Series 1933, No. 25 Issued April 1939

Soil Survey

(Reconnaissance)

The Red River Valley Area Minnesota

By
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SOIL SURVEY (RECONNAISSANCE) OF THE RED RIVER VALLEY AREA, MINNESOTA

By C. C. NIKIFOROFF,[1] in Charge, A. H. HASTY, G. A. SWENSON, and A. L. GRAY, Bureau of Chemistry and Soils, and E. A. FIEGER, SAM HILL, H. C. NEWMAN, C. H. MATTSON, J. C. HIDE, and ERIC KNEEN, University of Minnesota [2]

AREA SURVEYED

The Red River, which separates Minnesota from North Dakota, is formed by the confluence at Breckenridge of Bois de Sioux and Otter Tail Rivers. Bois de Sioux River is the outlet of Lake Traverse, the northern end of which is about 30 miles south of Breckenridge. This sluggish prairie stream has the same general course south of Breckenridge as that of Red River north of Breckenridge. Red River flows almost due north and empties into Lake Winnipeg, 285 miles north of Breckenridge. It occupies the axial depression of a vast plain which ranges from 40 to 50 miles wide in its southern part and is about 300 miles long, extending from Lake Traverse to Lake Winnipeg. This expanse, widely famed for its productive soils, is commonly called Red River Valley. The area is divided among the States of Minnesota and North Dakota and the Canadian Province of Manitoba. That part of it situated in Minnesota occupies the northwestern corner of the State (fig. 1).

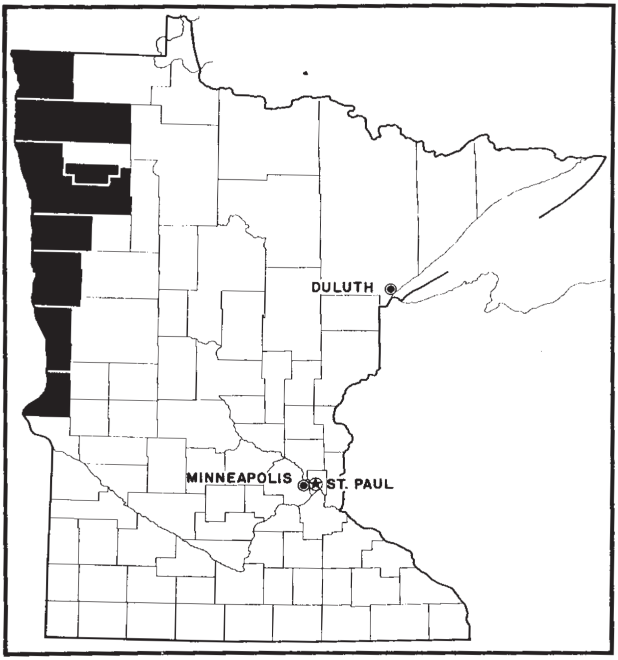

FIGURE 1.—Sketch map showing location of the Red River Valley area, Minn.

[1] This project was initiated while the senior author was assistant professor of soils at the University of Minnesota.
[2] P. R. McMiller, of the University of Minnesota, also assisted the field party.

The area surveyed comprises Kittson, Marshall, Red Lake, Polk, Norman, Clay, Wilkin, and Traverse Counties. All eight counties lie in the northern section of the extreme western tier of counties in Minnesota. The area extends about 232 miles in a north and south direction and ranges in width from about 14 miles in the southern part of Wilkin County to 72 miles in Marshall County. It covers 8,544 square miles, divided among the eight counties as follows:

Kittson County occupies 1,111 square miles. It is nearly rectangular, the distance from north to south being a little more than 31.5 miles and that from east to west ranging from 37.5 to 32.5 miles.

Marshall County comprises 1,788 square miles. This also is approximately rectangular, with a length from east to west of about 72 miles and a width from north to south of 25.5 miles.

Polk County comprises 1,979 square miles, and Red Lake County 432 square miles. As Red Lake County is surrounded on three sides by Polk County, the maps of the two counties are published as a unit. The combined area of the two extends from north to south for 42 miles, and its east-west dimension ranges from 72 to about 61 miles.

Norman County, comprising 878 square miles, is roughly rectangular, with a length from east to west of 36 or 37 miles and a width from north to south of 24 miles.

Clay County comprises 1,043 square miles, its east and west dimension being about 30 miles and its north and south dimension 36 miles.

Wilkin County occupies an area of 745 square miles. It extends from north to south for 42 miles and ranges in width from 24 to 14 miles.

Traverse County comprises 568 square miles. Like Wilkin County, it is rather irregular in shape, its north-south dimension being 30 miles and its width from east to west ranging from 15 to 29 miles.

By far the greater part of the entire area lies within the borders of the territory occupied in the past by the great lake known as glacial Lake Agassiz. The remaining part, which is divided into two separate tracts, belongs to the extensive section of the upland surrounding the area of the ancient lake. One of these tracts occupies the southern part of Traverse County, and the other occupies the eastern parts of Clay and Norman Counties together with the northeastern corner of Wilkin County and the southeastern corner of Polk County.

Thus, the original shore line of Lake Agassiz divides the entire area into two strikingly different physiographic sections. The country west of this shore line was covered by the waters of Lake Agassiz for a long period after the retreat of the great glacier. The waves of the large but relatively shallow lake leveled the bottom and produced an exceedingly smooth and monotonous surface for this area (fig. 2). The ancient shore line gradually rises from an altitude of 1,056 feet above sea level in its southern part in Traverse County to about 1,180 feet in the southeastern part of Polk County, where it crosses the boundary of the area. The smooth surface of the plain very gradually falls northward and westward from the shore line.

The general northern slope ranges from about 2 feet to only one-half foot a mile. It is greater in the southern counties than in the northern counties. According to Upham,[3] the descent from the

[3] UPHAM, W. THE GLACIAL LAKE AGASSIZ. U. S. Geol. Survey Monog., v. 25, 658 pp., illus. 1895. See p. 20.

southern border of the lake to Breckenridge is 90 feet in a distance of 43 miles. From Breckenridge to Moorhead the fall is 1.5 feet a mile; from Moorhead to Grand Forks it averages about 1 foot a mile; and farther north in the 74 miles from Grand Forks to the international boundary the elevation falls about 40 feet, or about one-half foot a mile.

The slope westward toward Red River is considerably greater and less uniform than the slope toward the north, ranging from less than 3 feet to more than 15 feet a mile. Generally speaking, throughout the entire length of the valley the slope is somewhat greater near the eastern margin of the plain than near Red River. A strip of essentially flat land extends along the river; its width, in Minnesota, ranges from 5 to about 15 miles, and the ascent of its surface east from the river averages about 1 foot a mile. In Traverse and Wilkin Counties this strip occupies nearly the whole width of the

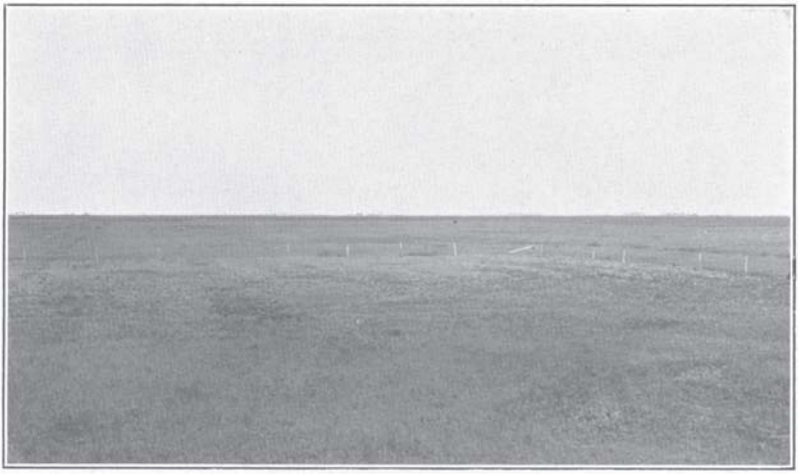

FIGURE 2.—Smooth relief of the bed of a glacial lake in the western part of Marshall County.

valley. North of the Wilkin County line the general ascent of the land surface east of this flat area becomes greater, rising 5, 10, or even more than 10 feet a mile. The land with such slope forms the second strip, the width of which averages between 8 and 10 miles. Farther east of this middle belt the surface of the country is again more or less flat with rather insignificant descents north and west.

The relief of the upland section of the area, situated back from the ancient shore line, is gently undulating to rolling (fig. 3), ranging in elevation from about 1,100 to 1,300 feet above sea level. The difference in elevation between the high and the low points ranges in different places from 15 to about 50 feet, although in some particularly rough areas it may be close to 100 feet. The outstanding feature of the relief of this section is the frequent occurrence of small depressions and pot holes ranging in size from less than 1 acre to more than 1 square mile and in depth from less than 5 feet to more than 20 feet.

The drainage of the area is carried entirely by Red River and its tributaries. The drainage of the greater part of the upland section is fair, with the exception of a few rather flat tracts, one of which is in the southeastern corner of Traverse County and another in the eastern half of Waukon Township in Norman County. The deficiency of the natural drainage from both these tracts, however, has been improved by the construction of drainage ditches. Some of the pot holes, which are conveniently located for the construction of tiling systems, are also drained. The removal of the excess surface water from the entire upland region is accomplished through a system of numerous U-shaped watercourses, most of which are dry for a greater part of the year, but some of which are fed by springs and carry running water all year. The general direction of the surface drainage here is toward the lake-bottom section of the area, entering which the watercourses become diffused, and even lost, or their waters are collected by the few principal streams which flow across the plain into the main channel of Red River.

