN SILTY CLAY LOAMS WITH CLAYPAN (SOLONETZ) AREAS

The subgroup of dark grayish-brown silty clay loams with claypan (Solonetz) areas includes areas of dark grayish-brown silty clay loams influenced by spots of claypan or Solonetz development. This subgroup is represented by one complex—Farland-Wade silty clay loams—differing from the member of the following subgroup—Wade-

Farland silty clay loams—in that the larger proportion of the total area is Farland silty clay loam, bare clay spots are fewer, and the claypan layer is less intractable.

Farland-Wade silty clay loams.—This complex represents (1) areas of Farland silty clay loam in which claypan or clay spots are more or less uniformly distributed but in which the claypan is comparatively weakly developed; and (2) areas of Farland silty clay loam in which, though the claypan is of the usual dense and intractable nature, the spots of its occurrence are less numerous than in the Wade-Farland complex.

This soil complex lies on nearly level benches or terraces along the streams of the eastern uplands. Both surface and internal drainage are slow but are adequate for satisfactory production of crops. Probably 60 percent of the land is tilled, most of which is used for small grains and hay. It is managed in the same ways as other claypan soils, and the yields equal or slightly exceed those obtained on Morton-Rhoades loams. Its relative values as cropland and grazing land are about 60 and 75 percent, respectively, of those of the most desirable land in the county.

DARK GRAYISH-BROWN SILTY CLAY LOAMS WITH NUMEROUS CLAYPAN (SOLONETZ) AREAS

The dark grayish-brown silty clay loams with numerous claypan (Solonetz) areas contain more numerous bare clay spots, or the proportion of the total area adversely affected by the claypan or Solonetz condition is greater, than in the Farland-Wade silty clay loams complex. Also these areas contain soils adversely affected by soluble salts. These soils are characterized by "puff" spots that are nearly bare. They are of loose consistence and without definite structure. Such soils are technically known as Solonchaks.

Wade-Farland silty clay loams.—This soil complex consists of Wade and Farland silty clay loams and is characterized by its position on alluvial flats and by the numerous bare clay spots. The clay spots are generally similar in character to those of the Rhoades and Moline soils. The soils of the interspot areas range from Farland silty clay loam to Wade silty clay loam, the latter having a definite claypan.

Wade silty clay loam in the interspot areas has a very dark gray or dark grayish-brown friable silty clay loam surface layer, about 7 inches thick. It rests on a claypan layer similar to that of the other claypan soils. This layer is somewhat darker than the surface layer and is from 4 to 7 inches thick. Below this, the soil grades into somewhat more friable dark olive-drab silty clay containing numerous white salt flecks.

Numerous areas of this soil complex vary markedly from this description. Some have an uneven surface similar to that of the normal claypan soils, but the higher parts are soft mounds, or puff spots. The puff spots range from 4 to 12 feet in diameter and rise from 4 to 12 inches above the surrounding surface. They occupy from 40 to 85 percent of the ground area and are practically bare of edible vegetation. Seepweed and saltgrass are the most common plants, neither of which has any grazing value. During dry weather, either a thin

uneven cover of white salt efflorescence or a thin gray siliceous semi-crust forms on the surface of these spots. The 8- or 9-inch layer below this consists of dark grayish-brown very fine sandy clay or clay, with white flecks of carbonates distributed through it. Below this layer the color fades to light brown with an olive tinge. All the soil material to a depth ranging from 12 to 20 inches, except the thin surface crust, is moist and very friable so that a spade may very easily be inserted its full length into the ground. Carbonates are present throughout. These puff spots are known technically as Solonchak soils, a term that signifies they are saline or salty because of a high content of soluble salts.

Areas in which the puff spots are developed occur along some of the streams of the eastern uplands. The largest single area, of which a great part contains puff spots, borders a small tributary of the Green River in the northwest quarter of T. 141 N., R. 98 W.

The areas between the puff spots resemble in general character the interspot areas of the claypan soils. Generally the 3- or 4-inch surface soil is dark-gray or dark grayish-brown fairly friable clay loam underlain by a darker claypan layer. Below a depth of about 10 inches this grades into olive-drab or olive-gray clay containing numerous salt flecks. This material, although not so friable as the surface layer, is less hard and dense than the claypan layer. The grass cover, which is generally good, is composed predominantly of blue grama with saltgrass and some western wheatgrass intermixed.

The surface of Wade-Farland silty clay loams is very nearly level except for the puff and bare clay spots. Both surface and internal drainage are very slow. Practically none of this soil is tilled, and, because of the bare spots and the inedible character of much of the vegetation, its grazing value is low. The best areas have a value of about 25 percent of that of the most desirable grazing land, but areas where the puff-spot condition is strongly developed are very nearly worthless.

SOILS OF THE ALLUVIAL BOTTOMS AND FANS

The last major group of soils considered in this report are those of the alluvial bottoms and fans. Those of the smaller streams are shown as undifferentiated loam soils and undifferentiated clay soils because textural changes commonly occur within very short distances and cannot be shown accurately on the scale of mapping used. In addition, such textural changes are likely to occur with each overflow, and even if they were shown on a map, the boundaries would likely become inaccurate in a comparatively short time.

The soils of the little Missouri River flood plain are classified in the Banks and Havre series. The Banks soils are primarily those underlain at a slight depth by sandy sediments, some of which are comparatively recent. The Havre soils are composed of finer textured alluvium that is more stable and resistant to soil blowing. These soils are commonly covered by brush or trees, principally cottonwood, ash, and elm. The Huff soils occur on natural levees built up by aggrading streams, and they are mapped also on alluvial fans where tributary streams discharge their loads of sediment upon

the flood plain of the master stream. The natural levees merge gradually with the adjoining flood plain or low terrace.

BROWNISH-GRAY CLAY LOAMS AND SILTY CLAYS

The brownish-gray loams and silty clays of this subgroup are the heavier soils of the bottom lands—Banks clay loam and Havre silty clay—and they differ essentially in the character of the underlying material. Both are young soils in the sense that they do not show evidence of soil development, and both are comparatively light colored. The uncleared areas are covered with trees and brush.

These soils are characterized by a brownish-gray color to a depth of at least 8 inches, a friable consistence, an abundance of carbonates throughout, and a lack of definite soil structure. They occupy the nearly level areas of first bottom alluvium along the Little Missouri and Knife Rivers. These soils are well adapted to tillage and are suitable for the production of all the crops commonly grown in this section. Their total acreage is small, and much of the land in the Little Missouri River Valley is uncleared. The tilled areas in this valley are devoted primarily to feed crops.

Banks clay loam.—The 4- to 12-inch surface soil of Banks clay loam is dark-gray silty clay or clay loam, which is friable and readily breaks into fragments that are easily crushed. The underlying material is yellowish-gray fine sand. Included with this soil are a few areas having a brown or light-brown fine sandy loam layer to a depth ranging from 6 to 12 inches. This material is underlain by dark-gray fairly friable clay, and sandy material occurs at a depth of 3 to 4 feet. These included bodies are Havre silty clay and Banks clay loam that have been covered by more recent deposits of more sandy material.

The surface is nearly level, and most areas represent slight depressions associated with sandier Banks soils. Drainage is adequate for the production of crops. The native vegetation differs considerably. The open areas are covered with grass, most of which is blue grama. A few areas are wholly or partly occupied by cottonwood trees, and others are covered partly or wholly by a brushy growth.

Only a few small bodies of this soil, most of them less than 60 acres in size, are mapped in the Little Missouri River Valley. Probably 40 percent of the land is tilled, and the rest is used for grazing. Because of its occurrence in the Badlands, where tillable land is comparatively scarce, this soil is prized by many ranchers for meadow and for the production of corn for forage. These two crops occupy a large part of the tilled acreage. The most favorably located areas are fairly well adapted to the growing of alfalfa and sweetclover. Forage yields, especially of hay crops, are slightly more than those obtained on Banks very fine sandy loam, and the values of these two soils as cropland are about equal. Banks clay loam ordinarily is preferred to Banks very fine sandy loam for grazing, as it generally supports a better grass cover.

Havre silty clay.—The 4- or 5-inch surface soil of Havre silty clay is dark olive-gray or brownish-gray friable silty clay. Below this depth the soil is variegated or slightly mottled with shades of gray, olive gray predominating. In some places the mass breaks readily

into definite flattened angular fragments of silty clay that are very resistant to pulverization; whereas in other places it breaks into irregular fragments that are fairly easily crushed. In all places the material is easily broken into small fragments. This silty clay material extends to a variable depth. In most places light-yellow fine sand or lenses of yellow sand occur below a depth of 18 inches. Sufficient carbonates are present throughout to cause effervescence when the soil is treated with an acid.

The aggregate area of Havre silty clay is not large. A few bodies occur in the Little Missouri River Valley, and most of the small area of bottom land along the Knife River is occupied by this soil. All the areas are well enough drained to be successfully cropped. The areas in the Little Missouri River Valley are slightly depressed, compared with the areas of Banks loamy fine sand and Banks very fine sandy loam with which Havre silty clay is everywhere associated throughout this valley. The areas along the Knife River lie approximately 12 feet above the level of the stream.

The native vegetation varies from place to place. Some areas support a cover of grass, several are partly occupied by brush similar to that growing on some areas of Banks very fine sandy loam, and on a few, cottonwood trees grow. Most of this soil is devoted to grazing or the production of wild hay. The dominant grass is western wheatgrass. The tilled acreage in the Little Missouri River Valley is used largely for small grains for hay, and some corn is grown. The tilled areas along the Knife River are devoted principally to small grains and hay. Some of the small grain is wheat grown as a cash crop. The hay crops are composed of small grains (principally oats), slender wheatgrass, and alfalfa.

Havre silty clay is a fairly productive soil, and yields obtained on it are comparable with those obtained on Morton clay loam. Because of its position, tilth, and fertility, the Havre soil is well adapted to the production of alfalfa and sweetclover. When cleared, the relative value of this soil as cropland is about 75 percent of that of the most desirable soil of the county, and as grazing land it very nearly equals Arnegard silt loam.

GRAYISH-BROWN VERY FINE SANDY LOAMS AND LOAMY SANDS

The grayish-brown very fine sandy loams and loamy sands of the alluvial fans and terraces belong to the Banks series and are characterized by underlying beds of light brownish-yellow fine sand and by comparatively sandy surface textures. Banks very fine sandy loam is a desirable soil and is used largely for feed crops because it is rather well suited for such crops and because it occurs largely within the Badlands, which is the grazing section of the county.

Banks very fine sandy loam.—Banks very fine sandy loam occurs as first-bottom land along the Little Missouri River. In most places the 7-inch surface soil is grayish-brown very fine sandy loam; that of a few areas is loam or light silt loam. The material breaks under very slight pressure into fragments that are easily crushed. Below this layer the color fades to brownish yellow and the material becomes more sandy. Below a depth of about 15 inches the material is light brownish-yellow loose fine sand. In areas inclined to be

billowy, the crests of the billows are more sandy and some of the troughs or lower strips have a heavy loam texture to a depth of 8 to 10 inches. The areas of finer textured soil are noticeably more productive.

Open areas have a native vegetation composed of blue grama with a few patches of sandgrass. Many of the untilled open areas have a variable growth of sagebrush. A small part of the land is occupied by brush and trees; some cottonwoods grow near the river. Scattered thickets of ash and elm and patches of mixed buffaloberry, buckbrush, chokecherry, and wild plum grow in places. Because a larger proportion of this soil is tilled, such growth is not so common on this soil as it is on Banks clay loam and Havre silty clay.

The surface of Banks very fine sandy loam is mainly gently undulating, and a few areas are billowy. No definite surface drainage is developed, but subsurface drainage is good to excessive, owing to the sandy subsoil. Most of the areas of this soil lie about 20 feet above the level of streams. A few areas are flooded occasionally. This is the most extensive soil on the bottoms of the Little Missouri River, and it occurs to limited extent along a few of the tributaries of that river.

Much of this soil is tilled, and, like the Cherry and Huff soils, it is used principally for the production of subsistence crops. Corn is a commonly grown crop and is one of the best adapted feed crops. Small grains are commonly grown for hay, and many of the lower lying areas of finer textured soil are suitable for growing alfalfa and sweetclover. Such areas are more fertile and are more favorably located for the maintenance of sufficient soil moisture. With the exception of alfalfa and sweetclover, Banks very fine sandy loam and Huff very fine sandy loam are devoted to the same crops and are managed in about the same way. The relative value of Banks very fine sandy loam when cleared is about 50 percent of that of the most desirable soil in the county.

Banks loamy fine sand.—The 5-inch surface soil of Banks loamy fine sand consists of brown loose loamy fine sand or brown loose fine sand. It grades into light-yellow or yellowish-gray fine sand. Carbonates are present very near the surface and in many places are at the surface. The relief of this soil generally is gently billowy, owing evidently to the action of the wind. Although no surface drainage is developed, drainage is excessive because of the pronounced sandy texture.

The native vegetation on many strips of this soil bordering the river channel is mostly cottonwood, and the mature trees range from 18 to 24 inches in diameter. Other trees and shrubs that commonly grow in thickets are ash, elm, buffaloberry, chokecherry, and willow. The native grass on the open areas is blue grama with numerous patches of sandgrass, but the blue grama is not common on the sandiest patches.

Banks loamy fine sand occurs in the first bottoms throughout the valley of the Little Missouri River and along a few of its larger tributaries. The aggregate area is about the same as that of Banks very fine sandy loam. The loamy fine sand generally borders the

river channel, whereas the heavier textured soils lie farther from the channel. Because of its extremely sandy character, very little of this soil is tilled. Only a very few areas are sufficiently fertile and retentive of moisture to be at all suitable for the production of crops. In general, the soil is low in plant nutrients, is extremely droughty, and is very subject to soil blowing. It is devoted almost wholly to grazing and for this purpose has a relative value of about 10 percent of that of the most desirable grazing land of the county.