FIGURE 3.—Gently rolling relief of the upland surrounding the lake bed area in the eastern part of Clay County.

Red River, as described by Upham,[4] flows—

in a direct general course from south to north, but meanders almost everywhere with minor bends, which carry it alternately a half to 1 mile or more to each side of its main course. Thus its length from Breckenridge and Wahpeton to St. Vincent and Pembina is 397 miles, according to survey of the United States Engineering Corps, but the distance in a direct line is only 186 miles; yet the river nowhere deviates more than 5 or 6 miles from this straight line.

The descent of Red River from Breckenridge to Lake Winnipeg, a course of nearly 600 miles, is 233 feet, averaging less than 5 inches a mile. The width of Red River in the area ranges from a few to about 20 rods. The river has eroded a channel from 20 to 50 feet deep, and the banks in most places rise steeply, or by two or three short steps, to the level of the adjoining plain. The width of the channel is only slightly greater than the width of the winding river

[4] See footnote 3, p. 2.

bed; consequently, only narrow isolated strips of bottom land border the river.

The main tributaries of Red River which drain the area are Otter Tail River, Buffalo River, Wild Rice River, Sandhill River, Red Lake River and its tributaries, Clearwater and Thief Rivers, Snake River, Tamarac River, and Two River. All except the last three flow from the upland section in a general west or northwest direction. Like Red River itself, they all have extremely winding courses and have cut similar channels although not quite so deep. Buffalo River in Clay County, Wild Rice River in Norman County, and Sandhill and Red Lake Rivers in Polk and Red Lake Counties, however, have cut deep ravines where they pass from the upper to the lower plain.

According to natural drainage conditions, the entire area can be divided into three sections, the approximate boundaries between them being more or less parallel to Red River.

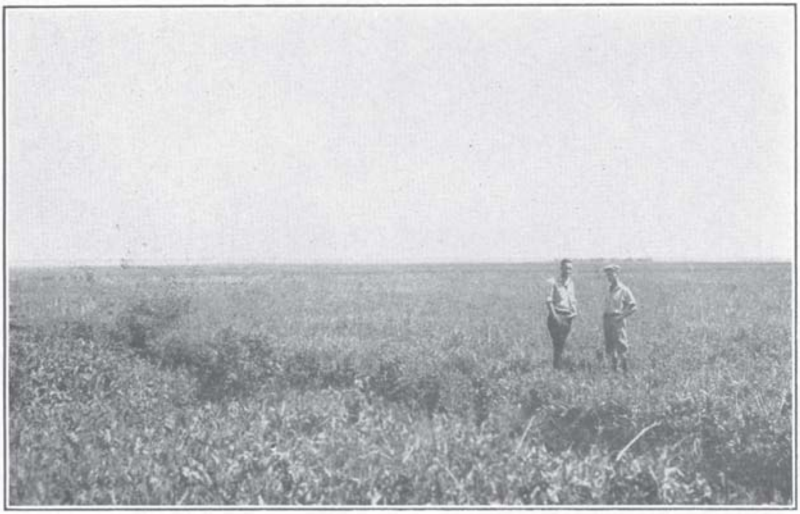

FIGURE 4.—Open peat bog in the eastern part of Marshall County.

The northeastern section, which occupies the eastern parts of Kittson, Marshall, Red Lake, and Polk Counties, is almost untouched by erosion. The drainage of the greater part of this section is rather poor, and many peat bogs and sloughs occupy the wide flats scattered through it. These range in size from spots only a few rods in diameter to areas covering more than a township (fig. 4). The intervals between the peat bogs and sloughs are occupied by somewhat elevated and, in most places, very gently undulating land, which rises only a few feet above the surface of the wet land.

The section adjoining Red River, and the flattest belt of the valley, extends the full length of the area from Traverse County to Kittson County. Because of the general levelness of the surface, the natural drainage is very slow and in many places inadequate. Only the largest streams which cross the plain have eroded definite channels, and most of the small streams entering it from the east become diffused and lost in the sloughs of the wide flats. Only the narrow strips of land adjoining the banks of the main channels have adequate surface drainage. The intervals, ranging from 5 to 15 miles, between these relatively better drained strips are almost unmarked by any watercourses and remained wet until they were artificially drained. Deep, wide ditches with a total length of several hundred miles were dug across the plain, mostly in an east-west direction, and many of these are only 1 mile apart.

Between the eastern and the western flat sections in the six northern counties of the valley lies an intermediate relatively better drained belt, ranging in width from 2 to more than 10 miles. Because of the comparatively greater western slope its natural surface drainage ranges from moderate to good. This belt is crossed by a number of watercourses running in an east-west direction, many of which are dry most of the year and are marked by narrow strips of only slightly depressed, wet, and in places sloughy land; but the larger streams crossing this belt have eroded well-defined channels, which

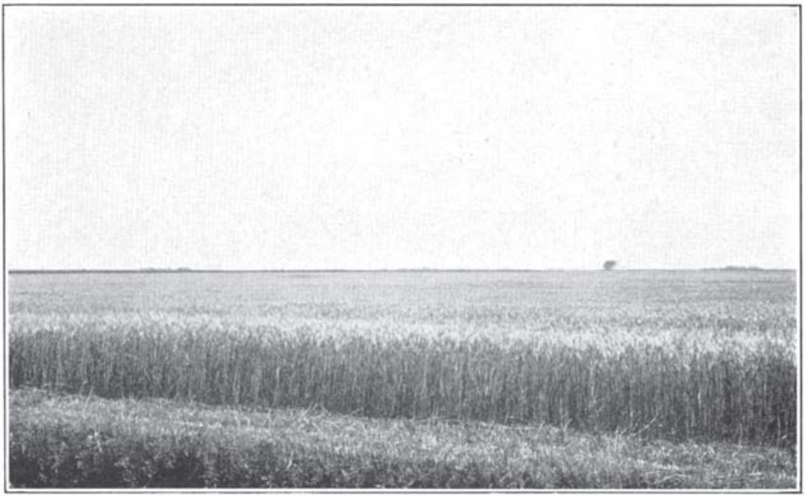

FIGURE 5.—Wheatfield on Fargo silty clay loam of Red River Valley.

are especially deep where they cross the so-called terrace. This terrace consists of a rather steep escarpment, eroded by the waves of an ancient lake, extending northward from Barnesville in the southern part of Clay County in a general direction nearly parallel to Red River.

The intermediate, better drained belt does not extend into Wilkin and Traverse Counties, and the eastern portions of both these counties have insufficient natural drainage. To a great extent, especially in Wilkin County, the drainage depends upon the numerous gravelly ridges heaped here by the rollers. Most of these ridges have smoothly rounded tops, range in width from a few rods to more than one-half mile, rise 5 to 15 feet above the adjoining land, and run in an approximate north-south direction or across the axes of the general descent of the land surface. Many of them extend for several miles and act as natural levees holding back the excess surface moisture and forming strips of sloughs. The largest and wettest of these is in Wilkin County, and a considerable tract in Tanberg and Akron

Townships is covered by a thick deposit of peat and muck. The excess moisture here is supplied by a number of copious springs. The gravelly ridges mark the consecutive shore lines of the gradually diminished lake and extend the entire length of the valley.

The boundary which separates prairie land and woodland in Minnesota crosses the area in an approximately north-northwest south-southeast direction, with the prairie land to the west and the woodland to the east.

The western part comprises the whole of Traverse and Wilkin Counties, the greater parts of Clay and Norman Counties, and the western parts of Polk, Marshall, and Kittson Counties. This is an open natural grassland and can be classified as a humid prairie. At present it is almost entirely under cultivation and is covered by grainfields (fig. 5), only isolated tracts of land, unsuitable for the common crops, being left unbroken. Before the colonization of the area the vast expanse of prairie was covered with abundant wild

FIGURE 6.—Coniferous forest on peat bog in the eastern part of Marshall County.

grasses, and large tracts of sloughs and marshes, some of which covered many square miles, occupied a large part of it.

The natural forest vegetation in this part of the area is confined to the narrow strips of bottom land and the banks bordering the larger streams, such as Red River and its main tributaries, Buffalo, Wild Rice, Red Lake, and Tamarac Rivers, and some other streams. These scattered strips of forest range in width from several rods to almost one-half mile, but in most places are less than one-fourth mile. The forest vegetation is composed of white ash, white elm, slippery elm, bur oak, ironwood, poplar, boxelder, wild plum, huckleberry, prickly and smooth gooseberry, black currant, hazelnut, and some other trees and shrubs.

Some small isolated groves of various trees grow on the banks of the short ravines cutting the bluff of the upland which surrounds the lake-bottom plain. The only forest of considerable size in the prairie part of the area is on the slope of the upland toward Lake

Traverse in Traverse County. Some small groves of willow bushes and of somewhat crooked aspen grow in a few places through the low wet tracts at a considerable distance west of the general boundary of the forest land.

The forested part of the area is composed of about two townships in the northeastern corner of Clay County; the northeastern corner of Norman County; the eastern parts of Polk, Marshall, and Kittson Counties; and Red Lake County. Most of the forest in Clay, Norman, and southeastern Polk Counties is on the rolling upland. It is composed of common deciduous trees including birch, aspen, oak, maple, and elm. The conifers grow only in the two extreme southeastern townships of Polk County. The forest of the lake-bottom section near its western margin is composed mainly of aspen and willow bushes. Some distance behind this line, birch, oak, and the other trees appear. The conifers grow chiefly on large peat bogs in eastern Marshall and Polk Counties (fig. 6).

CLIMATE

The climate combines some typical features of the continental climate of the Central States with a medium rainfall and must be classified as subhumid. It is characterized by long winters and by relatively hot summers. About 75 percent of the annual precipitation occurs during the warm period of the year (fig. 7).

The climatic conditions do not differ greatly throughout the area. The normal annual temperatures range from 42.9° F. in Wheaton, Traverse County, to 37.1° F. in Hallock, Kittson County. Table 1 shows the normal monthly, seasonal, and annual temperatures at seven Weather Bureau stations in the area.

TABLE 1.—*Normal monthly, seasonal, and annual temperatures at seven Weather Bureau stations in the Red River Valley area, Minn.*

Month	Hallock, Kittson County	Argyle, Marshall County	Crookston, Polk County	Ada, Norman County	Moorhead, Clay County	Campbell, Wilkin County	Wheaton, Traverse County
	°F.	°F.	°F.	°F.	°F.	°F.	°F.
December	7.9	8.5	11.8	10.8	11.5	13.2	14.7
January	.5	3.3	3.7	4.2	3.8	5.8	9.7
February	4.6	9.0	7.4	7.5	8.1	11.0	16.7
Winter	4.3	6.9	7.6	7.5	7.8	10.0	13.7
March	20.2	22.8	22.3	22.9	22.7	25.2	28.2
April	40.4	41.0	41.8	42.1	40.6	42.8	44.5
May	52.9	53.7	54.0	54.0	55.1	54.1	55.3
Spring	37.8	39.2	39.4	39.7	39.5	40.7	42.7
June	62.7	63.5	64.5	63.7	64.4	64.4	65.6
July	66.8	68.0	69.0	68.6	68.1	69.1	71.8
August	64.8	66.1	66.2	66.1	66.1	66.6	69.3
Summer	64.8	65.9	66.6	66.1	66.2	66.7	68.9
September	55.6	56.7	57.0	57.0	58.2	57.5	60.2
October	42.9	42.7	44.1	43.8	44.5	44.2	46.9
November	25.3	26.1	26.5	26.1	27.1	27.9	31.2
Fall	41.3	41.8	42.5	42.3	43.3	43.2	46.1
Year	37.1	38.5	39.0	38.9	39.2	40.2	42.9
Highest recorded	103.0	99.0	106.0	106.0	110.0	106.0	108.0
Lowest recorded	−51.0	−42.0	−45.0	−43.0	−48.0	−40.0	−38.0

The coldest month is January, the normal temperature ranging from 9.7° F. in Wheaton to 0.5° in Hallock. The warmest month is July, when the normal temperature ranges from 71.8° to 66.8° at the same stations, respectively. The general range between the normal temperatures of the coldest and warmest periods is, therefore, 62.1° to 66.3°; but the difference between the highest and the lowest recorded temperatures is about 150°. Almost every summer during

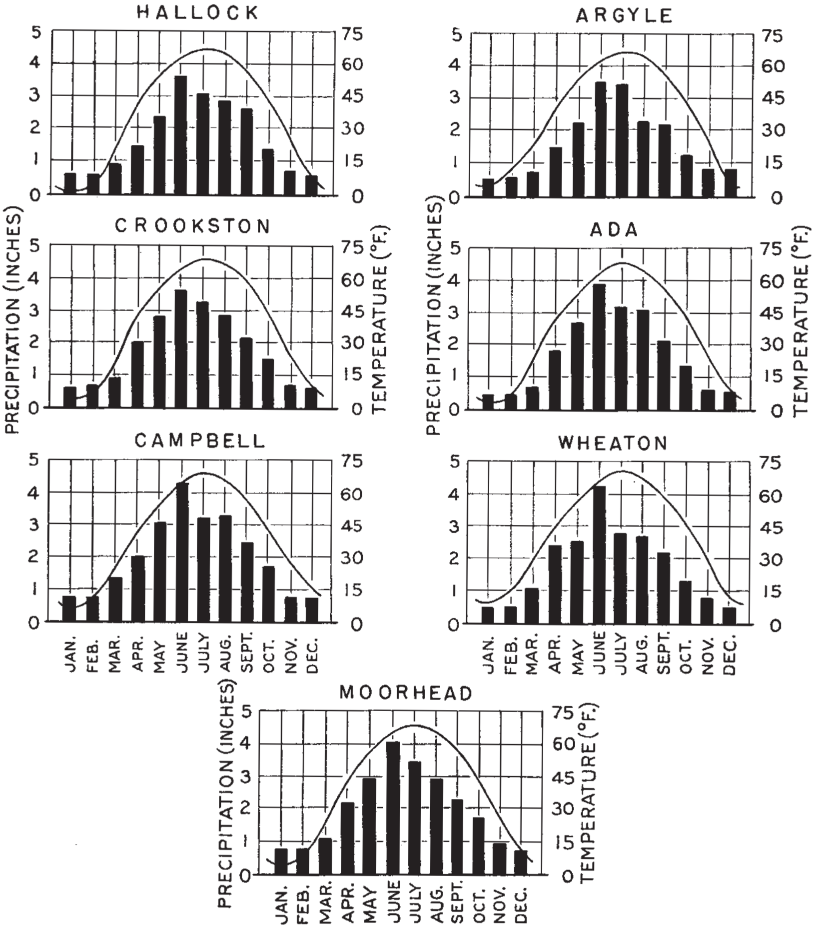

FIGURE 7.—Graphs of average precipitation and temperature at each of seven Weather Bureau stations in the Red River Valley area, Minn.

several days the temperature reaches 100° or higher. Temperatures lower than −40° are less common, although such low temperatures have been recorded at most stations. Both heat waves and cold waves are of short duration.

The changes from one season to another are, as a rule, rather sudden. The change from fall to winter commonly occurs at the close of October or during the first half of November, when a sudden cold wave freezes the water and the ground and stops work in the fields.

The first snowfall occurs at the same time or somewhat earlier. The snowfall during the entire winter is rather scant, seldom exceeding a foot in depth, and much of the snow blows away, because of the exposure of the flat and open country to the winds; consequently the ground in some places freezes to a considerable depth. Nearly every winter has from one to four severe blizzards, in which the snowfall is accompanied by a strong wind and often by a very low temperature. The spring break of the cold period commonly occurs during the latter half of March or the beginning of April. The scant snow cover melts rapidly, and the land thaws and dries sufficiently to allow the beginning of agricultural operations, in most places, as early as the middle or the latter part of April. Ground frost may be encountered at considerable depth in some places, however, as late as the end of May or the beginning of June.

Because of their undulating or rolling relief, which provides for a better run-off of the spring rains, the fields in the open part of the upland section dry considerably faster than do those in the lake-bottom plain. The soils of this section are ready for spring field work and are sufficiently warmed for germination of seed somewhat earlier than the soils of the plain. The run-off from melting snow in spring from the flats in the lake-bottom section is naturally slow. The deep drainage ditches are often filled with ice and snow, which do not thaw in time to render the ditches most serviceable, and a slow opening of the ditches delays the run-off and causes the submergence of large areas of land sometimes for several weeks.

The last killing frost occurs, generally, during the latter part of May throughout most of the area, but in the northern half the last frost may occur during the early part of June. The earliest frost generally occurs in the latter part of September. Table 2 shows the frost data from 1920 to 1935 recorded at seven Weather Bureau stations in the area.

TABLE 2.—*Frost data as recorded at seven Weather Bureau stations in the Red River Valley area, Minn., 1920–35*

LAST IN SPRING

Year	Hallock, Kittson County	Argyle, Marshall County	Crookston, Polk County	Ada, Norman County	Moorhead, Clay County	Campbell, Wilkin County	Wheaton, Traverse County
1920	June 3	May 14	May 2	June 3	May 1	May 13	May 1
1921	May 18	May 17	May 15	May 17	May 3	May 16	May 16
1922	Apr. 28	Apr. 27	Apr. 26	Apr. 27	Apr. 19	Apr. 27	--------
1923	May 21	May 20	May 16	May 20	May 12	May 16	May 16
1924	June 7	June 7	June 6	May 25	May 19	June 6	May 25
1925	May 24	May 25	May 17	do	May 17	May 24	May 24
1926	June 18	May 22	May 22	May 22	May 22	May 22	--------
1927	June 5	June 5	May 15	June 5	May 14	May 15	May 11
1928	June 3	June 3	June 3	June 3	May 5	May 28	May 12
1929	June 12	May 24	May 24	May 23	May 20	May 16	May 16
1930	May 30	May 29	May 29	May 29	May 24	May 29	May 25
1931	June 7	June 7	May 22	May 22	May 22	May 20	May 20
1932	May 28	May 28	May 17	May 28	May 1	Apr. 30	May 1
1933	May 20	May 20	May 20	May 14	May 10	May 10	May 10
1934	May 24	May 24	May 24	May 24	May 11	May 24	Apr. 27
1935	June 7	June 7	June 6	June 7	May 10	May 10	May 10
Average date	May 30	May 25	May 20	May 24	May 11	May 17	May 13
Latest recorded	June 18	June 7	June 6	June 7	May 24	June 6	May 24

TABLE 2.—*Frost data as recorded at seven Weather Bureau stations in the Red River Valley area, Minn., 1920–35*—Continued