LIGHT GRAYISH-BROWN VERY FINE SANDY LOAMS OF THE FANS AND NATURAL LEVEES

Huff very fine sandy loam is the only representative of the subgroup of light grayish-brown very fine sandy loams of the fans and natural levees. It is the comparatively light-colored and light-textured soil overlying comparatively recent sandy deposits that have been deposited principally on alluvial fans or on natural levees by tributary streams entering the Little Missouri River Valley.

Huff very fine sandy loam.—The 12-inch surface soil of Huff very fine sandy loam is grayish-brown or light grayish-brown very fine sandy loam or fine sandy loam. The mass breaks into easily crushed pieces that have a semblance of a nut structure. Below this depth the color gradually fades from light brown to olive gray. The material below a depth of 20 inches is generally sandy, although finer textured material occurs in many places at or below a depth of 30 inches. In most places the material from the surface downward has enough carbonates in it to cause effervescence when treated with an acid, and white flecks of carbonates commonly occur below a depth of 14 inches. A few included areas of dark grayish-brown soil are free of carbonates to a depth of more than 14 inches. Generally, the soil of these areas has a more nearly prismatic structure approaching that of Farland silt loam. This variation is more desirable than typical Huff very fine sandy loam, but, because of its small extent, it is included with the Huff soil.

Huff very fine sandy loam is not an extensive soil, and most of it occurs along the Little Missouri River. A few areas are practically on the first bottom, although most of the sandy soils of the first bottom belong to the Banks series. The variation described as resembling the Farland soil occurs chiefly along the streams of the eastern uplands.

The surface of this soil for the most part is nearly level or gently undulating, and both surface and internal drainage are good, internal drainage being somewhat excessive in the areas of sandier soil.

The native vegetation on most areas of this soil is blue grama with some patches of sandgrass. A few areas support cottonwood trees, and in some places thickets of buffaloberry, ash, elm, chokecherry, and wild plum are common.

Probably 40 percent of this soil is tilled. Corn is commonly grown, as well as tame grasses and small grains for hay. Corn is distinctly the more productive crop, as the soil is too droughty for the shallow-rooted grasses. Areas of this soil in the Little Missouri River Valley are farmed largely under a rotation including hay crops for 2 or 3 years followed by corn or small grain for a year or two. The

areas on the eastern uplands are devoted to wheat as a cash crop, in addition to the crops commonly used for feed. Because of its loose sandy texture, this soil is subject to blowing, but not so much so as are the sandy soils on the exposed ridges of the eastern uplands.

Yields of hay probably range from $\frac{1}{2}$ to 1 ton an acre. The yields vary considerably according to the amount and distribution of precipitation. Yields of corn for forage are comparatively high, ranging from 1 to 3 tons an acre. Very little small grain, at least in the Little Missouri River Valley, is grown for other purposes than to be cut for hay. The relative value of this soil is about 50 percent of that of the most desirable land of the county. It is fairly good grazing land, but its sandy porous subsoil causes it to dry early in the season. This same characteristic, however, allows the growing crop to make more efficient use of light midsummer showers.

UNDIFFERENTIATED SOILS OF THE STREAM BOTTOMS

The undifferentiated soils of the smaller stream bottoms are of variable texture and occur only in the comparatively narrow flood plains of the smaller, generally intermittent, streams.

Alluvial loam soils, undifferentiated.—This complex includes the sandy loams and loams of the first bottoms and small remnants of benches along the drainageways. The material is extremely variable as to texture, color, relief, salt content, and drainage. That part bordering the drainageways of the Badlands is composed for the most part of gray strikingly laminated fine sand and silt.

The 3- or 4-inch surface soil generally is gray loose-structured material that falls or breaks easily into a fine-grained mass. Laminations, owing to deposition, are at least faintly visible. The texture ranges from fine sand to silt, although some small included areas have a texture approaching clay loam. Below this layer the material in many places also is strikingly laminated, the laminations being differentiated by sharp differences in texture and shades of gray. The texture of these layers ranges from fine sand to silt loam and in places to clay loam. Numerous areas are predominantly fine sand and loamy fine sand, and in such areas the laminations are not so prominent. The material below a depth of 2 to 3 feet is similar to that just described, except that the texture is coarser and in places is very sandy. Carbonates are abundant throughout.

This material of the Badlands occupies strips of first-bottom land along the many drainageways. Almost all of these strips are cut by the deep meandering channels or gorges of the drains and consequently are well drained except where the ditches are not cut so deeply and floodwater comes over the channel banks. In most places the native vegetation includes a fair to dense growth of sage, mostly gray sagebrush, with a scant growth of blue grama and some sandgrass. A few thickets of ash and elm grow along the banks of the streams, and cottonwood trees grow in a few places. Practically none of this land is tillable, and because of its poor grass cover its grazing value is low.

The areas in the eastern uplands have a similar physiographic position but are not so droughty as the areas in the Badlands. In the eastern part of the county the flow of the drains is more constant, the

soil material in general is a little darker colored, and the vegetation is more fixed and more valuable for grazing. Generally, the material to a depth of 5 or 6 inches is grayish brown or dark grayish brown, but the texture varies, even within very short distances, from fine sand to silt loam. The underlying material is lighter colored and in many places is more sandy than the surface layer, but a few areas consist almost wholly of fine sand or loamy fine sand throughout. This material invariably contains sufficient carbonates to cause effervescence when treated with an acid. Here and there areas of Farland soils, on remnants of terraces or benches, are included in mapping.

A few areas of this soil are very salty, although this condition is not so common as in the alluvial clay soils. The salty condition, which is indicated by an abundance of salt crystals or flecks in the soils and by a white salty crust on the surface, occurs for the most part in the more poorly drained areas.

The drainage of the areas that are not salty is fairly good, and the surface is generally more or less bumpy and invariably is severely cut by meandering drainage channels. Probably 50 percent of the area of this complex is subject to inundation during high water.

The native vegetation varies considerably. Most of the comparatively well drained loam areas and bench remnants support a fair stand of blue grama with some western wheatgrass intermixed, and a few patches of big bluestem are on the lower well-drained slopes or depressions. On the sandier areas much of the blue grama is displaced by sandgrass. Areas where the soil is salty have considerable saltgrass intermixed with the blue grama.

Because of severe dissection, commonly sandy texture, and a few salty and poorly drained patches, very little of this soil is tilled. A few small desirable patches are plowed either because they are especially suitable for garden crops or because they adjoin tilled areas of other soils. The average value of the nonsalty areas is about 60 percent of that of the most desirable grazing land. Most of the salty areas are almost worthless.

Alluvial clay soils, undifferentiated.—This soil complex includes clay loam and clay alluvium along the drainageways. It is composed for the most part of gray or dark-gray clay, which in places is mottled yellow and gray at a depth of 16 to 18 inches. Most of this soil, especially in areas throughout the eastern uplands, is decidedly salty. The material in such places is gray or dark-gray clay or clay loam and generally is fairly hard and impervious, but in some areas the salty material is soft and friable, and the mass may be dug from place with a spade very readily. An abundance of salts is everywhere present throughout the more salty areas. In places the salts are abundant enough to form a white crust on the surface.

Alluvial clay soils, undifferentiated, occupy the narrow strips of first-bottom land along some of the drainageways and small tributaries. Most of it is in the eastern uplands, and only a few areas are in the Badlands. The surface is hummocky or uneven and is more or less cut by drainage channels, which, through many areas, are not so well defined or cut so deeply as are those through areas of alluvial

loam soils, undifferentiated. Because of this fact and the heavier texture of the sublayers, drainage ordinarily is slower, and this is responsible for the generally salty character of this soil complex. Those areas in the Badlands in general are better drained or at least drier than those in the eastern uplands.

The native vegetation on the less salty areas in the Badlands is dominated by sagebrush, principally gray sagebrush. This is generally accompanied by a sparse stand of edible grasses, such as blue grama and western wheatgrass. The less salty areas of the eastern uplands support a fair to good stand of blue grama with which almost invariably some saltgrass is intermixed. The salty areas have a great abundance of saltgrass, and the poorest drained or boggy areas are occupied for the most part by lowland sedges. Many such areas have some arrowgrass, a plant that is poisonous to livestock.

Practically none of this soil complex is tillable, and a large part of the salty areas has low grazing value. The small acreage in the eastern uplands that is not salty or boggy affords fair grazing, with a carrying capacity equal to about 60 percent of that of the best range land.

Riverwash.—Riverwash is the fresh sandy alluvium occurring adjacent to the stream channel of the Little Missouri River and some of its larger tributaries. The areas lie but a few feet above the surface of the water and are partly or wholly subject to overflow whenever the river is at flood stage. The material is pale-yellow sand or fine sand showing no accumulation of organic matter since deposition. The surface of the areas is slightly billowy. Most of them occur as long comparatively narrow strips that lie next to and parallel with the river channel and opposite the cutting side of the channel. Most of the acreage is devoid of vegetation, although a few areas support a fair to thick stand of water willow saplings. This material has no agricultural value.

PRODUCTIVITY RATINGS AND LAND CLASSIFICATION

In table 6 estimates are given by means of indexes of the approximate yields obtained for the crops commonly grown on each soil type under the common farming practices. Estimates are given for average yields over a period of years and also for the average of the better years. It cannot be overemphasized that the indexes are largely estimates.

The indexes compare the productivity of each of the soils for each crop to a standard; namely, 100. This standard index represents the productivity, without the use of amendments or fertilizers, of the more productive soils of the region in which the crop is commonly grown. An index of 50 indicates that the soil is about half as productive for the specified crop as is the soil with the standard index. Soils given amendments, such as lime or commercial fertilizers, or unusually productive soils of small extent may have productivity indexes of more than 100 for some crops. The following tabulation sets forth some of the acre-yields that have been set up as standards of 100. They represent long-time average yields of crops of satisfactory quality on the better soils without the use of amendments.

Crop:		
Corn	-----bushels	50
Wheat	-----do	25
Barley	-----do	40
Oats	-----do	50
Flax	-----do	15
Potatoes	-----do	200
Corn (fodder)	-----tons	12
Alfalfa hay	-----do	4
Sweetclover hay	-----do	2
Millet	-----do	3
Wild hay	-----do	1
Pasture	-----cow-acre-days ¹	100

¹ "Cow-acre-days" is a term used to express the carrying capacity of pasture land. As used here it is the product of the number of animal units carried per acre multiplied by the number of days the animals are grazed without injury to the pasture. For example, a soil type able to support one animal unit per acre for 360 days of the year rates 360, whereas another soil able to support one animal unit per 2 acres for 180 days of the year rates 90. Again, if 4 acres of pasture support 1 animal unit for 100 days, the rating is 25. In other words, it represents the number of days per year that 1 acre of a given soil type can furnish grazing to one animal unit.

The principal factors determining the productivity of land are climate, soil, and management. Under the term soil, as used here, conditions of slope and drainage are included. Climate as a factor in crop production cannot be isolated from the soil factor, inasmuch as climate determines in part the type of soil. In Billings County, however, variations of the seasonal climate from year to year are very pronounced in their effect on crop production and overshadow the soil condition. As a result, the productivity of the land is rather definitely associated in the experience of the farmer with climate, particularly the amount and time of precipitation and the presence or absence of hot winds. Other elements that contribute to determine actual yields obtained by the farmer in this county are the infestation of insects, such as grasshoppers, and the prevalence of fungi, such as black stem rust. Two soil conditions of particular importance to productivity in this county are the content of soluble salts and the degree of saturation by sodium. Since these conditions are commonly associated and result in a series of bare circular spots locally known as "scab" or "gumbo" spots, distinctly scabby areas are mapped separately (see descriptions for alkali claypan and salty soils). These factors of soil, climate, and management do not operate independently of one another, and the productivity of all soils cannot be measured directly by any one of them. Crop yields over a long period of time furnish the best available summation of the combined effect of the factors, and they are used as a basis for the indexes wherever they are available. A lack of substantial data concerning yields on individual soil types has resulted in the indexes in table 6 being largely estimates based on the experience and judgment of local farmers, other agricultural workers, and members of the field party.

Certain slight differences are to be noted from the indexes assigned to similar soils in McKenzie County. Some of the soils differ slightly in characteristics. Thus, Havre silty clay of Billings County is confined to the alluvium of a smaller stream and is not considered so productive as that of the Missouri Valley in McKenzie County. Other soils differ in the range of slope, as mentioned previously, and still others in the number of bare clay spots. Again, there seems to

TABLE 6.—Productivity ratings of soils in Billings County, N. Dak.

Soil 1	Crop productivity index 2 for—																				General productivity grade 4		Principal occurrence in county	Percentage of county area	Grouping of soils on basis of physical suitability for use 4					
	Corn				Wheat	Barley	Oats	Flax	Alfalfa 3	Sweet-clover	Potatoes	Millet	Wild hay	Pasture																
	Grain		Fodder																											
	50 B	12 T	25 B	12 T	25 B	40 B	30 B	15 B	4 T	2 T	20 B	3 T	1 T	ca d	A	B														
Arnegard silt loam.....✓	40	60	30	40	50	80	45	70	45	70	50	80	30	40	55	90	30	50	50	70	70	90	23	40	5	3	Depressions in eastern upland.	0.4	Good cropland.	
Farland silt loam.....	35	55	25	35	35	60	35	55	35	60	45	70	25	35	50	80	25	40	40	70	60	80	21	35	6	4	Along Green River and other streams	.6	Fair to good cropland.	
Farland silt loam, high terrace phase.	35	55	20	30	35	60	35	55	35	65	45	70	15	30	50	80	25	40	40	65	50	70	20	33			High benches along Little Missouri River.	1.0		
Farland silty clay loam.....	30	45	20	30	35	60	35	55	35	60	45	70	25	35	50	80	25	40	40	70	60	80	21	35			Along Green River and other streams.	.3		
Morton loam.....	35	55	20	30	35	60	30	50	30	50	40	65	15	30	40	70	25	40	40	65	50	70	20	33			Eastern uplands.....	6.4		
Grall silty clay loam.....	30	45	15	25	35	60	35	55	35	65	45	70	20	35	50	80	20	35	40	70	60	80	21	35			Lower gentle slopes.....	1.3		
Cheyenne loam.....	30	50	20	30	35	60	30	50	30	50	40	65	15	30	40	70	20	40	35	60	40	60	18	30			Eastern uplands and high benches.	.3		
Havre silty clay.....	30	45	20	30	35	60	35	55	35	60	45	70	30	40	60	80	25	40	40	65	50	70	20	33			Knife River Valley.....	2		
Morton clay loam.....	30	45	15	25	35	60	30	50	30	50	40	65	15	30	40	70	20	35	35	60	50	70	20	33			Eastern uplands.....	1.4		
Searing loam.....	35	55	20	30	30	55	25	45	25	45	35	60	...	40	70	20	30	35	60	40	40	60	17	30	7	5	Associated with scoria beds..	.2	Fair cropland	
Patent silt loam.....	30	45	15	25	30	55	25	45	25	40	30	55	15	25	35	60	20	30	35	60	50	70	20	35			Draws of Badlands.....	1.2		
Cherry silty clay loam.....	25	45	15	25	30	55	25	40	25	40	30	55	15	25	35	60	15	25	35	60	50	70	21	35			Little Missouri River Valley	1.2		
Patent clay loam.....	25	40	15	25	30	50	25	40	25	40	30	50	15	25	35	60	20	30	35	60	50	70	20	35			Draws of Badlands.....	1.4		
Farland-Wade silty clay loams	20	35	10	20	30	50	20	35	20	35	25	40	...	10	20	20	35	35	55	14	25	Stream flats of eastern uplands.		.7
Banks clay loam.....✓	30	50	15	25	30	55	25	40	25	40	25	40	15	25	35	60	20	40	25	40	25	40	17	30			Little Missouri River Valley.	.1		
Banks very fine sandy loam✓	30	50	15	25	30	50	20	35	20	30	25	40	15	25	35	60	25	40	25	40	20	35	9	15			do.....	.6		
Flasher fine sandy loam.....	30	50	15	25	30	50	20	35	20	30	25	40	...	30	55	20	30	25	40	25	40	10	16	Eastern uplands.....		2.2
Huff very fine sandy loam, high-terrace phase.	30	50	15	25	30	50	20	35	20	30	25	40	...	30	55	20	30	25	40	25	40	11	20	High benches along Little Missouri River.		.2
Morton-Rhodes loams.....	20	35	10	20	25	45	20	35	20	35	25	40	...	10	20	20	35	35	55	14	25	Eastern uplands.....		2.2
Bainville loam, smooth phase✓	25	40	15	25	40	60	20	35	20	35	30	50	...	30	55	20	30	20	30	30	50	16	27	do.....		.2
Patent-Moline clay loams.....	20	35	10	20	25	45	20	35	20	35	25	40	...	10	20	20	35	35	55	14	25	Draws of Badlands.....		6.1
Morton-Rhodes clay loams.....	20	30	10	20	25	45	20	35	20	35	25	40	...	10	20	20	35	35	55	14	25	Eastern uplands.....		2.4
Bainville clay loam, smooth phase.	20	35	10	20	25	45	20	35	20	35	30	50	...	30	55	15	25	20	30	30	50	15	26	do.....		.2
Huff very fine sandy loam.....✓	25	45	15	25	25	40	20	35	20	30	20	35	...	30	50	20	30	20	30	15	30	9	15	Little Missouri River Valley.		.5

See footnotes at end of table.

Morton loam, rolling phase	15	25	10	20	20	30	15	25	20	30	20	30	10	30	25	40	10	20	20	30	30	50	14	23	} 7	Eastern uplands	1.2	} 8	Generally unsuited to permanent cropland. Best suited to grazing.		
Patent clay loam, slope phase	15	25	10	20	20	30	15	25	15	25	20	30	10	30	25	40	10	20	25	40	30	50	14	24		Lower slopes	3.3				
Morton clay loam, rolling phase	15	25	10	20	20	30	15	25	15	25	20	30	10	30	25	40	10	20	20	30	30	50	14	23		Eastern uplands	.3				
Searing loam, rolling phase	15	25	10	20	20	30	15	25	15	25	20	30	10	30	20	35	10	20	20	30	25	45	12	20		Associated with scoria beds	.6				
Bainville loam	15	25	10	20	20	30	15	25	15	25	20	30	10	30	25	40	15	25	20	30	25	40	11	20		Hilly uplands	1.3				
Bainville clay loam	10	20	5	10	15	25	10	20	10	20	20	30	10	30	25	40	10	20	20	30	25	40	11	20		do	.5				
Bainville-Rhoades loams	10	20	5	10	15	25	10	20	10	20	15	25	10	30	20	35	5	10	15	25	15	30	9	15		do	.2				
Bainville-Rhoades clay loams	5	10	5	10	15	25	10	20	10	20	10	20	10	30	20	35	5	10	15	25	15	30	9	15		do	.3				
Cheyenne gravelly loam	10	20	5	10	10	15	10	20	10	20	10	20	10	30	10	20	10	15	25	10	20	7	12	Eastern uplands and high benches		.1					
Morton-Rhoades loams, rolling phases	10	20	5	10	10	15	10	20	10	20	10	20	10	30	10	20	10	15	25	10	20	35	11	20		do	.3				
Patent-Moline clay loams, slope phases	5	10	5	10	10	15	10	20	10	20	10	20	10	30	10	20	10	15	25	10	20	35	11	20	Lower slopes	.9	} 9	} 9	} 9		
Flasher fine sandy loam, rolling phase	10	20	10	20	10	15	5	10	5	10	10	15	10	30	10	20	10	20	10	20	7	12	Sandy hills	1.8							
Morton-Rhoades clay loams, rolling phases	5	10	5	10	10	15	10	20	10	20	10	20	10	30	10	20	10	15	25	10	20	35	11	20	Eastern uplands	2					
Bainville-Rhoades loams, rolling phases					5	10								10	20						5	10	10	20	7	12				Hilly uplands	.1
Bainville-Rhoades clay loams, rolling phases					5									5	10						5	10	20	7	12	do	.3				
Rhoades loam complex					5									5							5	10	6	10	Eastern uplands	.4					
Moline clay loam complex					5									5							5	10	6	10	Lower slopes	2.3					
Rhoades clay loam complex					5									5							5	10	6	10	Eastern uplands	.3					
Alluvial loam soils, undifferentiated																							17	30	Small stream valleys	2.2					
Alluvial clay soils, undifferentiated																							12	20	do	.6					
Bainville loam, hilly phase																							9	15	Badlands	3.4					
Bainville clay loam, hilly phase																							9	15	do	4.8					
McKenzie clay																							7	12	Pond sites or flats	.1					
Patent silt loam, eroded phase																							5	8	do	1.9					
Moline clay loam complex, slope phase																							5	8	Lower slopes	.3					
Rhoades loam complex, rolling phase																							5	8	Eastern uplands	(*)					
Rhoades clay loam complex, rolling phase																							5	8	do	.1					
Bainville loam, steep phase																							5	8	Badlands	5.4					
Bainville clay loam, steep phase																							5	8	do	6.5					
Wade-Farland silty clay loams																							4	6	Stream flats or depressions	.5					
Flasher loamy fine sand																							4	6	Sandy hills	.3					

be a slight tendency for Billings County to experience slightly greater variability in crop yields, to be slightly more subject to adverse hot winds, and to receive slightly less rainfall than McKenzie County.

In table 6 the indexes in column A indicate the estimated average yield, whereas those in column B refer to the estimated average of the better years. Average yields, including seasons of partial and total crop failures, are probably not more than 60 percent of the average yields obtained in favorable years. The soils are listed in the order of their general productivity under dominant current practices, and productivity grade numbers are assigned in the column "General productivity grade." The general productivity grade is based largely on the indexes for wheat in this spring wheat region, although the actual placements recognized also the indexes for the other crops. Since it is difficult to measure mathematically either the exact significance of a crop in local agriculture or the importance and suitability of certain soils for particular crops, the placements are a result of inspection of the indexes and personal judgment rather than of precise mathematical computation. If the apparent average of the crop indexes for a soil type comes between 90 and 100, the soil type is assigned a grade of 1; if it comes between 80 and 90, a grade of 2 is given, and so on.

The column "Grouping of soils on basis of physical suitability for use" summarizes in a simple way the productivity and use capabilities of the various soils by placing them in a few groups on the basis of their relative suitability for dry farming and grazing.

Productivity tables do not present the relative roles that soil types, because of their extent and the pattern of their distribution, play in the agriculture of the county. The tables give a characterization to the productivity of individual types. They cannot picture the total quantitative production of crops by soil areas without the additional knowledge of the acreage of the individual soil types devoted to each of the specified crops.

Inasmuch as these ratings are based only on the characteristics of the soils and their productivity, they cannot be interpreted directly into land values except in a very general way. Distance to market, relative prices of farm products, and other factors influence the value of the land.

In connection with the use of the soil map as a basis for rural assessment for taxation, it may be stated that several of the units shown on the published soil map represent, for purposes of simplification, combinations of rather similar units that were shown on the field sheets and that were used in arriving at the rating of each tract of land. Factors other than comparative productivity that determined the relative rating of each unit area considered in the evaluation of land for assessment were distance to market, location in relation to other tracts, size, and present use. This productivity table, although similar to those set up for the assessment classification, cannot be considered identical with them.

GENERALIZED MAP OF SOIL ASSOCIATIONS

The soil map of Billings County graphically shows the extent and distribution of 49 soil types and phases, 10 complexes, and 6 miscellaneous land types. Figure 2 (p. 5) pictures the general features

of the relief and drainage of the county. An intermediate type of map, figure 3, gives the general distribution of nine associations of soil series: (1) Morton-Rhoades-Flasher association (symbol MR); (2) Patent-Moline association (symbol PM); (3) Farland-Wade-Havre association (symbol FW); (4) Farland-Huff-Cheyenne association on high terraces (symbol FH); (5) Cherry-Banks association (symbol CB); (6) Bainville-Flasher-Patent association (symbol BF); (7) rough broken land-Bainville-Patent association (symbol RB); (8) stony Bainville soils (symbol SB); and (9) stony land (symbol ST). Each kind of area shown on the map represents a rather definite kind of country (or land type), inasmuch as the soil components of each differ in respect either to the included soil series or to the proportionate areas covered by each of the included soil series. Reference to the earlier parts of this report for descriptions of soil series and soil types should clarify the principal external and internal characteristics of each.

The Morton-Rhoades-Flasher association (symbol MR) consists principally of the soils of the Morton series, the Morton-Rhoades and Rhoades soil complexes, and the smoother types of the Flasher soils. Associated inextensive soils are members of the Arnegard, Patent, Moline, and Bainville series. These individual soil types are closely associated over the eastern uplands, and reference to the detailed soil map shows that there are no single or extensive tracts of any one soil type. As a whole, these areas constitute the major part of the dry-farming area of the county, and they occupy the higher and smoother ridgelike crest of the eastern upland plain. The Flasher soils merge with the Morton soils on the lighter textured areas, and the Rhoades soils are most commonly situated at the heads of small draws or near the bases of gentle slopes. As a whole, the landscape throughout much of the year is one of uninviting monotony to the casual observer and only now and then is broken by farm homesteads, some of which, as a result of a series of droughty years, are abandoned. On the other hand, in years of favorable moisture supply, fields of waving grain present a more pleasing picture.

The Patent-Moline association (symbol PM) occupies, for the most part, the gentle slopes that fringe the drainageways of the eastern uplands. The soils are almost entirely those of the Patent and Moline series, although small hills, ridges, and depressions occupied by the Bainville, Morton, and Arnegard soils are necessarily included. One of the most extensive tracts lies south and southeast of Gorham. Here, the topography suggests a Morton landscape, but the soil character is that of the Patent soils. These areas are well suited for grazing, and a larger percentage of them is used for grazing than of the Morton-Rhoades-Flasher areas.

The Farland-Wade-Havre association (symbol FW) forms the stream terraces and bottoms along the Knife and Green Rivers and their tributaries in the eastern part of the county. The Farland and Havre soils are among the best in the county, but their occurrence in small strips associated with the Wade soils makes their use for cropping somewhat impracticable on many farms. The Wade soils generally occupy broad flats and are commonly characterized by puff spots that are bare or nearly so because of the salty soil condition.