FIRST IN FALL

Year	Hallock, Kittson County	Argyle, Marshall County	Crookston, Polk County	Ada, Norman County	Moorhead, Clay County	Campbell, Wilkin County	Wheaton, Traverse County
1920	Sept. 30	Sept. 30	Sept. 30	Sept. 23	Oct. 28	Sept. 30	Sept. 30
1921	do	Sept. 25	Oct. 2	Oct. 3	Oct. 3	do	Oct. 3
1922	Sept. 13	do	Oct. 11	Oct. 8	Oct. 12	Sept. 10	Oct. 9
1923	Aug. 24	Sept. 13	Sept. 13	Sept. 13	Sept. 13	Sept. 12	Sept. 13
1924	Sept. 5	Sept. 29	Oct. 7	Oct. 7	Nov. 2	Oct. 10	Oct. 7
1925	Sept. 21	Sept. 22	Oct. 2	Sept. 22	Sept. 21	Sept. 21	Oct. 1
1926	Sept. 19	do	Sept. 12	do	Sept. 24	Sept. 22	Sept. 25
1927	Sept. 25	Sept. 25	Sept. 25	Sept. 20	Sept. 23	Sept. 26	Sept. 23
1928	Sept. 17	Sept. 23	Sept. 23	Sept. 23	do	Sept. 23	Do.
1929	Sept. 13	Sept. 18	Sept. 17	Sept. 17	Sept. 18	Sept. 18	Sept. 18
1930	Sept. 28	Sept. 28	Sept. 28	Sept. 28	Sept. 28	Sept. 27	Sept. 28
1931	Oct. 8	Sept. 15	Oct. 5	Aug. 30	Sept. 24	Aug. 24	Aug. 30
1932	Sept. 17	Sept. 16	Sept. 17	Sept. 17	Oct. 5	Sept. 29	Sept. 29
1933	Sept. 26	Sept. 26	Oct. 4	Sept. 26	Oct. 8	Sept. 26	Oct. 4
1934	Aug. 28	Aug. 25	Sept. 6	Sept. 6	Sept. 21	Sept. 21	Sept. 16
1935	Aug. 31	Aug. 31	Sept. 9	Sept. 27	Sept. 27	Sept. 27	Sept. 27
Average date	Sept. 17	Sept. 19	Sept. 24	Sept. 22	Oct. 1	Sept. 22	Sept. 25
Earliest recorded	Aug. 24	Aug. 25	Sept. 6	Aug. 30	Sept. 13	Aug. 24	Aug. 30

The average length of the frost-free season in the area is between 110 and 143 days.

The sky is prevailingly clear. The average number of wholly sunny days annually is not less than 200. Almost 100 days are recorded as partly cloudy and only from 60 to 80 days as heavily cloudy. The number of days with precipitation ranges approximately from 50 to 100 during a year.

The mean annual rainfall is about 21 inches for the entire area. About 16 inches, or more than 75 percent, falls during the warm period from April to September, inclusive. More than 9 inches of rain, or nearly one-half of the annual rainfall, occurs during May, June, and July, whereas the winter months, December, January, and February, have less than 2 inches.

Table 3 shows the normal monthly, seasonal, and annual precipitation at seven stations in the area.

TABLE 3.—*Normal monthly, seasonal, and annual precipitation, as recorded at seven Weather Bureau stations in the Red River Valley area, Minn.*

Month	Hallock, Kittson County	Argyle, Marshall County	Crookston, Polk County	Ada, Norman County	Moorhead, Clay County	Campbell, Wilkin County	Wheaton, Traverse County
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
December	0.56	0.68	0.60	0.51	0.72	0.66	0.40
January	.52	.48	.56	.45	.67	.73	.49
February	.56	.55	.63	.50	.69	.75	.49
Winter	1.64	1.71	1.79	1.46	2.08	2.14	1.38
March	.85	.71	.85	.68	1.01	1.25	.92
April	1.31	1.49	1.70	1.76	2.18	2.04	2.15
May	2.39	2.36	2.83	2.78	2.89	3.03	2.51
Spring	4.55	4.56	5.38	5.22	6.08	6.32	5.58
June	3.48	3.34	3.46	3.68	4.05	4.09	3.98
July	2.94	3.35	3.17	3.03	3.43	3.16	2.74
August	2.69	2.11	2.73	2.72	2.89	3.18	2.69
Summer	9.11	8.80	9.36	9.43	10.37	10.43	9.41

TABLE 3.—*Normal monthly, seasonal, and annual precipitation, as recorded at seven Weather Bureau stations in the Red River Valley area, Minn.*—Con.

Month	Hallock, Kittson County	Argyle, Marshall County	Crookston, Polk County	Ada, Norman County	Moorhead, Clay County	Campbell, Wilkin County	Wheaton, Traverse County
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
September	2.55	2.19	2.12	2.11	2.22	2.33	2.14
October	1.48	1.48	1.54	1.42	1.69	1.69	1.34
November	.82	.90	.73	.75	.90	.83	.90
Fall	4.85	4.57	4.39	4.28	4.81	4.85	4.38
Year	20.15	19.64	20.92	20.39	23.34	23.74	20.75
Driest year	12.33	11.42	11.25	10.07	9.94	12.12	12.89
Wettest year	26.55	27.13	30.30	27.49	34.01	36.29	27.12
April to September, inclusive	15.36	14.84	16.01	16.08	17.66	17.83	16.21
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Percent of total for year	76.2	75.6	76.5	78.9	75.6	75.1	78.1

The data for the driest and the wettest years show great variation, although neither deviation from the normal rainfall is so extreme as to be completely unfavorable for agriculture, and notable deviations occur very seldom. The distribution of the precipitation during the year may be such, however, that conditions of either flood or drought are severe enough to injure crops. It may happen that during any given month two or three times the normal amount of rain may fall, or, on the contrary, only one-half or one-third of the normal amount, but such extremes are not common.

Injury from excess moisture is relatively more common in the western part of the area adjoining Red River, because of the heavy texture of both the surface soils and the subsoils and the flatness of the country, which reduce drainage activity both on the surface and through the soil. Injury by drought more frequently occurs on the sandy soils which occupy the central and eastern parts of the lake-bottom plain.

Both the lake-bottom and the upland sections have practically the same amount of precipitation per unit of surface, but because of the difference in relief the soils of the lake-bottom section are able to retain a far greater proportion of the rain water than are the soils of the upland region. Thus, during the summer, especially in dry years, the soils of the plain are more greatly benefited from the precipitation, and, in adidtion, these soils are not susceptible to erosion, whereas the slopes of the rolling country are marked by many "baldpates" resulting from the washing away of the dark-colored surface soils and the exposure of the light-colored subsoils.

The flat prairie land of Red River Valley is fully exposed to all wind movements, and, although the wind velocity usually is not very high, strong winds may occur in all seasons. Two especially windy periods occur during the year, each of about 1 or 2 weeks' duration—one late in spring, usually in the second half of May, and the other in the fall, usually in October. Both occur at the time when at least a part of the cultivated land is unprotected by crops, and drifting soil during these periods not infrequently causes serious damage to growing crops.

The total amount of rainfall and its normal distribution through the growing season, as well as the normal temperature, are suitable for all the crops grown in the area, but the snowfall during the winter usually is insufficient for the proper protection of winter crops from severe cold. Both spring and fall are relatively dry, and the excess of moisture from melting snow and from rains normally does not interfere with the spring preparation and planting of the land or with the maturing and harvesting of crops and fall plowing. Late spring and early fall frosts are not unknown, but most of them are not so severe as to cause very serious damage.

AGRICULTURAL HISTORY AND STATISTICS

A far-stretching prairie, flat and monotonous like the sea, covered by tall grasses in summer and by a dazzling snow in winter, is the primitive picture of Red River Valley before the arrival of white men. Countless herds of buffaloes roamed the area. The country was occupied by several Indian tribes which located their villages on the banks of the rivers and lakes and derived their subsistence largely by hunting and fishing. Some tribes cultivated small patches of land and grew corn, potatoes, and squash, but nearly all of them devoted themselves to hunting, fishing, and continuous intertribal wars.

It is assumed that this area was discovered by white men in 1734, when they became acquainted with the country in connection with the activities of the fur companies. These pioneers, including Scotch, English, and, predominantly, French Canadians, established a number of trading posts and forts for their protection.

The real agricultural history began more than 100 years ago with a farming enterprise in the extreme northern part. In 1811 and 1812 the first Scotch colony was established by Lord Selkirk near the present site of Winnipeg, Canada. The first attempts of the newcomers to introduce agriculture into their new home were unsuccessful for several years, and it was not until 1820 that the first grain crop was grown and harvested in Red River Valley. Selkirk's colony prospered after that time in spite of the fact that the methods of farming and the implements were crude and primitive.

The early history of Red River Valley south of the international boundary, after the appearance of white men, comprises two distinct periods—the era preceding railroads and that following.