The Farland-Huff-Cheyenne association on the high terraces (symbol FH) is dominated by Farland silt loam, high-terrace phase, and,

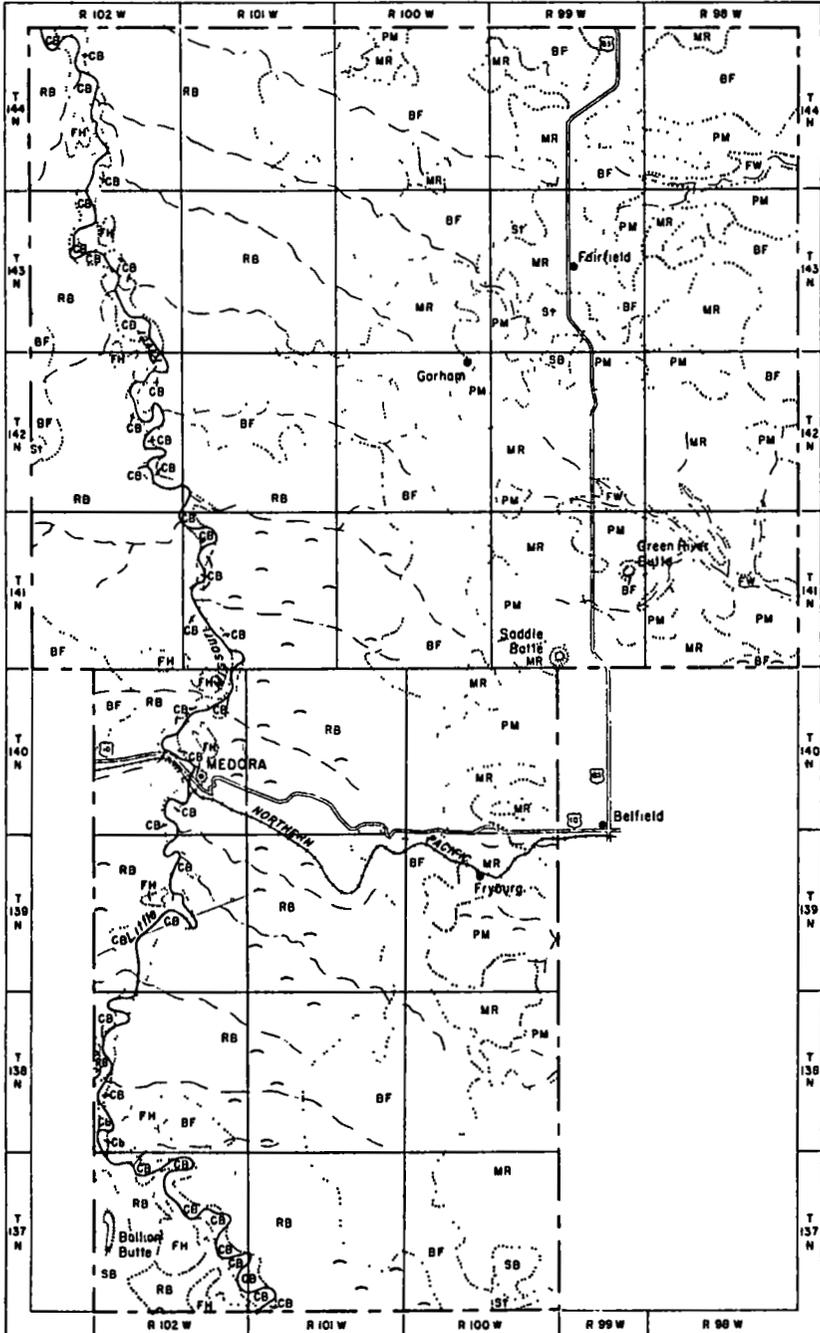


FIGURE 3.—Soil associations of Billings County, N. Dak. *BF*, Bainville-Flasher-Patent association; *CB*, Cherry-Banks association; *FH*, Farland-Huff-Cheyenne association on high terraces; *FW*, Farland-Wade-Havre association; *MR*, Morton-Rhoades-Flasher association; *PM*, Patent-Moline association; *RB*, rough broken land-Bainville-Patent association; *SB*, stony Bainville soils; *ST*, stony land; curves designate the general occurrence of scoria.

as such, comprises level flats of comparatively deep and dark soil high (200 feet or more) above the floor of the Little Missouri River Valley. Inaccessibility and isolation from more extensive tracts of level land cause the smaller tracts to be left as grazing land. The fronts of these old high terraces bordering the valley proper of the Little Missouri River have become eroded and constitute a steep wall of rough broken land.

The soils of the Cherry-Banks association (symbol CB) occur chiefly on the floor of the Little Missouri River Valley. Except for the high terraces nearby, they offer about the only sites for the growing of feed crops in the Badlands. It is on them that the ranch homesteads and their artesian wells are located. Here are seen some of the more impressive views of the surrounding Badlands.

The Bainville-Flasher-Patent association (symbol BF), for the most part, constitutes the grassed hills that lie between the smoother uplands and the Badlands. An exception to this general geographic relationship is the belt of hills or escarpment in the northeast where the upland gives way to the slopes of the Knife River watershed. The Flasher soils generally occur on the higher sandy knobs derived from exposed sandstone, whereas the Patent soils are in the upper drainageways or on the lower slopes. The intermediate hills and slopes comprise the areas of Bainville soil. This soil association is definitely grazing land, although settlers and homesteaders have in places attempted to dry-farm some of the area.

By far the most extensive association in the county is the rough broken land-Bainville-Patent association (symbol RB). The south-facing slopes or walls are steep and bare, whereas those on the north are generally grass- or brush-covered. There are also a few thickets of juniper and ash. Thus, the association is Bainville soils on the north-facing slopes, rough broken land on the south-facing slopes, and Patent soils along the valley slopes or draws.

The stony Bainville soils (symbol SB) are intermediate in character between rough stony land and the Bainville soils. The two most extensive tracts are on the lower slopes of Bullion Butte in the southwest and adjacent to Rocky Ridge in the southeast. Except for stoniness, they are rather comparable to areas of the Bainville soils.

Stony land (symbol ST) is an association of rough stony land, stony Bainville soils, and stony Morton soils. The stone is an indurated sandstone and in places is nearly as dense as quartzite. These areas commonly occur on the higher uplands and vary in their usefulness for grazing according to stone content.

LAND USES AND AGRICULTURAL METHODS

A planned agricultural program for Billings County will involve the production of feed crops for livestock, the extensive grazing of meat animals, and the limited production of cash crops. Because of the numerous crop hazards, only the most productive soils can be tilled profitably, and, in order to maintain sufficient reserves of feed, much of their acreage must be devoted to feed crops. The remaining acreage may be considered as available for cash crops. The kinds of cash crops, however, are limited by both climatic conditions and the comparatively long distance to markets. The production of feed crops deserves the more serious attention of the

farmers because of the hazards in crop production and the serious consequences to livestock farming if there is a shortage of feed.

During the period of settlement by homesteaders and the subsequent continued expansion brought about by the World War and mechanized agriculture, tillage of soils spread rapidly over the eastern upland and onto the very high terraces along the Little Missouri River. Experience of recent years has shown that crops cannot be successfully produced on the less productive soils, and, based on the general welfare of the county, isolated areas of even more productive soils should be turned over to meadow or grazing land. Since about 1935 the Land Utilization Division of the Resettlement Administration (more recently transferred from the Bureau of Agricultural Economics to the Soil Conservation Service) has been acquiring those extensive areas that are best utilized as grazing land, where grazing districts will be set up and grazing rights leased to livestock producers. The expected consequences of this program will be to return unproductive tilled areas to grazing land, to eliminate isolated farmed areas that are expensive to the community, and to improve the quality and stability of the grazing areas by eliminating overcrowding and consequent overgrazing of the range.

Even under the best plan of operation, land operators in this section will be confronted by crop and range hazards. Successive years during which cash crops will fail, feed reserves become seriously reduced, and grazing becomes sharply curtailed will occur occasionally. Such a regional condition makes a demand on credit not experienced in more uniformly productive sections; it calls for an elastic, low-cost, though conservative, plan of credit that will bridge these occasional unproductive periods and spread the financial burden over the more prosperous years.

Most of the soils that are suitable for crop production are in a fairly high natural state of fertility compared with those of the more humid sections of the eastern United States. They are well supplied with nitrogen and are sufficiently calcareous for the satisfactory growth of plants, such as alfalfa, that require comparatively large quantities of lime. The natural fertility of these soils has decreased only slightly during the cropping history of the county, in spite of the fact that cash grain crops are the main source of income, and very little effort has been made to return plant nutrients to the soil, either through legume crops, barnyard manure, or commercial fertilizers. This relatively slow diminution is due, at least in part, to low average yields and slow loss of plant nutrients through oxidation of plant residues. At some time in the near future, however, the effect of continual tillage and removal of crops without return of plant nutrients to the soil, accompanied in places by erosion and other physical difficulties intensified by drought conditions, probably will be reflected in a diminution of yields. Lower yields will be noticed first on the less fertile soils; in fact, such a trend has already begun.

Phosphorus is probably the most nearly deficient of the plant nutrients. It has been definitely determined that the regular application of phosphate fertilizer is advantageous to most crops produced on irrigated areas of adjacent counties. Its use on dry-farmed areas is as yet questionable, because a lack of available moisture limits yields

to such a low figure as to make the probable return on money invested in fertilizer of this sort extremely low. Barnyard manure, however, although a relatively low carrier of phosphorus, can be used to good advantage even on the dry-farmed areas. The usual practice is to spread the comparatively small available supply of manure on the stubble land in winter or early spring. Some farmers assert that light applications worked into summer-fallowed land, or otherwise thoroughly incorporated with the soil, give justifiable returns; and experiments conducted at the United States Northern Great Plains Field Station indicate increased yields where barnyard manure was used (13).

Operators on dry-farmed areas probably influence productivity of their soils more through their treatment of soil structure and tilth than through their treatment of soil fertility, drainage, or any of the other soil-productivity factors. The natural structure of the more productive soils of this county is very suitable for plant growth, much better in fact than in soils of more humid sections, and it is conceded that the productivity of these soils is jeopardized by the destruction of this natural structure. Continuous tillage breaks the natural fragments of clods to a fine or nearly single-grained condition, making the soil mass considerably more subject to blowing and water erosion, and by destroying the natural vesicles or air channels, makes the soil less well aerated. Another detrimental effect of tillage is the development, in certain soils, of a hardened layer or plow sole just below the plow layer. Observations, particularly of fine sandy loam and loam soils, indicate that the use of moldboard plows for a long time develops this hard, dense plow sole, ranging from 1½ to 3 inches in thickness. This condition interferes with the movement of soil moisture and the growth of plant roots. The productivity of these soils very probably would be enhanced by subsoil tillage that would break up the plow sole. The cost of such an operation, however, will be an important item in determining its practicability.

The farmer recognizing the general desirability of maintaining natural soil structure, however, is faced by the unavoidable necessity of seedbed preparation and crop cultivation. The nearest approach to the most desirable condition is to follow a cultural system that provides sufficient tillage for satisfactory crop growth with implements designed to disturb as little as possible the natural structure (1) and to cover or turn under only partly the surface sod or stubble. Leaving a roughened surface containing bits of stubble and other vegetation tends to check soil blowing and in fall-plowed areas tends to act as catch basins for snow.

Most of the silty clay loam and clay soils have their tilth improved by fall plowing, as the natural weather conditions in winter slake or soften the hard chunks and clods; but fall tillage may be detrimental even to these soils because of increased soil blowing. On the other hand, the retention of snow is an advantage not to be entirely overlooked. In general, silty clay loams and clays are much less subject to damage by soil blowing in winter as a result of fall plowing than are loams and sandy loams. The so-called claypan soils have their productivity improved by tillage over a period of years. Improvement here is due to the breaking up of the claypan and the distribution and incorporation of the more loamy surface layer of the interspot areas with the less productive clay of the clay spots,

but tillage of these soils should be moderate and only sufficient for the accomplishment of this purpose.

The presence of excessive amounts of salts ("white alkali") in soils practically eliminates them from consideration for crops requiring tillage of the soil under present agricultural conditions in the dry-farming section of the county. The matter of possible salt intrusion and accumulation deserves particular attention on areas that may be irrigated from the creeks and drains whose sources of water are local. Limited experience with irrigation from creeks in this and adjoining counties indicates that, with few exceptions, accumulation of salts will be difficult to avoid.

Although a great many of the soils have many inherent characteristics favorable to a high productivity for dry farming, many of the characteristics of the environment are distinctly undesirable and seriously discount the otherwise high productivity of the soils. These are principally lack of sufficient moisture during the growing season, hot periods during the midsummer, winds of high velocity, hail, black stem rust, and insect pests. Lack of sufficient moisture is considered the primary limiting factor in crop production in this county. Selection and diversification of crops, selection of improved varieties, and cultural and rotation methods are the most effective means of coping with the above-mentioned hazards. Diversification of crops reduces the chances of total crop losses. For example, a season that may result in a total loss of the wheat crop may be comparatively favorable for corn or millet. Selection of crops involves the choosing of those that have a comparatively low water requirement and are either drought-resistant or early maturing. Thus, the small grains—rye, wheat, and barley—are early maturing, and corn, sorghum, flax, and millet are at least moderately tolerant of dry periods. Most of these crops have been improved by the development of new varieties and by varietal research conducted by the North Dakota Agricultural Experiment Station and other stations, in regard to weather, disease, and insect hazards. For further information on the varieties of cereal crops adapted to the soils of Billings County, see the Bimonthly Bulletin of the North Dakota Agricultural Experiment Station for September 1940 (11). This article contains complete information on the results of long-time tests of oats, emmer, flax, barley, and corn varieties. A summary of wheat varieties at the Dickinson substation is contained in the Bimonthly Bulletin for January 1940 (12).

The hazards of crop production in counties such as Billings have been called to the attention of the public in recent years by the occurrence and recurrence of drought, duststorms, grasshoppers, rust, and low prices. Weather data indicate that the recent droughty years are only a part of a cycle of comparatively wet and dry years. Variations in moisture from year to year make it impossible to recommend standard or fixed systems of crop rotation. In fact, flexibility is a prerequisite of a rotation. Again, practices of land use and soil management suitable for the wetter part of the cycle proved to be unsuited or even detrimental for the drier years. Thus, the number of soil types that may be safely cultivated in the wetter years is reduced in the drier years. Practices of management necessarily are changed. For example, summer fallowing was much more successful before than during the recent droughty years. Of course, changes in the structure and organic-matter content of soils, with continued tillage, may be partly responsible, but differences in

climate from year to year also contribute. The following experimental data and recommendations are offered, with the realization that they do not apply to all soil types and in all years.

A common and suitable rotation for this section, according to recommendations of the Northern Great Plains Field Station, is a 3-year rotation of corn, wheat, and oats or barley. As corn seldom occupies as much as one-third of the acreage on most farms, summer fallow should be practiced on the remainder of this one-third. The primary object of including either an intertilled crop or summer fallow in the rotation, in a region of low rainfall where drilled or broadcast small grains occupy an important part of the acreage, is to keep down the growth of weeds and thereby conserve the moisture for the benefit of the crop to follow. For this purpose summer fallow is more efficient than growing intertilled crops, as the growth of weeds is more thoroughly suppressed, the acre cost of tillage is lower, and a moisture reserve is built up to the benefit of the following year's crop, at least during its early stages of growth. The growing of an intertilled crop, however, has the marked advantage of producing a crop during the same season that the weed-control measures are in operation. According to information from the Northern Great Plains Field Station, a rotation including summer fallow followed by wheat yielded 21 bushels of wheat an acre, whereas a rotation including corn followed by wheat yielded 25 bushels of corn, plus forage, and 17 bushels of wheat an acre. Other crops that can be successfully used in this part of the rotation are sorghum and potatoes.

The most satisfactory grasses for the area are crested wheatgrass, western wheatgrass, brome-grass, and slender wheatgrass. Brome-grass tends to become sodbound, and slender wheatgrass is not very long-lived. Sweetclover is used for both hay and pasture. Alfalfa is generally a hay crop that is not suited to grazing. Western wheatgrass is not commonly seeded, but on some of the clay loam soils it frequently reestablishes itself if given an opportunity to do so before the roots of the native sod have been completely killed by tillage. It is the most desirable native grass for hay meadows. Sweetclover is a biennial, but if allowed to develop sufficient seed it will reseed itself, making at least a partial stand in later years. It is suitable for both hay and grazing, but as a hay crop on areas suitable for alfalfa the yields are not so high as those of alfalfa. Sweetclover as a pasture crop is a good supplement to crested wheatgrass, as it affords comparatively good midsummer grazing at a time when crested wheatgrass is dormant.

It should be recognized that deep-rooted legumes, such as alfalfa and sweetclover, draw heavily on the soil moisture. Hence, these crops, especially alfalfa, should be seeded in those areas where sufficient moisture has a chance to accumulate.

Crested wheatgrass, according to Westover and others (14), is especially well adapted to the northern Great Plains, as it is suitable for both hay and pasture and is hardier than alfalfa, alfalfa being a somewhat hazardous crop, owing to its susceptibility to winter killing. Alfalfa, however, is probably the most satisfactory hay crop on the most productive soils, as the yields are much larger than those of crested wheatgrass, and the chances of maintaining a stand on these desirable areas are comparatively good. Crested wheatgrass, however,

is probably the most satisfactory crop for establishing a permanent meadow or a grazing crop on at least the better areas of those unproductive soils that should be removed from tillage. According to Stephens and others (13), it is a very desirable grass for early spring and fall grazing, but it should be supplemented by a pasture crop better adapted to midsummer grazing, such as sweetclover or deferred native pasture, that is, pasture that has not been grazed early in the season, in order to provide grazing for livestock through midsummer when the crested wheatgrass is likely to be injured.

The most satisfactory method of establishing stands of these hay and grazing crops is to prepare the land by summer fallowing or by growing an intertilled crop. Alfalfa and sweetclover are seeded either with or without a nurse crop, but the best stands, according to Stephens and others (13), are obtained where no nurse crop is used. The other hay and pasture crops should be seeded without a nurse crop.

Although these and some other forage plants are of great value to the agriculture of this section, the problem of reestablishing a good grazing crop in places where the native stand of grass has been destroyed by tillage, particularly on the sandy and the less fertile soils has not as yet been solved satisfactorily.

Because of the danger of losing stands of these more permanent hay and grazing crops as a result of winter killing, dry weather, and other hazards, it is necessary to have some annual forage crops on which to rely. Millet, small grains cut before maturity, sorghums, Sudan grass, and corn are the most satisfactory for this purpose.

The stand of native vegetation on many areas, according to observations of cattlemen and investigators, has suffered considerably from overgrazing, particularly during recent years. This practice has either thinned or killed much of the more edible vegetation, and the growth of weeds has increased proportionately. As a result, both the carrying capacity and the quality of the grazing vegetation on such areas has been markedly reduced. Generally, the native vegetation will reestablish itself if grazing is curtailed sufficiently.

Grazing experiments (10) on an area composed predominantly of Williams silt loam and Arnegard silt loam were conducted at the Northern Great Plains Field Station near Mandan, N. Dak., for several years starting with 1915. These trials demonstrated the results of different rates of continuous grazing and a system of deferred and rotation grazing. Two-year-old steers and a 5-month grazing period starting from May 15 to June 1 and continuing to October 15 to November 1 were used. The deferred and rotation system of grazing was designed to allow each division of the pasture to mature a crop for 2 successive years before it was grazed by the cattle in the fall of each year. Grazing on each division was deferred and rotated, so that each unit had an equal chance to produce a maximum crop normally before it was disturbed. Following are some of the conclusions drawn from the results of these experiments as set forth by Sarvis (10, pp. 42-45):

The measure of efficiency of a pasture or system of grazing is not determined by one factor but by several of equal importance. * * *

The most efficient system of grazing is one that will insure sufficient forage during the entire season to produce the greatest total gain in weight with the least number of cattle on the minimum unit of land without permanent injury to the native vegetation. The requirements of this measure of grazing efficiency

are most nearly fulfilled by the deferred and rotation system of grazing. * * *

Native pastures deteriorate when grazed because of (1) too early grazing in the spring, (2) continuous grazing, and (3) overgrazing. All of these factors can be controlled. * * *

* * * The 70-acre pasture, grazed at the rate of one steer to 7 acres, provides approximately the area of land required to produce the maximum gains per head under a system of continuous grazing. The 50-acre pasture, grazed at the rate of one steer to 5 acres, is not large enough to allow the cattle to make maximum gains per head. This pasture is overgrazed. * * * Under a system of deferred and rotation grazing the number of acres required per head is reduced to between 4 and 5. This acreage will provide enough feed to allow the cattle to make gains per head intermediate between those made in the 50-acre pasture and those made in the 70-acre and 100-acre pastures. This system allows the maximum utilization of the vegetation without the injury to it accompanying overgrazing.

MORPHOLOGY AND GENESIS OF SOILS

Soil is the product of forces of weathering and soil development on soil materials deposited or accumulated by geological agencies. The characteristics of the soil at any given point depend on the internal soil climate, native vegetation, composition of the parent material, and the length of time the forces of soil development have acted upon the soil material. Soil climate, in turn, depends on the usual climatic factors of rainfall, temperature, and humidity, and locally it is greatly modified by relief as it affects drainage, aeration, and runoff.

The climatic conditions prevailing throughout Billings County favor the development of dark grayish-brown Pedocals. The average annual precipitation at Fryburg is approximately 16 inches, of which more than four-fifths falls between April 1 and November 1. Freezing conditions prevail within the ground for about 4½ months of the year. Ground moisture very seldom becomes abundant enough to cause complete percolation through the soil, with the consequence that the material at a depth of 3 feet is in a comparatively dry condition most of the time.

The dominant vegetation consists of short grasses with some taller grasses intermixed, and where conditions are particularly favorable the taller grasses dominate the short grasses. The principal species of vegetation on the normal soils are blue grama (*Bouteloua gracilis*), niggerwool (*Carex filifolia*), western wheatgrass (*Agropyron Smithii*), and western needlegrass (*Stipa comata*). Sandgrass (*Calamovilfa longifolia*) is dominant in patches on the sand areas, and little bluestem (*Andropogon scoparius*) is the most common grass on the dry sites of the finer textured soils.

Hanson and Whitman, of the North Dakota Agricultural Experiment Station, made a series of field investigations (3) in which they determined the frequency and percentage of cover of plants for each species of the native vegetation on several important soil types in western North Dakota. The results of their observations are presented in table 7.

Following the tabulation of plants on Patent clay loam, Hanson and Whitman give this summary:

The abundance of *Bouteloua gracilis*, *Agropyron smithii*, and *Carex filifolia*, the scarcity or absence of other grasses, and the fairly low total number (20) of species, were associated with clay loam to clay soil, shallow solum, (14.5 inches), carbonates within 3.5 inches of the surface and a more compact layer at 26 to 47 inches, alkaline reaction throughout, high calcium content, long, gradual slope, and usually, only moderate erosion (3, p. 70).

Following the tabulation of plants on Flasher fine sandy loam, Hanson and Whitman give this summation:¹⁹

The scarcity of *Agropyron smithii*, the presence of *Calamovilfa*, the abundance of *Bouteloua*, *Stipa*, *Koeleria*, *Carex* spp., and forbs; the high number of species (46) appears to be associated with the uniform sandy loam soils, * * * and its freedom from salinity, absence of shallow carbonate layer, and the friable structure and dark-brown color of the well-developed solum which extended to a depth of 20.5 inches. Vegetation development and soil development are apparently nearing maturity. Factors responsible for this development are freedom from continued overgrazing, cultivation, excessive mowing, and serious erosion (3, p. 64).

TABLE 7.—Frequency of native vegetation and percentage of cover on Patent clay loam and Flasher fine sandy loam in western North Dakota

Plants	Patent clay loam ¹		Flasher fine sandy loam ²	
	Frequency X abundance ³	Percentage of cover ⁴	Frequency X abundance ³	Percentage of cover ⁴
<i>Bouteloua gracilis</i>	75	23	95	26
<i>Agropyron smithii</i>	63	35	5	3
<i>Stipa comata</i>	6	3	98	25
<i>Koeleria cristata</i>	1	.....	47	6
<i>Carex filifolia</i>	66	12	49	10
<i>Carex stenophylla</i>	2	6	59	13
<i>Plantago purshii</i>	45	.....	.....	.....
<i>Draba nemorosa</i>	6	.....	.....	.....
<i>Calamagrostis montanensis</i>.....	.....	.....	12	3
<i>Calamovilfa longifolia</i>.....	.....	.....	4	.....
Miscellaneous grasses.....	0	1	3	.....
Miscellaneous forbs.....	16	8	65	10
Bare ground.....	.....	12	.....	4

¹ Golden Valley County, 16 miles southeast of Sentinel Butte.

² Golden Valley County, 10 miles northwest of Sentinel Butte.

³ Frequency X abundance is a measure of the relative number of plants, plant stems, and stalks growing on the area investigated.

⁴ Percentage of cover is a measure of the relative amount of the ground covered by the vegetation of the various species growing on the area investigated.

Trees are confined to the stream valley floors and to the more favorable of the upland draws and coulees. Cottonwood occurs as strips or copse along the Little Missouri River and a very few of its larger tributaries. Ash and elm are the dominant tree growth along the upland draws. Cedar is common on the north-facing slopes and in the draws of the rougher parts of the Badlands.

The parent material consists of sedentary sands, silt, and clay of the Tertiary Fort Union formation and alluvium along the streams and on high benches bordering the Little Missouri Valley. The clay strata of the Fort Union formation are predominantly olive gray. In places layers of gray and yellowish-gray clay and silt are interlain with the olive-gray material. The sand strata are light olive drab. Carbonates are plentiful enough in the material of this formation to cause effervescence when treated with acid.

For the purpose of discussing the morphology of these soils, they have been grouped as follows: (1) Very dark brown or dark grayish-brown and reddish-brown loams and clay loams—Morton, Arnegard, Searing, Farland, Cheyenne, and Grail soils; (2) grayish-brown and brownish-gray loams and clay loams—Bainville, Patent, and Cherry soils; (3) grayish-brown sandy soils—Flasher and Huff soils; (4) light-colored soils of the first bottoms—Banks, Havre, alluvial loam

¹⁹ Flasher fine sandy loam was formerly called Morton fine sandy loam and is so named by Hanson and Whitman (3).

soils, undifferentiated, and alluvial clay soils, undifferentiated; and (5) soils abnormal because of salt or sodium influence—Moline, Rhoades, McKenzie, Wade, and Sage soils.

The important characteristics of the Chestnut soils (6, 9) as they occur in Billings County are a slightly eluviated layer, 2 or 3 inches thick, underlain by a dark grayish-brown layer having a well-developed prismatic structure, carbonates sufficient to cause effervescence when the soil material from a depth of about 12 inches is treated with acid, and a visible accumulation of carbonates at a depth of about 18 inches (pl. 7, A). Comparatively unaltered parent material lies at a depth of about 28 inches.