The first period was characterized by the complete domination by interests centralized outside the valley. The fur trading of the Hudson Bay, Northwest, and other companies and later the colonization of Manitoba were the most influential factors in the early development of the valley; and the valley itself remained a great thoroughfare through which passed a traffic of considerable volume during this period. At the middle of the nineteenth century three different travel routes passed through Red River Valley to St. Paul. From Pembina, N. Dak., southward these routes passed on both sides of Red River, one turning eastward from Red River near the mouth of Buffalo River, the second turning near the point where later Fort Abercrombie, N. Dak., was established, and the third following Red River, Big Stone Lake, and Minnesota River. Dog sleds in winter, oxcarts in summer, and, later, stage coaches were the means of transportation. A steamboat made its first trip from Fort Abercrombie to Fort Garry along Red River in 1859. A number of stations and trading posts, established along trails and on the riverbanks, provided some occupation for a number of persons. Nearly the entire white population, which up to 1870 comprised about 1,000 persons in 12 counties of the valley on both sides of the river, were there incidental to the traffic and fur trade and not as permanent residents. The country supplied the earlier settlers with fish and game, all the garden vegetables needed were raised, and flour and other commodities were purchased. Gardens and small fields were cultivated in connection with the settlements, and some barley and oats were grown for feed for horses and oxen, but it is doubtful whether more than a few hundred acres were in crops at that time.

The years 1870 and 1871 began the second era in the development of this area, when railroads were constructed connecting it with the eastern seaboard. The Northern Pacific Railway completed the construction of the line from Duluth to Red River at Moorhead, and the main line of the Great Northern Railway reached Breckenridge late in the fall of 1871. Within the next decade several other lines were constructed which crossed the plain from east to west and from north to south.

The years 1870 and 1871 may be considered the time of the beginning of wheat growing in Red River Valley south of the international boundary, and the increase in acreage of this crop was very rapid. The first carload of wheat from the valley was shipped to Lake Superior in 1873, and in 1878 the first grain elevator, with a capacity of 110,000 bushels, was erected at Moorhead.

The settlement of this country was rather quickly accomplished after the Government land, excepting the areas granted to the railroads, was opened to homesteaders. According to Upham [5]—

> multitudes came bringing housekeeping equipments in their emigrant wagons (prairie schooners), which passed in long processions through St. Cloud and Alexandria, Minn., on their way from the older portions of this State and from other States farther east and south. Many also came directly from the old world, especially from Sweden and Norway.

The population rose from 1,000 in 1870 to about 56,000 in 1880. The population was 166,000 in 1890 and about 350,000 in 1900. Of the latter number, 107,606 were living in the area surveyed on the Minnesota side of the Red River Valley. The population in the area continued to increase until it reached its maximum of 129,223 in 1920, according to the United States census. The 1930 census reports the total population of the area as 124,507, of which 16,894 are classed as urban and 107,613 as rural.

Table 4 gives the population of the Red River Valley area as reported by the Federal census for the years 1890 to 1930, inclusive, and the farm population as reported by the 1935 census.

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[5] UPHAM, W. THE SETTLEMENT AND DEVELOPMENT OF THE RED RIVER VALLEY. Coll. Minn. Hist. Soc. 8: 19. 1898.

TABLE 4.—*Population of eight counties in the Red River Valley area, Minn., from 1890 to 1930 inclusive, and total farm population in 1935*

County	1890	1900	1910	1920	1930	1935 [1]
Kittson	5,387	7,889	9,669	10,638	9,688	6,882
Marshall	9,130	15,698	16,338	19,443	17,003	13,051
Red Lake		[2] 12,196	[2] 6,564	7,263	6,887	4,704
Polk	[2] 30,192	35,429	36,001	37,090	36,019	20,766
Norman	10,618	15,045	13,446	14,880	14,061	9,809
Clay	11,517	17,942	19,640	21,780	23,120	10,513
Wilkin	4,346	8,030	9,063	10,187	9,791	5,967
Traverse	4,516	7,573	9,049	7,942	7,938	5,090
Total	75,706	119,802	119,770	129,223	124,507	76,782

[1] Farm population only; total population not reported.
[2] Polk County originally included all of Red Lake and Pennington Counties. Red Lake County was formed from Polk County in 1897, and Pennington County was formed from Red Lake County in 1910. Pennington County is not included in the area surveyed.

The figures show that the density of population in 1930 was 14.6 persons a square mile; however, 49,260 persons, or 39.5 percent of the total population, were living in the cities and villages, and the remaining 75,247 persons were living on farms, which gives a density of the strictly farm population of 8.8 persons a square mile.

Side by side with the farms established on the homesteads, several large farm enterprises, the so-called "bonanza farms," were also organized. Many tracts of land granted to the railroad companies, comprising many thousands of acres were acquired by private parties without being subject to the regulations of the homestead law. These bonanza farms exerted a strong influence on the development and character of the general structure of the agriculture in the young country. They were a sort of wheat factory or establishment for mass production of farm products on a purely commercial basis, which became a model for general farming throughout the entire region. Raising wheat as a cash crop, both on a large scale and on the small farms, overshadowed the evolution of a self-supporting agriculture, although such a narrowly specialized system of farming was suggested and influenced by the monotony of the country, its soils, climate, and other natural conditions.

In Minnesota Agricultural Experiment Station Bulletin 282 [6] it is stated:

> The growing of spring grains continuously on the same fields gradually subjected wheat growing to the usual hazards that accompany single-crop farming—declining productivity of the soil, increase of weed pests, the accumulation of plant diseases, and frequent ravages of insects, with attendant declines in yields. * * * The many natural hindrances to wheat growing, especially weeds, together with the increased competition from newer areas, are bringing about the introduction of additional cash crops to the Valley as well as crops that aid in controlling the weeds. As early as 1910 the acreage of wheat in the Valley had decreased fully 40 per cent below that recorded in 1900. * * * With an increasing amount of feed crops to dispose of, there has been a strong impulse toward the development of livestock enterprises in conjunction with grain farming. Thus, a system of mixed farming is gradually displacing the old system, under which the farmer gave his attention almost exclusively to spring grains.

Another important factor in the development of Red River Valley was the organized drainage of the vast marshy areas. By act of the

[6] POND, G. A., SALLEE, G. A., and CRICKMAN, C. W. AN ECONOMIC STUDY OF CORN PRODUCTION IN THE RED RIVER VALLEY OF MINNESOTA. Minn. Agr. Expt. Sta. Bull. 282, 110 pp., illus. 1931. See p. [5].

legislature, drainage districts were organized at the close of the nineteenth century and were empowered to issue long-term bonds to raise money for drainage work, the debt being paid gradually by taxes in proportion to benefits conferred. This brought about a great improvement of several thousand acres of otherwise almost worthless land and a great increase in the arable land.

The United States census of 1930 gives the number of farms in the area as 15,288. The number in general, ranges from 14 to 156 in a civil township, although one township in Kittson County has only 7 and another 8 farms. The 1935 census reports 16,886 farms, averaging 285.1 acres. The farms range in size from less than 100 acres to more than 1,000 acres. Table 5 gives the number of all farms, the average size of farms, and the number of farms by size in the several counties, as reported by the 1935 Federal census.

TABLE 5.—*Number, average size, and number of farms by size, in the Red River Valley area, Minn., as reported by the 1935 Federal census*

County	Farms	Average size of farms	Less than 100 acres	100 to 499 acres	500 to 999 acres	1,000+ acres
	Number	*Acres*	*Number*	*Number*	*Number*	*Number*
Kittson	1,481	325.6	199	1,095	152	35
Marshall	2,971	293.6	379	2,266	290	36
Red Lake	981	251.4	146	774	61	0
Polk	4,729	242.7	956	3,401	323	49
Norman	2,068	259.6	339	1,539	172	18
Clay	2,207	279.8	243	1,755	185	24
Wilkin	1,278	332.9	72	1,043	142	21
Traverse	1,171	295.4	53	1,005	108	5
Total	16,886	[1] 285.1	2,387	12,878	1,433	188

[1] Average.

Table 6 gives the number of acres in farms by classes of land and the value of land and buildings in the several counties as reported by the 1935 Federal census.

TABLE 6.—*All land in farms by classes and value of land and buildings in the several counties in the Red River Valley area, Minn., as reported by the 1935 census*

County	Approximate land area	Proportion in farms	All land in farms	Improved land [1]	Woodland and other pasture	Other land in farms [2]	Value of land and buildings	
							Per farm	Per acre
	Acres	*Percent*	*Acres*	*Acres*	*Acres*	*Acres*	*Dollars*	*Dollars*
Kittson	711,040	67.8	482,269	377,444	63,451	41,374	6,162	18.92
Marshall	1,144,320	76.2	872,176	591,892	114,631	165,653	4,716	16.06
Red Lake	276,480	89.2	246,598	170,060	41,511	35,027	4,318	17.18
Polk	1,266,560	90.6	1,147,621	901,019	127,086	119,516	6,234	25.69
Norman	550,400	97.5	536,838	451,460	37,601	47,777	7,144	27.52
Clay	667,520	92.5	617,449	532,586	45,271	39,592	7,651	27.35
Wilkin	476,800	89.2	425,443	396,819	7,357	21,267	9,671	29.05
Traverse	363,520	95.2	345,950	325,633	7,507	12,810	7,903	26.75
Total	[3] 5,456,640	[4] 85.7	4,674,344	3,746,913	444,415	483,016	[4] 6,725	[4] 23.57

[1] Improved land includes cropland and plowable pasture.
[2] Other land includes land occupied by buildings, feed lots, roads, and waste land.
[3] Figures from 1935 census only approximately correct.
[4] Average.

Approximately 85.7 percent of the entire area was classified in 1935 as land in farms, of which 80.2 percent was classed as improved land, including cropland and plowable pasture. The pasture in four northern counties of the area—Kittson, Marshall, Red Lake, and Polk—comprised approximately 12.6 percent of the total farm land as compared with about 5.1 percent in four southern counties.