The Morton soils occur on the sedentary silt and clay strata of the Fort Union formation. Following is a description of an average profile of Morton loam, as observed in an exposure of this soil in the SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 26, T. 139 N., R. 100 W.:

- 0 to $\frac{3}{4}$ inch, grayish-brown silt loam that shakes easily from the grass-root mat as soft fine aggregates.
- $\frac{3}{4}$ to 1 $\frac{1}{4}$ inches, dark grayish-brown silt loam that breaks with some brittleness into friable subangular fragments. This layer is not so firmly bound by grass roots as the layer above.
- 1 $\frac{1}{4}$ to 5 $\frac{1}{2}$ inches, dark grayish-brown silt loam. This is the darkest colored layer of the solum. It has a well-defined prismatic structure. The prisms are from $\frac{3}{4}$ to 1 $\frac{1}{2}$ inches in diameter and break from each other readily. These prisms break horizontally with a comparatively smooth surface into nut-sized fragments. The fragments are held together by grass roots that extend vertically through the prisms. Although the fragments are firm, they break with a brittleness into a soft fine-grained mealy mass. The unbroken pieces have a visible vesicular character.
- 5 $\frac{1}{2}$ to 11 inches, dark grayish-brown, grading with depth into lighter grayish-brown silt loam. The structure is similar to that of the layer above except that the prisms are a little larger and the fragments tend to break into smaller pieces rather than into a mealy mass. As with the layer above, the pieces of prisms are held together by grass roots after the prisms have been broken horizontally. The unbroken pieces have a visible vesicular character. Effervescence occurs at a depth of about 11 inches when the mass is treated with an acid.
- 11 to 15 inches, dingy buff-colored soft loam containing a few white salt flecks. The vertical structure is still evident, but the prisms are ill defined and the horizontal breakage is not prominent. The mass does not have the firm brittleness of that in the two layers above. The fragments are soft and, though definite, are easily crushed into a fine-grained mass.
- 15 to 28 inches, grayish-yellow soft silt loam that has practically no vertical structure below a depth of 18 inches. The material contains numerous white salt flecks and salt crystals.
- 28 to 33 inches, yellowish-gray or light creamy-buff soft silt that comes from place in irregular soft chunks that are easily crushed to a fine-grained mass. There are some white salt flecks and crystals throughout this layer. The material below a depth of 28 inches in some areas is sandy rather than silty, this feature varying according to the character of the parent material.

The Arnegard soils represent areas in the Morton soils that have developed a darker color because of more favorable water relations for plant growth and consequent accumulation of organic matter. They occur in depressions that have benefited from the runoff of the immediately surrounding upland areas but are well enough drained internally to prevent the accumulation of salts. The color profile, to a depth of 12 to 14 inches, is dark grayish brown to very dark grayish brown and suggests that of a soil occurring only under a more moist climate. In general, the Arnegard soils as mapped in Billings County are not so dark as the Arnegard soils mapped on the glacial till in McKenzie County, and the dark color does not extend to so great a

depth. The structural profile of the Arnegard soil is similar to that of Morton loam.

The Searing series represents the reddish-brown soils developed principally from scoria. The reddish-brown color is inherited from the parent material. The prismatic structure is not so well defined in this soil as in Morton loam, and scoria beds lie at a depth ranging from 18 to 28 inches.

The Farland series represents the dark grayish-brown or brown soils developed on the older terraces or benches along the streams. The solum is very similar to that of the Morton soils.

The Cheyenne series represents mature dark grayish-brown or brown soils developed on gravelly and sandy alluvium. The profile characteristics are similar to those of Morton loam. Visible accumulation of salts is frequently markedly evident on the surface of the stones at the upper edge of the gravel stratum and the lower edge of the solum.

The Grail series represents the dark grayish-brown soils developed on the gentle alluvial slopes of the valleys. The origin and position of these soils are similar to those of the Patent series. The latter are lighter colored, do not have such well-developed structure, and consequently appear to be less mature soils. Following is a description of a profile of Grail silty clay loam as observed in an exposure in the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 17, T. 139 N., R. 100 W.:

- 0 to 2 inches, dark grayish-brown floury silt loam. The material falls from the root mat as a fine-grained mass.
- 2 to 5 inches, dark grayish-brown heavy silt loam that has a fairly well developed prismatic structure. The prisms are not so inclined to break apart either vertically or horizontally as they are in such soils as Morton loam. The fragments are firm but crush easily into a mealy mass.
- 5 to 14 inches, the darkest layer of the solum, the color approaching very dark grayish brown. The prisms break apart readily and have a roughly horizontal cleavage. The unbroken fragments are somewhat vesicular. The roots in this layer have a pronounced vertical arrangement and tend to hold the prism fragments together after they have been broken horizontally. The fragments range from $\frac{1}{2}$ to 1 inch in diameter and crush fairly easily into minute fragments. They are less inclined, however, to crush into a mealy or floury mass than are the fragments of the corresponding layer in Morton loam.
- 14 to 21 inches, olive-brown or dingy yellowish-brown silty clay. This layer has a definite vertical structure, but the prisms are not quite so easily fractured into the nut-sized fragments as are those in the layer above.
- 21 to 32 inches, similar to the layer above except that the fragments are harder. Effervescence when the mass is treated with acid occurs at a depth of about 30 inches.
- 32 to 38 inches, olive-gray or olive-drab silty clay containing numerous salt flecks. The mass breaks into firm, almost angular fragments that are very resistant to pressure.

The grayish-brown and brownish-gray loams differ basically from the soils of the first group in having a much less mature profile. This comparison is based on the facts that (1) the amount of organic matter accumulated and the depth to which it extends in the solum as indicated by the color are much less; (2) the prismatic structure is not so strikingly developed; and (3) the depth to carbonates or salts is, as indicated by effervescence with acid, much less in the soils of this group.

The Bainville series includes the grayish-brown soils developed on sedentary silt and clay beds of the Fort Union formation. Their position, compared with that of the Morton soils, is generally on noticeably drier sites, such as knobs and exposed slopes. Following

is a description of a profile of an exposure of Bainville loam, as observed within an area of Bainville loam, hilly phase, in the NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 36, T. 143 N., R. 100 W.:

- 0 to 1½ inches, grayish-brown silt loam, firmly bound in place by a mat of niggerwool and selaginella roots. When the root mat is shaken, the soil material falls away as soft fine particles.
- 1½ to 5½ inches, dark grayish-brown silt loam that breaks into definite sub-angular fragments ¼ to 1 inch in diameter. They break with a little brittleness but are comparatively easily crushed into a mealy or floury mass. The fragments show very little indication of vertical breakage or cleavage.
- 5½ to 8½ inches, brownish-yellow silt loam that comes from place in indefinite soft chunks that crush very easily. The material in this layer and in those below effervesces when treated with acid.
- 8½ to 12 inches, brownish-gray (olive-yellow when wet) silt loam with an abundance of white flecks. The mass breaks into irregular easily crushed pieces.
- 12 to 28 inches, similar to the layer above except that the fragments are a little firmer and at about this depth take on the characteristics of the comparatively unaltered underlying geologic material.

Generally the surface layers of Bainville clay loam are lighter colored than those of Bainville loam, and carbonates sufficient to cause effervescence with an acid are near or even at the surface.

The position and parent material of the soils of the Patent series are similar to those of the Grail series. Following is a description of a profile of Patent clay loam as observed in an exposure within an area of Patent clay loam, slope phase, in the NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 17, T. 142 N., R. 101 W.:

- 0 to 1½ inches, gray clay loam having a fairly well defined platy structure. (Platiness is not everywhere evident in this layer.)
- 1½ to 8 inches, dark-gray or brownish-gray friable clay loam having a fairly well developed prismatic structure. The prism pieces break easily into fine fragments that crush readily into a mealy mass. The uncrushed mass has a slightly vesicular character.
- 8 to 12 inches. The brownish-gray color grades into lighter shades through this layer. The structure is similar to that of the layer above.
- 12 to 16 inches, olive-drab clay loam. The vertical structure continues through this layer, but the mass breaks into coarser, more angular pieces. The material is friable, however, and has a slightly vesicular character.
- 16 to 21 inches, light yellowish-gray clay loam with numerous white mottlings, showing some vertical structure.
- 21 to 30 inches, dark olive-drab clay that breaks easily into chunks that are more angular and firmer than in the layer above and contains a considerable amount of carbonates. The material shows a very slight vertical structure.
- 30 to 38 inches, light-gray and olive-drab soft almost structureless silt. This material is laminated and appears as practically unaltered parent material.

This soil reacts with acid throughout the entire profile, violent reaction taking place below a depth of 16 inches. Some small tracts of this soil have a well-developed prismatic structure, whereas at the other extreme, are numerous areas in which the structure is markedly weaker than in the profile from which the above description was taken. Many areas included in the Patent silt loam, especially those having a very fine sandy loam texture to a depth of 6 to 8 inches, have a light-brown to grayish-brown color approaching that of the surface layers of Morton loam. These areas generally show at least a faintly developed prismatic structure. Any darker graduations of Patent clay loam are generally toward the very dark grayish brown of the Grail soils.

The Cherry soils are on alluvial benches. Relative to adjoining first-bottom lands, these benches lie about as do the benches on which the Farland soils occur. All the Cherry soils, however, are confined to the Badlands of the Little Missouri River, whereas most of the areas of the Farland soils are on the comparatively older relief, that is, on the eastern upland. Cherry clay loam is similar to Patent clay loam except that it generally has a better defined prismatic structure. Effervescence with acid occurs throughout the entire soil mass, as it generally does with Patent clay loam. The Cherry soils in few places, if anywhere, show indications of development of a claypan. This statement applies, with but few exceptions, to all soils of the Badlands except those on the few high ridges that are remnants of the terrain that existed previous to the cutting of the Little Missouri River Valley.

The group of grayish-brown sandy soils includes all sandy soils except those of the first-bottom lands. The Flasher series includes those soils developed from sedentary sand beds of the Fort Union geologic formation. The smoother, less eroded areas are characterized by a grayish-brown to dark grayish-brown color that extends to a depth ranging from 12 to 18 inches, a chunky rather than prismatic structure, and a lack of carbonates sufficient to cause effervescence to a depth greater than that of the Morton soils. Because of their greater susceptibility to soil blowing, the exposed parts have a markedly shallow solum, and carbonates sufficient to cause effervescence are at or very near the surface. The finer textured areas of Flasher fine sandy loam resemble Morton loam particularly in regard to color and structure. The average of the type, however, has a distinctly brittle fragmentary structure rather than the friable prismatic structure of Morton loam.

Table 8 gives the results of mechanical analyses of samples of the surface, subsurface, and subsoil layers of Flasher fine sandy loam.

TABLE 8.—*Mechanical analyses of Flasher fine sandy loam*

Sample No.	Depth	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay
		Percent	Percent	Percent	Percent	Percent	Percent	Percent
352164.....	<i>Inches</i> 0-1½	1.1	2.4	13.6	28.8	8.9	25.7	19.5
352165.....	1½-4	.3	1.2	13.9	31.2	9.4	24.3	19.9
352166.....	4-7	.5	1.1	14.9	33.6	8.9	20.8	20.1
352167.....	7-16	.5	1.2	17.3	36.3	9.0	15.7	19.9
352168.....	16-24	1.2	1.4	13.5	43.0	8.6	13.5	18.8
352169.....	24-32	4.9	2.7	17.8	40.8	7.6	9.7	16.5

Flasher loamy fine sand has little definite structure, the material below a depth of 6 or 8 inches coming out, when dug, as soft chunks or lumps.

The Huff series represents the sandy soils that occupy the alluvial fans and natural levees and have carbonates sufficient to cause effervescence at or within a few inches of the surface. Their color averages lighter than that of the Flasher soils, and ordinarily they are associated with the Cherry soils. A few areas, however, in the eastern uplands are somewhat darker colored and are free of abundant carbonates to a depth of 12 inches or more. These darker areas of the eastern uplands are terrace or bench correlatives of Flasher fine sandy loam,

but because of their inextensive acreage and similarity of agricultural use they are included in this county with the Huff soils.

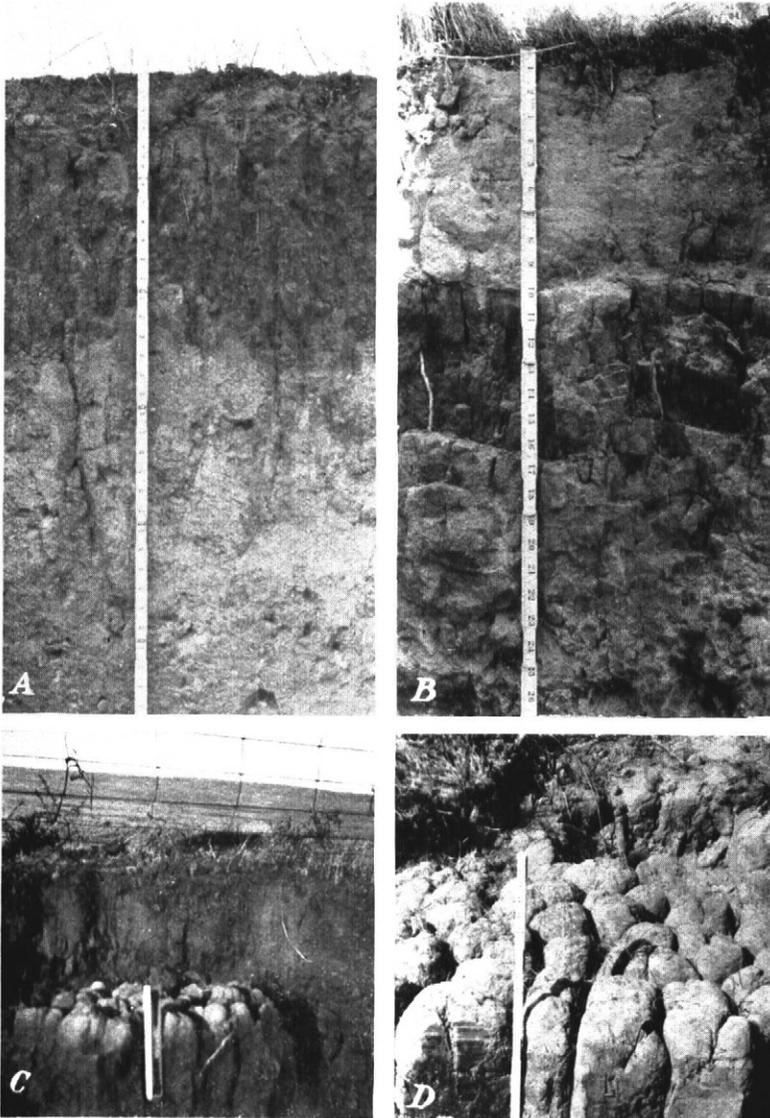
The light-colored soils of the first bottoms are the youngest soils as regards profile development. Soils of the Banks and Havre series occur on the bottom lands along the largest streams, principally along the Little Missouri River. The Banks soils are the more extensive of the two. These soils are developed largely from sandy material. The clay loam member is a distinctly gray soil and has no definite soil structure, although some organic matter has accumulated in the surface soil in some places. Light-colored loose sand lies from 4 to 12 inches below the surface. Effervescence with acid occurs throughout the entire soil mass. The other two sandy members of this series, especially Banks very fine sandy loam, have a grayish-brown to light grayish-brown color to a depth of about 10 inches. Below this layer is loose light-colored sand. Effervescence takes place at or within a few inches of the surface. Except for their position, these two sandy soils resemble the Huff soils. In general the color is lighter and the average structure is less well defined than those of the Huff soils.