The total acreage of the farm land was 3,730,842 acres in 1900, as compared with 4,674,344 acres in 1935. About 11.6 percent of the total number, or 1,822 farms, of the 15,590 were operated by tenants in 1900, and the rest were operated by the owners. In 1935, of the 16,886 farms in the area, 5,624 were operated by full owners, 3,823 by part owners, 7,392 by tenants, and 47 by managers. Table 7 shows the number of farms of the various classes of operators and the acreage operated by each class.

TABLE 7.—*Number of farms and acreage operated by owners, part owners, tenants, and managers in the Red River Valley area, Minn., in 1935*

County	Farms operated by—				Acreage operated by—			
	Full owners	Part owners	Tenants	Managers	Full owners	Part owners	Tenants	Managers
	Number	*Number*	*Number*	*Number*	*Acres*	*Acres*	*Acres*	*Acres*
Kittson	466	369	642	4	93,925	185,708	181,976	20,660
Marshall	845	915	1,207	4	168,448	357,858	342,870	3,000
Red Lake	325	278	377	1	57,713	96,895	91,350	640
Polk	1,938	889	1,892	10	328,332	328,751	486,438	4,100
Norman	720	470	866	12	139,879	159,725	231,579	5,655
Clay	744	454	999	10	167,659	165,605	276,644	7,541
Wilkin	306	282	684	6	82,204	120,070	217,931	5,238
Traverse	280	166	725	----------	69,631	66,721	209,598	----------
Total	5,624	3,823	7,392	47	1,107,791	1,481,333	2,038,386	46,834

The acre rental of farm land ranges from $2 to $3 in the four southern counties and from less than $1 to more than $2 in the northern counties. A considerable proportion of the cash tenants are relatives of the owners. The remaining number of rented farms are rented mostly for a share of the crops.

Most of the farmsteads on the prairie land are protected from the winds and summer heat by groves of planted willow, cottonwood, ash, or some other trees (fig. 8). Nearly all the farm buildings are painted. Two-story frame houses are most common (fig. 9). The barns, as a rule, are the largest buildings on the farms, being large enough to house the cattle and work animals and provide storage for feed and for some or all of the farm machinery and implements. More than half of the farms are equipped with telephones, but only a few of them have electric lights and water pumped into the houses.

Most of the farms are fairly well equipped with modern machinery. The farmers of the area in 1930 used 5,799 tractors, 2,592 trucks, and 15,957 automobiles, 1,086 electric motors, and 9,592 stationary gas engines for farm work. The common equipment includes grain drills, cultivators, binders, plows, and harrows.

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By far the greater part of the farm labor is done by the farmers and by the members of their families. In threshing, labor is ex-

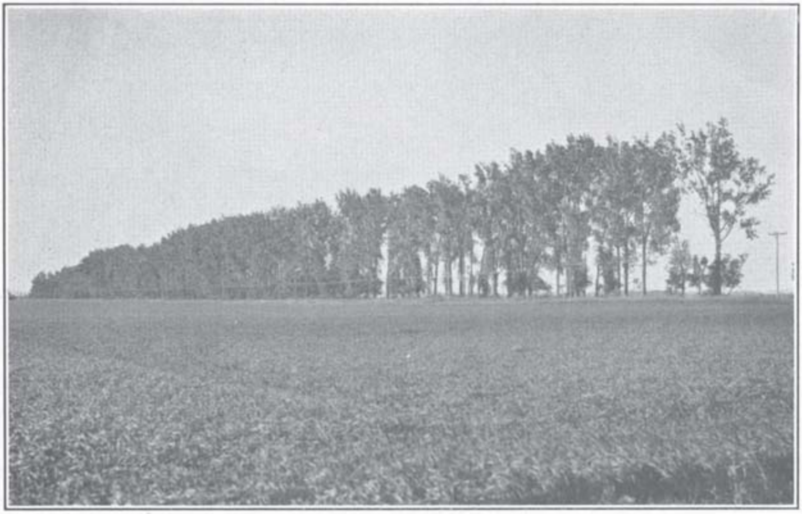

FIGURE 8.—Windbreak in Red River Valley, Minn.

changed among neighboring farmers, and some hired help is used. The 1930 census reports that 10,179 farmers of the area spent $3,080,-483 for hired labor in 1929. The total number of days of labor em-

FIGURE 9.—Typical farmstead in Red River Valley, Minn.

ployed was 1,342,670, an average of about $2.25 a day of work and about 130 labor days on each farm. A relatively greater part of the hired labor is employed in the potato-growing districts and on the sugar-beet plantations. The use of commercial fertilizers is insignificant in the area.

Table 8, compiled from the United States census of 1935, shows the acreage of grain, forage, and other crops in 1934 and the main crops produced in this year by the eight counties comprising the area.

TABLE 8.—*Acreage of the principal crops grown in the Red River Valley area, Minn., by counties, in 1934, as reported by the 1935 census*

Crop	Kittson	Marshall	Polk	Red Lake	Norman	Clay	Wilkin	Traverse	Total
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Corn for all purposes	11, 041	20, 026	38, 231	7, 672	29, 612	39, 003	55, 185	60, 285	261, 055
Harvested for grain	42	17	450	215	408	2, 619	5, 106	1, 810	10, 667
Wheat threshed	69, 116	61, 666	152, 528	14, 337	61, 040	84, 956	37, 171	18, 205	499, 019
Oats threshed	45, 406	67, 902	122, 922	38, 964	93, 930	75, 303	26, 998	15, 826	487, 251
Cut and fed unthreshed	1, 738	536	1, 884	1, 397	364	667	106	448	7, 140
Barley threshed	35, 850	42, 021	77, 724	6, 894	54, 770	50, 266	19, 925	8, 962	296, 412
Rye threshed	5, 113	12, 626	8, 834	2, 854	13, 742	10, 838	7, 187	857	62, 051
Mixed grains threshed	1, 095	3, 900	6, 104	1, 228	2, 703	2, 013	457	1, 038	18, 538
Flax threshed	31, 444	49, 684	60, 979	14, 408	12, 310	8, 864	11, 574	7, 368	196, 631
Potatoes	9, 916	4, 930	24, 998	1, 327	17, 529	39, 823	6, 018	531	105, 072
Sugar beets	579	2, 012	8, 506	-------	401	850	-------	-------	12, 348
Hay and forage	62, 962	142, 717	201, 863	39, 915	73, 959	114, 873	60, 833	43, 110	740, 232
Timothy and clover	2, 346	8, 906	4, 629	2, 479	1, 511	1, 071	241	199	21, 382
Sweetclover and lespedeza	14, 678	14, 649	27, 740	6, 500	8, 296	10, 055	4, 138	2, 102	88, 158
Alfalfa	3, 010	8, 039	24, 005	7, 289	9, 125	8, 885	4, 705	5, 024	70, 082
Small grains for hay	7, 316	10, 241	10, 361	797	7, 699	3, 118	10, 205	24, 678	74, 415
Other tame and wild grasses	33, 831	100, 362	134, 611	22, 847	46, 870	91, 252	41, 283	10, 914	481, 970
Legumes for hay	148	141	310	-------	55	44	-------	20	718

The 10-year average acre yields as compiled from the annual crop reports of the Minnesota State Department of Agriculture prior to 1930, are wheat 11.8 bushels, oats 27.7 bushels, barley 23.7 bushels, flax 8 bushels, corn 27.2 bushels, rye 14.2 bushels, potatoes 93.6 bushels.

Almost three-fourths of the acreage planted to corn was in the southern four counties, and almost one-third of this acreage was in Traverse County, especially in its southern upland section. Practically all of the corn was cut for silage and fodder or was hogged off, only 4.1 percent being harvested for grain in 1934.

Wheat is mostly spring sown, only a small acreage being sown to winter wheat. Approximately one-third of the total acreage is devoted to durum, or macaroni, wheat. Wheat is seeded at a rate of 1½ bushels an acre. Wheat is the principal crop, and is grown mainly in the western part of the area along Red River.

Oats are grown extensively throughout the area. The relative proportion of the acreage devoted to this crop in the southern four counties is slightly greater than that in the northern part of the area. Oats are seeded at a rate of about 2.5 bushels an acre. The most generally grown varieties are Gopher and White Russian.

The acreage of barley is more or less proportionally distributed throughout the area. The amount of seed used averages about 2 bushels an acre.

Potatoes are grown mostly in Clay County and along Red River in the southern part of Polk County. Early Ohio and Irish Cobbler are the most commonly grown varieties. The amount of seed used ranges from 10 to 14 bushels an acre.

The acreage of the wild grasses cut for hay represents mainly the area of the poorly drained lands, mostly located back of the gravelly ridges and especially along the shores of the ancient lake. It includes, also, the narrow strips of wet land which border the smaller watercourses and which are unsuitable for cultivated crops. Wild hay yields an average of about two-thirds ton an acre.

Timothy, alfalfa, and all kinds of clover are the leading tame grasses. Timothy, alone or mixed with clover, yields slightly less than 1 ton of hay an acre; alfalfa an average of about 1¼ tons; and clover an average of 1 ton. A considerable acreage of sweetclover is used for pasture. Some clover, alfalfa, and timothy are harvested for seed.

Table 9 shows the acreage sown to the principal crops in 1899 and in 1929.