The Havre soils differ from the Banks soils in having silty clay material to a depth of at least 20 inches. The surface material is similar to that of Banks silty clay. In many places the clay below a depth of 4 or 5 inches has a schistoselike structure, the mass breaking up readily into dark-gray angular well-defined flattened fragments that are resistant to pulverization. This structure is inherited from deposition of the material in quiet water. The entire soil mass effervesces when treated with acid.

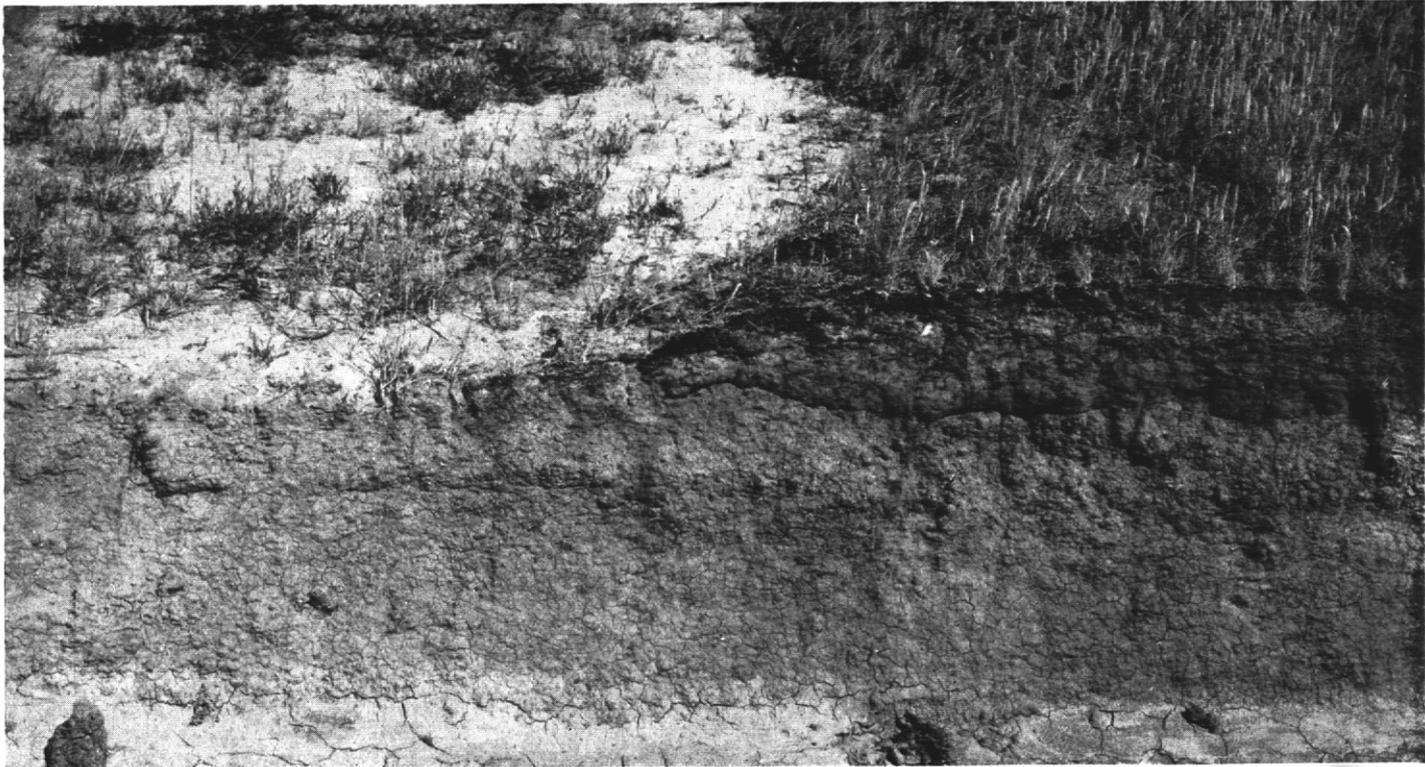
The undifferentiated alluvial soils are composed for the most part of variable and comparatively recent alluvial deposits and small irregular included tracts of the more mature soils developed on terraces or benches. Only a weak and irregular color profile is developed, and most of the material shows a definite reaction with carbonates when treated with an acid. Salt or alkali accumulation, however, has taken place locally where poor drainage or seepage has favored such a process. It is noticeable that the undifferentiated alluvial soils are younger in the Badlands than in the eastern uplands. Those of the Badlands have, on the average, grayer surface soils, and the grass vegetation is less well established. The areas of these soils in the Badlands also average coarser in texture and have, on the average, drier sites. This latter feature is due, evidently, to the generally coarser texture, the steeper gradient of the drains, the greater depth of the drain gorges or channels that dissect the alluvial areas, and the less constant flow of water through these drains. Although edible grasses are not abundant and the flow of water for the most part is intermittent in the drainageways of the Badlands, grass is abundant and the flow of water is fairly constant, especially in the large drains or creeks of the eastern uplands.

Considerable areas of soils in this county are or have been more or less affected by salts. These soils are included in the Moline, Rhoades, Wade, McKenzie, and Sage series. They are in positions that allow, or did allow at one time, the movement of salt-laden water into the soil.

According to the general scheme of evolution of Solonchak, Solonetz, and Soloth soils (5), the development of the Moline, Rhoades, and Wade soils has been dominated by salt-laden capillary water, and



A, Characteristic profile of normal Chestnut soil, like the Farland or Mcaton. Note grass roots and platy structure of the topmost 3 inches, prismatic structure of the main body of dark soil, and zone of accumulated lime below. *B*, Characteristic profile of solodized-Solonetz soil, like the Rhoades. Note the platy light-colored surface soil over dark heavy columnar material. *C*, Columnar soil in the B horizon of solodized-Solonetz. *D*, Close-up view of columns.



Boundary of clay spot and interspot area showing erosion of surface horizon above the columnar claypan

the development of the Sage and McKenzie soils has been dominated by salt-laden floodwaters. The most common locations of those soils influenced predominantly by capillary water are on broad benches along streams or on gentle valley and upland slopes. Most of those developed under the influence of flooding by saline water are on old pond sites or alluvial fans.

All the soils developed under the influence of salt-laden capillary water present an extremely spotted or pocked appearance—a condition that is due partly to differences in the amounts of salt intrusion and removal and partly to differential wind and water erosion of the eluviated surface layers.

The Solonchak represents the first stage in the development of the Solonchak-Solonetz-Soloth evolution. The process under which the Solonchak develops is salinization in which excess soluble salts, some of which generally are sodium salts, accumulate. Solonchak soils are characterized by their lack of a definite structure and profile differentiation.

If drainage conditions improve, the excess soluble salts are removed, and the sodium ions will usually be sufficient to dominate the colloids so that they become dispersed. The soil becomes highly alkaline through hydrolysis of the exchangeable sodium to sodium hydroxide. Organic matter becomes dispersed and distributed over the other soil particles. Dense columnar structure, high alkalinity, and low content of soluble salts characterize the Solonetz soils, and the processes involved are desalinization and alkalization, collectively called solonization.

As soon as the colloids become dispersed they tend to move downward to produce surface horizons lighter in color and lower in clay content. This process is known as solodization and leads to the development of the Soloth. Actually most of the so-called Solonetz, or claypan, soils described in this report are solodized-Solonetz soils and have a platy friable and nearly white surface overlying the dense intractable columns forming the claypan. Figure 4 illustrates the development of these different types of intrazonal soils.

As stated above, the dominant condition found in the group of salt- or sodium-influenced soils, or soils developed under imperfect drainage conditions, is that in which an extremely spotted solodized-Solonetz complex has developed. The clay spots, which are irregular in shape, occur as slight depressions ranging from 4 to 12 inches below the general surface of the area about them and are from 2 to 20 feet in diameter. They appear to be eroded patches and have an incomplete profile (pl. 8). The zonal soil and also the solodized-Solonetz soil may occupy the area between the clay spots (pl. 7, B). Plate 7, C and D, illustrates the columnar structure that is a dominant feature of solodized-Solonetz soils.

Following is a description of a profile of an exposure of Moline loam observed in the NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 1, T. 137 N., R. 100 W. and included in an area of Moline clay loam complex. This description is that of the solodized-Solonetz part, which represents the interspot areas or the areas between the clay spots.

0 to 1½ inches, light grayish-brown very fine sandy loam. When the mass is put under stress, the soft soil aggregates fall away from the grass roots readily.

1½ to 3 inches, yellowish-brown very fine sandy loam. This is the material directly below the root mat. The mass breaks into somewhat firm

- blocks that are easily crushed. Close examination shows a well-defined platy structure, the platelets being about one-fiftieth of an inch thick and about one-tenth of an inch in diameter. The mass breaks with a noticeable horizontal cleavage.
- 3 to 7 inches, heavy loam, grayish brown when crushed and yellowish brown when moist. The mass breaks into firm blocky fragments. The color of this layer is actually a very fine mottling of gray and dark brown. Platiness is not recognizable in this layer, but the material is noticeably vesicular.
- 7 to 10 inches. The material in this layer breaks sharply and easily from the layer above. A gray powdery filmlike layer, a small fraction of an inch thick, lies at the point of breakage. The body of this layer is composed of dark-brown to very dark brown columns about 1 inch in diameter. They are extremely hard and break from one another readily along well-defined cleavage lines. The top surfaces are well-defined rounded surfaces, to which a part of the white film clings. The upper one-half inch of the columns is noticeably more gray than is the main part of the columns. The very dark brown color reaches its maximum about 1 inch below the tops of the columns, and the color begins to fade about 2 inches below the tops of the columns. The columns break easily into hard, angular, somewhat cubelike fragments. The upper 1½-inch part does not break apart so readily into the cubelike fragments as does the lower part of this layer. The entire layer is noticeably dense, no vesicular character being recognizable.
- 10 to 13 inches, dark yellowish-brown hard columnar clay that falls apart readily into cubelike fragments. This material is similar to the main body of the layer above except for the lighter color.
- 13 to 20 inches, dark olive-brown clay with whitish-gray and yellowish-gray salt flecks. The material has a definite vertical structure and breaks into angular pieces that are not so resistant to pressure as are those of the two overlying layers. The material of this layer effervesces profusely when it is treated with acid, but no reaction takes place with the material of the layers above.
- 20 to 25 inches, dark-gray clay containing numerous strikingly white salt flecks. The mass breaks into angular fragments one-half inch in diameter that are fairly easily crushed. This material shows no definite vertical cleavage.

Following is a description of the profile of the eroded clay spots that are associated with the solodized-Solonetz soil described above.

- 0 to ½ inch, gray very fine sand crust. The material is brittle and extremely vesicular or pumicellike, many of the bubblelike cavities being about one-fiftieth of an inch in diameter.
- ½ to 2 inches, dark olive-brown hard clay, which may be considered either a remnant of the old claypan layer or the beginning of a new one. The mass breaks into fine, hard irregular-shaped fragments and contains fine vertical cracks about one-quarter of an inch apart, but they are not so completely developed as to cause the mass to break readily, or even easily, along them. The breakage between this layer and the surface crust is well defined, the crust cracking away easily. The surface of this hard layer is smooth, with the surface corners of the fragments noticeably rounded.
- 2 to 5 inches, brown fairly hard clay that breaks easily into angular fragments.
- 5 to 14 inches, dingy-brown clay with some salt flecks. The mass breaks into hard angular fragments. Some effervescence occurs when the material is treated with acid, whereas the layers above show no reaction with acid.
- 14 to 20 inches, dark-gray clay with many white salt flecks and a few ferruginous fragments. The mass breaks easily into angular fragments that are fairly easily crushed.
- 20 to 30 inches, the comparatively unaltered parent material. It is gray clayey material with some yellowish-gray lenses and some thin dark lignitic layers. It contains no noticeable quantity of salt flecks.
- All the material below a depth of 5 inches effervesces when treated with acid.

The solonized part of the first profile described is that part between depths of 7 and 13 inches. The material above a depth of 7 inches has been solodized or eluviated to a marked degree, the most striking evidence of eluviation being in the layer between depths of $1\frac{1}{2}$ and 3 inches.

A solodized-Solonetz-Solonchak complex occurs in some areas of Wade-Farland silty clay loams and Moline clay loam. This complex has a spotted condition similar in outward appearance to that of the solodized-Solonetz complex. The microrelief of the former is apparently due to differential erosion of the solodized or eluviated layer, whereas the microrelief of the latter is due to the development of salinized or puff spots. These salinized spots are sharply outlined partly or wholly bare low hummocks or billows rising from 4 to 10 inches above the surrounding solonized areas. These so-called puff spots are composed of salinized material and represent a condition in which the soil in these spots is being subjected to the accumulation of soluble salts. The interspot soil of this complex is similar to that of the interspot areas of the solodized-Solonetz complex except that the process of eluviation is not so well defined and the areas occupy the lower rather than the higher parts of the microrelief. Following is a description of Moline clay loam as observed in NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 14, T. 140 N., R. 100 W. The first description is of a soil in a salinized spot.

- 0 to $\frac{1}{4}$ inch, light-gray (olive-gray when wet) crusty silt or very fine sandy loam. It is noticeably vesicular or pumicelike, crushes to a powder easily, and effervesces explosively when treated with acid.
- $\frac{1}{4}$ to 2 inches, light grayish-brown silty clay loam having a fairly well defined platy structure and a noticeable vertical cleavage. The cracks are about one-third of an inch apart. The pieces are angular, sharply defined, and fairly brittle. When the pieces are crushed they break into fairly definite small platy or flattened pieces. The mass is somewhat vesicular. Very little effervescence occurs in the upper part of this layer, and none appears in the lower half.
- 2 to $6\frac{1}{2}$ inches, olive grayish-brown soft friable moist clay with a great abundance of small salt crystals. These crystals have the appearance of frost. The mass crumbles easily into fine subangular fragments that are fairly easily crushed. The heaviest salt accumulation is between $4\frac{1}{2}$ and $6\frac{1}{2}$ inches below the surface. Acid reacts explosively with the material of this layer, as well as with the material of the layers below.
- $6\frac{1}{2}$ to 10 inches, brown moist mealy clay with numerous chalky salt flecks. The mass crushes into a semiplastic condition. It is noticeably more gray after being crushed than when in an undisturbed condition.
- 10 to 30 inches, brown moist mealy clay with dingy salt flecks and some white flecks. Salt accumulation is less prominent than in the layer above. The color gradually becomes more gray with depth. The concentration of the salts varies in intensity as the salts occur in weakly defined horizontal bands or lenses.
- 30 to 47 inches, olive-drab moist amorphous silty clay with some white flecks. Instead of being mealy, this material is inclined to be plastic when crushed.

The description of the profile that follows is of the solodized-Solonetz soil of the depressed areas between the salinized spots:

- 0 to 2 inches, strikingly platy gray silt loam that powders easily. This material effervesces somewhat when treated with acid.
- 2 to 5 inches, dark brownish-gray hard clay having a platy structure. The mass breaks into platy lumps under pressure. This platiness is not so well defined as it is in the layer above.

- 5 to 8 inches, the color is possibly a little darker; the structure is hard, the lumps breaking only under firm pressure; the material shows a definite vertical structure but is not distinctly dispersed.
- 8 to 13 inches, the solonized layer. The material is dark grayish-brown hard dense clay. The mass is very difficult to break apart. It shows no well-defined columnar structure or column caps. The change from the layer above to this layer is a gradation rather than a sharp change. The densest part of the layer is between depths of 9 and about 14 inches. No salt flecks are in this layer, and the material does not react with acid.
- 13 to 15 inches, dark grayish-brown fairly hard clay with numerous dingy salt flecks distributed through it. The mass breaks into angular fragments from $\frac{1}{2}$ to 1 inch in diameter. White carbonate flecks are throughout this layer and in the material below it.
- 15 inches + The material grades within a few inches into material similar to that occurring below a depth of 30 inches in the salinized profile.

Soils of three series are included in the solodized-Solonetz complexes, the characteristics differentiating between them being their physiographic positions. The soils of the Moline series are the most common. Their surface layers are grayish brown or brownish gray, and they occupy gentle alluvial slopes. The Rhoades series includes grayish-brown to dark grayish-brown solodized-Solonetz soils developed on sedentary silt and clay beds of the Fort Union geologic formation. The Wade series includes solodized-Solonetz soils developed on the alluvial flats or benches. The color of the surface layers of the Wade soils is dark to very dark grayish brown.

The soils of the McKenzie series have solonized profiles in which little or no solodization has taken place. Unlike the complexes just described, these soils are uniformly developed and do not contain claypan in spots. They are essentially dark, hard, dense soils developed on sites of former ponds in the eastern uplands. Following is a description of a profile of McKenzie clay as observed in the NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 15, T. 142 N., R. 100 W.:

- 0 to $1\frac{1}{4}$ inches, dark-gray hard clay, which comes from place in small sharp angular fragments. This material is more easily crushed than is that of the layers below. It does not effervesce when treated with hydrochloric acid.
- $1\frac{1}{4}$ to 13 inches, dark-gray or gun-metal-colored hard clay. The material in this layer shows vertical cleavage, the cracks being from 3 to 12 inches apart. The chunks are very resistant to pressure and when forced apart break into smaller hard, angular pieces. Fine lighter colored material has sifted down from the layer above and has covered the surface of many of the fragments along the cracks. Freshly made cracks expose surfaces that have a glossy sheen. None of the material of this layer effervesces when treated with acid.
- 13 to 23 inches, very dark gray to nearly black hard dense clay similar in structure to the material above. The vertical cracks do not occur within this layer. There are a few white salt flecks in this layer, and the material effervesces when treated with acid.
- 23 to 28 inches, material similar to that in the layer above except that the mass breaks more easily into small hard angular pieces.
- 28 to 40 inches, dark-gray material with an olive cast, containing numerous dingy-white carbonate flecks. This material is hard when dry, but in its normal condition it is generally at least moist. The material becomes lighter colored with depth. It effervesces abundantly with acid.
- 40 to 58 inches, dark olive-drab clay with numerous dingy-gray salt flecks. Dark-brown mottlings occur, especially in the lower part of this layer. The material effervesces abundantly when treated with acid.

Alluvial soils, undifferentiated, also are affected by salt in places and strongly salinized areas are common. These areas have a nearly

white crust of salt efflorescences a fraction of an inch thick, below which is dingy olive-gray moist clay containing an abundance of salt crystals. Saltgrass and seepweed are the only plants growing on such areas. Other spots or areas of this soil have a slightly gray siliceous crust a fraction of an inch thick. This crust when dry is pumicelike in that it has an abundance of air bubbles in it. Below this layer there is generally fairly hard gray clay to a depth of a few inches, below which is moist friable clay containing an abundance of salt crystals and flecks. Less salty areas of this soil are dingy dark-gray moist plastic clay. The best growths of vegetation, principally lowland sedges, occupy these areas. These salinized areas have gained their excess salts through the effects of flooding by saline waters, whereas the salinized complex associated with the claypan soils has evidently gained its excess of salts primarily through capillary action of saline water.

SUMMARY

Billings County is situated slightly east and south of the middle of the North Dakota-Montana boundary line and forms a part of the Missouri Plateau, locally designated as the Missouri slope. The Little Missouri River flows from south to north through the western part of the county. It occupies a fairly deep gorgelike valley that is bounded on the east and west by belts of rough country, each from 12 to 20 miles wide, that are together known as the Little Missouri Badlands. East of the Badlands the Missouri Plateau proper forms a gently rolling upland plain. The underlying Fort Union geologic formation of the Tertiary period is composed of strata of olive-drab, yellow, and ash-gray shale, sandstone, and clay, with numerous beds of lignite interspersed.

The climate is temperate and semiarid. The dominant native vegetation, except on the alluvial soils of the Little Missouri River Valley and a few of the northward-facing slopes of the Badlands, consists of short grasses with some taller grasses intermixed. Cottonwood constitutes a large proportion of the native vegetation on the alluvial soils, and western redcedar grows on the north slopes of the Badlands.

Chestnut soils, having a well-developed prismatic structure, have developed on the smooth well-drained areas. Solodized-Solonetz soils occur in intimate association with the Chestnut soils on the areas that are or have been affected with salt-laden waters.

Variations in color of the surface soil, depth to carbonates, structure, parent material, topography, and topographic position give rise to 18 soil series and 65 soil-mapping units. The principal soils are those of the Morton, Bainville, Flasher, Patent, Rhoades, Moline, Farland, and Cherry series. The Rhoades, Moline, and Wade soils are mapped as members of soil complexes.

Much of the acreage of the Chestnut soils is devoted to cash grain crops, principally wheat, with the remaining part devoted to the production of feed crops and grazing.

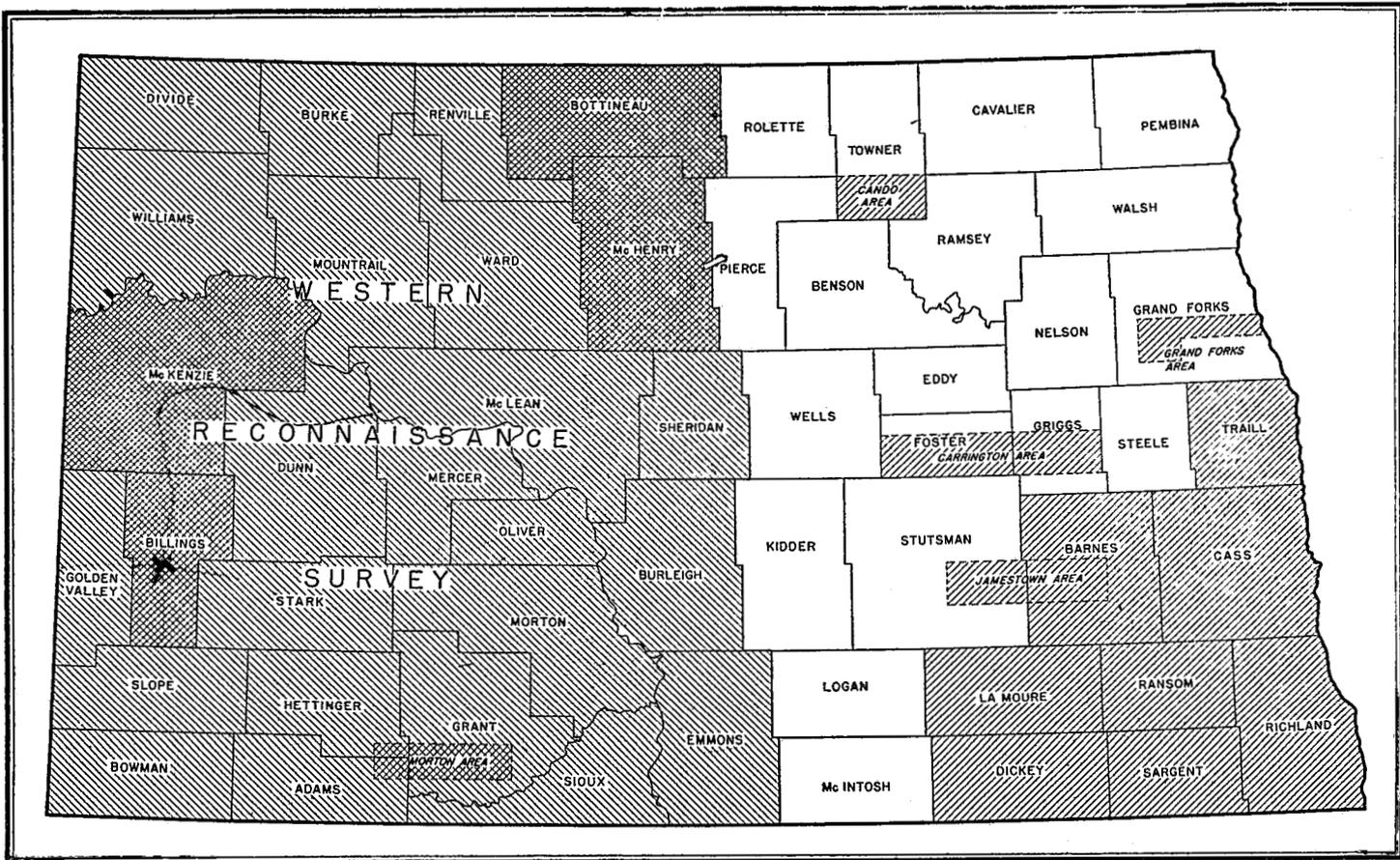
Because of the narrow margin between the amount of precipitation received and the amount necessary to produce a profitable grain crop, augmented by other crop hazards common to this section, cash grain farming offers an extremely variable and hazardous source of income.

The extensive rough areas constituting the Little Missouri Badlands are devoted almost wholly to raising beef cattle, sheep, and horses. The inability to produce a plentiful supply of feed and to regulate grazing have been distressing factors to producers of meat animals.

The trend of agriculture has been toward an increased acreage of cash crops and a stabilized production of meat animals. Recent drought years have seen a tendency for the less productive and less accessible areas to revert to grazing land.

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Areas surveyed in North Dakota shown by shading. Detailed surveys shown by northeast-southwest hatching; reconnaissance surveys shown by northwest-southeast hatching; cross-hatching indicates areas surveyed in both ways.

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To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at http://www.ascr.usda.gov/complaint_filing_cust.html and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by:

- (1) mail: U.S. Department of Agriculture
Office of the Assistant Secretary for Civil Rights
1400 Independence Avenue, SW
Washington, D.C. 20250-9410;
- (2) fax: (202) 690-7442; or
- (3) email: program.intake@usda.gov.

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