TABLE 9.—*Acreage of the principal crops grown in the Red River Valley area, Minn., in 1899 and 1929*

Crop	1899		1929	
	Acres	Percent	Acres	Percent
Corn	13,440	1	182,101	11
Wheat	1,231,018	77	441,440	27.5
Oats	276,496	17	539,525	34
Barley	83,857	5	443,155	27.5
Total	1,604,811	100	1,606,221	100

The total acreage sown to the four principal crops in 1929 was practically the same as that in 1899. In 1929, however, wheat occupied only about 36 percent of the area sown to it in 1899. The decrease of about 790,000 acres was distributed among barley (about 360,000 acres), oats (about 260,000 acres), and corn (about 170,000 acres). This shift was more pronounced in the four southern counties, where the acreage of wheat in 1929 comprised only 29 percent of that in 1899. These changes, resulting from changing economic and natural conditions, indicate a general shift from strictly cash crops to feed crops. In conformity with this general process, the acreage of tame hay increased markedly, from slightly more than 40,000 acres in 1900 to more than 300,000 acres in 1930.

Table 10 shows the numbers of different kinds of livestock, by counties, as reported by the Federal census in 1930 and in 1935. The figures for 1930 are as of April 1, and those for 1935 are as of January 1 and do not include the annual spring increase of many kinds of livestock.

TABLE 10.—*Livestock on farms in the Red River Valley area, Minn., Apr. 1, 1930, and as reported by the Federal census Jan. 1, 1935*

Kind of livestock	Kittson	Marshall	Polk	Red Lake	Norman	Clay	Wilkin	Traverse	Total
APR. 1, 1930									
Horses	8,453	12,366	22,519	4,248	11,627	13,259	8,512	7,531	88,515
Cattle	21,950	39,268	61,221	15,845	29,019	28,517	21,114	18,328	235,262
Cows milked, 1929	8,797	17,175	27,771	7,032	13,253	13,111	8,573	7,360	103,072
Sheep	22,850	38,116	31,953	12,167	9,338	4,837	7,002	8,263	134,526
Swine	2,880	4,242	10,023	1,983	10,295	8,105	19,966	25,888	83,382
Chickens, over 3 months old	75,203	136,430	281,366	51,455	149,225	139,555	100,347	104,873	1,038,454
Turkeys	48,188	113,223	93,852	25,124	40,814	48,400	25,625	17,789	413,015
Ducks	539	3,465	5,425	1,222	4,582	4,155	6,832	9,452	35,672
Geese	1,825	4,893	5,922	2,324	4,090	2,437	4,203	5,760	31,454
Hives of bees	394	578	1,613	611	492	1,101	273	343	5,405
JAN. 1, 1935									
Horses	6,348	11,526	19,942	4,325	11,080	11,986	7,696	6,219	79,122
Cattle	24,241	40,174	67,987	16,680	35,532	33,872	22,644	16,612	257,742
Cows milked, 1934	11,060	21,799	34,502	8,544	15,851	15,524	9,905	8,150	125,335
Sheep	24,100	40,154	36,091	10,216	11,155	10,728	9,973	7,933	150,350
Swine	2,661	4,512	9,878	2,452	6,236	6,441	5,972	7,327	45,479
Chickens	61,345	122,187	265,967	45,179	141,104	121,073	80,572	82,607	920,034
Turkeys	9,092	18,795	17,447	5,428	8,895	9,195	6,509	3,846	79,207

FIGURE 10.—Grazing sheep in Clay County. Sheep from drier sections farther west are frequently finished in Red River valley.

Nearly every farmer raises some cattle. The total number in the area averages about 15 a farm, of which almost 50 percent are milk cows. The total production of milk in 1929 was 58,938,828 gallons, and in 1934 it was 49,764,225 gallons. The principal item of the income from dairy cows was cream sold as butterfat, 13,789,706 pounds being sold in 1929, an average of 133.8 pounds a cow. Another considerable item was the butter churned on the farms, the total production being 2,084,933 pounds. Only about 10 percent of this was sold, and the remainder was consumed at home. The total value of the dairy products sold was reported as $7,150,889, an average of $69.37 a cow.

Poultry are raised on nearly every farm. The chicken eggs produced numbered 6,713,049 dozen in 1929, of which 4,434,338 dozen were sold. Chickens sold alive or dressed numbered 722,548. The 1935 census reports 6,200,504 dozens of eggs produced in 1934.

The total value of all domestic animals and poultry was reported by the 1930 census as $22,827,729.

Because of differences in collecting the census data, no strict comparison can be made between the numbers of the different kinds of livestock in the area in 1900 and in 1935, but the numbers were about doubled during this period. The total number of milk cows increased from about 56,000 in 1900 to 125,335 in 1935; sheep from about 50,000 in 1900 to more than 150,000 in 1935 (fig. 10); swine from about 60,000 in 1900 to about 83,000 in 1930, but this number decreased to 45,479 in 1935; chickens from 509,232 in 1900 to 920,034 in 1935; and turkeys from 3,688 in 1900 to 79,207 in 1935.

In addition to the general increase in numbers, definite improvement has been made in the quality of the livestock, especially of the dairy cows. The latter resulted in an increase of the milk production from slightly more than 21 million gallons in 1899 to almost 49¾ million gallons in 1934. These changes are closely related to the general shift from cash-crop farming to feed-crop farming.

SOIL-SURVEY METHODS AND DEFINITIONS

A soil survey consists of the examination, description, classification, and mapping of soils in the field.

Every soil is made up of several layers or horizons called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is characterized by definite color, texture, structure, porosity, consistence, and content of organic matter, gravel and other stones, and various salts. All these characteristics are studied in detail. For this purpose test pits are dug in appropriate locations. The soil type being established, its geographical distribution is examined by additional pits and borings and by an observation of all available exposures of the soil profile, such as those in roads or railroad cuts, ditches, and cliffs. The external features of the land, such as drainage, relief or lay of the land, vegetation, and stoniness, are described in connection with each profile.

The soils are classified or grouped into various categories according to their characteristics, both internal and external. The units of the two principal categories of soil classification are series and type. In addition to these, soil phases are recognized, and also several so-called miscellaneous land types, such as peat, riverwash or bottom land, sand dunes, and rough broken land.

A soil series is a group of soils developed from a particular type of parent material and having a similar arrangement of the horizons in the profile. Thus the series includes soils having essentially the same parent material, color, and sequence of the horizons, the same natural drainage condition, range in relief, and natural vegetation, and the same origin or mode of formation. All these external and internal characteristics may vary within limited ranges, provided these variations are due to quantitative changes rather than to qualitative changes. The texture of the upper part of the soil, however, may vary within a series qualitatively. The soil series are given names of places or geographic features near which they were first found; for example, the Fargo series includes soils first described in the vicinity of Fargo, N. Dak.; the Barnes series includes the black soils first described in Barnes County, N. Dak.; the Pelan series is composed of soils first described in Pelan Township, Kittson County, Minn.

A soil type is a unit within a soil series, defined according to the texture of the upper part of the soil, including that commonly plowed. Several classes of soil texture, such as sand, loamy sand, sandy loam, loam, silt loam, clay loam, silty clay loam, and clay, are recognized. The class name of soil texture added to the series name gives the complete name of the soil type; for example, Fargo clay, Barnes loam, and Barnes silt loam. The soil type is the principal unit of mapping and, because of its specific character, is usually the land unit to which agronomic data are referred.

A soil phase is a minor, and in most instances local, subdivision of the soil type or soil series which differs from the normal soil in some minor characteristic. The difference by which a soil phase can be distinguished from the normal soil is naturally not greater than that permitted by the range of variability within this unit; nevertheless, it may have an important practical significance.

Because of the small scale of the soil maps, a majority of the soil phases are not shown separately. These phases, however, were examined and have been described so that they can be recognized easily in the field.

In several instances groups of two or three different but closely related soils are indicated on the maps as a unit made up of several soil types, or series, undifferentiated. This indicates that variations of some soil characteristics in such areas are greater than those permitted by the ranges established for each series or type, the precise mapping of which was not justified by the scale of the maps or by practical consideration.

SOILS AND CROPS

Two principal physiographic divisions—the upland and the lake bottom—have been described, and these can be subdivided into six smaller areas on the basis of the character of the dominant soils. These subdivisions extend north and south in more or less distinct belts, and each of the six subdivisions is dominated by one of the soils composing the group.

Beginning at the western boundary of the area, the first subdivision is that occupied by the heavy clayey soils. This extends along the entire length of the area surveyed. East of this is the second subdivision covered by mellow, soft, silty, and loamy soils. This extends as an uninterrupted belt across Norman and Clay Counties, but is broken into isolated tracts in Wilkin, Traverse, and Polk Counties and is practically absent in the northern counties. Farther east, in the third subdivision, loose sandy soils cover an almost continuous strip of land from the middle of Wilkin County to the northern end of the area. East of this, in the three northern counties of the area—Kittson, Marshall, and Red Lake—and in several townships in Polk County, lies the fourth subdivision occupied by a combination of different soils with a considerable proportion of gravelly types. This is a forested section, whereas the first three subdivisions are all open land. East of the third subdivision, in the southern half of the area in Norman and Clay Counties, the northeastern part of Wilkin County, the southeastern part of Polk County, and the southern part of Traverse County, lies the upland part of the area, which comprises two subdivisions—one forested and one open. The soils of the area which are most extensive in the six subdivisions and for which the six groups are named, are the Fargo, Bearden, Ulen, Pelan, Barnes, and Waukon. Several of these groups includes more than the one series of soils by which the group is named.

In the following pages the soils of the Red River Valley area are described in detail, and their agricultural relationships are discussed; the accompanying soil maps show their location and distribution; and tables 11–19 give their acreage and proportionate extent in the area as a whole and in each county separately.

TABLE 11.—*Acreage and proportionate extent of the soils mapped in the Red River Valley area, Minn.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Fargo clay	1,016,064	18.6	Barnett clay loam	1,152	0.1
Fargo silty clay loam	636,672	11.6	Taylor silt loam	15,168	.3
Bearden loam	256,704	4.7	Barnes loam	261,248	4.8
Bearden silt loam	160,000	2.9	Barnes silt loam	45,504	.8
Ulen loamy sand	585,152	10.7	Barnes silt loam, slope phase	6,272	.1
Ulen sandy loam	25,088	.4	Barnes sandy loam	37,312	.7
Grimstad fine sandy loam	168,064	3.1	Barnes stony loam	8,448	.2
Poppleton loamy fine sand	363,072	6.6	Parnell silty clay loam	21,760	.4
Poppleton loamy fine sand, shallow phase	14,848	.3	Pierce gravelly loamy sand	8,064	.1
			Waukon loam	124,352	2.3
Tanberg soils, undifferentiated	141,632	2.6	Waukon silt loam	22,528	.4
			Waukon loamy sand	15,232	.3
Sioux loamy sand	145,152	2.6	Nebish loam	101,632	1.8
Arveson sandy loam	28,992	.5	Mahnomen loamy sand	15,296	.3
Foxhome sandy loam	123,648	2.2	Alluvial soils, undifferentiated	160,960	2.9
Foxhome loamy sand	9,088	.2			
Gatzke clay	4,480	.1	Dune sand	3,392	.1
Kittson silt loam	6,336	.1	Peat	425,472	7.8
Kittson gravelly silt loam	3,008	.1	Rough broken land	8,576	.2
Kittson clay loam	6,208	.1			
Kittson, Gatzke, and Nereson soils, undifferentiated	113,472	2.1	Total	5,468,160	
Pelan and Kittson soils, undifferentiated	378,112	6.9			

TABLE 12.—*Acreage and proportionate extent of the soils mapped in Kittson County, Minn.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Fargo clay	153,920	21.7	Gatzke clay	4,480	0.6
Fargo silty clay loam	114,560	16.1	Kittson silt loam	4,992	.7
Bearden loam	5,760	.8	Kittson gravelly silt loam	3,008	.4
Ulen loamy sand	35,840	5.0	Kittson clay loam	576	.1
Grimstad fine sandy loam	13,440	1.9	Pelan and Kittson soils, undifferentiated	91,712	12.9
Poppleton loamy fine sand	166,400	23.4			
Tanberg soils, undifferentiated	3,072	.4	Alluvial soils, undifferentiated	21,248	3.0
Sioux loamy sand	10,368	1.5	Dune sand	960	.1
Arveson sandy loam	14,784	2.1	Peat	65,920	9.3
			Total	711,040	

TABLE 13.—*Acreage and proportionate extent of the soils mapped in Marshall County, Minn.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Fargo clay	148,096	12.9	Kittson clay loam	5,632	0.5
Fargo silty clay loam	94,400	8.3	Kittson, Gatzke, and Nereson soils, undifferentiated	83,648	7.3
Bearden loam	20,928	1.8	Pelan and Kittson soils, undifferentiated	233,600	20.4
Bearden silt loam	7,936	.7	Barnett clay loam	1,152	.1
Ulen loamy sand	102,144	8.9	Mahnomen loamy sand	5,632	.5
Grimstad fine sandy loam	30,080	2.6	Alluvial soils, undifferentiated	20,096	1.8
Poppleton loamy fine sand	87,488	7.7	Peat	234,368	20.5
Tanberg soils, undifferentiated	23,424	2.0	Total	1,144,320	
Sioux loamy sand	38,592	3.4			
Arveson sandy loam	5,760	.5			
Kittson silt loam	1,344	.1			

TABLE 14.—*Acreage and proportionate extent of the soils mapped in Red Lake County, Minn.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Fargo clay	6,464	2.3	Kittson, Gatzke, and Nereson soils, undifferentiated	22,848	8.3
Fargo silty clay loam	12,672	4.6	Pelan and Kittson soils, undifferentiated	27,968	10.1
Ulen loamy sand	55,296	20.0	Taylor silt loam	14,720	5.3
Grimstad fine sandy loam	19,968	7.2	Mahnomen loamy sand	1,344	.5
Poppleton loamy fine sand	38,976	14.1	Alluvial soils, undifferentiated	19,072	6.9
Poppleton loamy fine sand, shallow phase	13,632	5.0	Peat	21,248	7.7
Tanberg soils, undifferentiated	3,136	1.1	Total	276,480	
Sioux loamy sand	4,800	1.7			
Arveson sandy loam	1,856	.7			
Foxhome sandy loam	12,480	4.5			

TABLE 15.—*Acreage and proportionate extent of the soils mapped in Polk County, Minn.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Fargo clay	228,992	18.1	Taylor silt loam	448	0.1
Fargo silty clay loam	222,464	17.5	Barnes loam	6,720	.5
Bearden loam	25,984	2.0	Barnes silt loam	3,072	.2
Bearden silt loam	61,376	4.8	Barnes sandy loam	21,632	1.7
Ulen loamy sand	117,376	9.3	Parnell silty clay loam	2,496	.2
Grimstad fine sandy loam	17,152	1.4	Waukon loam	92,416	7.3
Poppleton loamy fine sand	47,744	3.8	Waukon silt loam	11,840	.9
Poppleton loamy fine sand, shallow phase	1,216	.1	Waukon loamy sand	15,232	1.2
Tanberg soils, undifferentiated	19,840	1.6	Nebish loam	101,632	8.0
Sioux loamy sand	28,736	2.3	Mahnomen loamy sand	8,320	.7
Arveson sandy loam	6,336	.5	Alluvial soils, undifferentiated	35,520	2.8
Foxhome sandy loam	78,528	6.2	Dune sand	2,176	.2
Kittson, Gatzke, and Nereson soils, undifferentiated	6,976	.5	Peat	77,504	6.1
Pelan and Kittson soils, undifferentiated	24,832	2.0	Total	1,266,560	

TABLE 16.—*Acreage and proportionate extent of the soils mapped in Norman County, Minn.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Fargo clay	100,480	17.9	Barnes loam	30,016	5.3
Fargo silty clay loam	76,480	13.6	Barnes silt loam	2,944	.5
Bearden loam	63,232	11.3	Parnell silty clay loam	640	.1
Bearden silt loam	38,336	6.8	Waukon loam	31,936	5.7
Ulen loamy sand	106,816	19.0	Waukon silt loam	10,688	1.9
Poppleton loamy fine sand	22,464	4.0	Alluvial soils, undifferentiated	17,664	3.1
Tanberg soils, undifferentiated	21,248	3.8	Dune sand	256	.1
Sioux loamy sand	21,888	3.9	Peat	6,336	1.1
Arveson sandy loam	256	.1	Rough broken land	7,424	1.3
Foxhome sandy loam	2,816	.5	Total	561,920	

TABLE 17.—*Acreage and proportionate extent of the soils mapped in Clay County, Minn.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Fargo clay	129, 600	19. 4	Barnes loam	140, 160	21. 0
Fargo silty clay loam	36, 864	5. 5	Barnes silt loam	3, 328	. 5
Bearden loam	88, 448	13. 3	Barnes sandy loam	4, 288	. 6
Bearden silt loam	22, 336	3. 3	Barnes stony loam	8, 448	1. 3
Ulen loamy sand	102, 400	15. 3	Parnell silty clay loam	11, 776	1. 8
Ulen sandy loam	6, 912	1. 0	Pierce gravelly loamy sand	8, 064	1. 2
Grimstad fine sandy loam	9, 920	1. 5	Alluvial soils, undifferentiated	21, 952	3. 3
Tanberg soils, undifferentiated	31, 360	4. 7	Peat	15, 424	2. 3
Sioux loamy sand	19, 840	3. 0	Rough broken land	1, 152	. 2
Foxhome sandy loam	2, 048	. 3			
Foxhome loamy sand	3, 200	. 5	Total	667, 520	

TABLE 18.—*Acreage and proportionate extent of the soils mapped in Wilkin County, Minn.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Fargo clay	157, 888	33. 1	Foxhome sandy loam	20, 800	4. 4
Fargo silty clay loam	47, 232	9. 9	Foxhome loamy sand	5, 888	1. 2
Bearden loam	16, 896	3. 5	Barnes silt loam	15, 488	3. 3
Bearden silt loam	11, 392	2. 4	Barnes sandy loam	10, 240	2. 2
Ulen loamy sand	55, 872	11. 7	Parnell silty clay loam	960	. 2
Ulen sandy loam	18, 176	3. 8	Alluvial soils, undifferentiated	17, 664	3. 7
Grimstad fine sandy loam	51, 520	10. 8	Peat	4, 672	1. 0
Tanberg soils, undifferentiated	28, 224	5. 9			
Sioux loamy sand	13, 888	2. 9	Total	476, 800	

TABLE 19.—*Acreage and proportionate extent of the soils mapped in Traverse County, Minn.*

Type of soil	Acres	Percent	Type of soil	Acres	Percent
Fargo clay	90, 624	24. 9	Barnes loam	84, 352	23. 2
Fargo silty clay loam	32, 000	8. 8	Barnes silt loam	20, 672	5. 7
Bearden loam	35, 456	9. 8	Barnes silt loam, slope phase	6, 272	1. 7
Bearden silt loam	18, 624	5. 1	Barnes sandy loam	1, 152	. 3
Ulen loamy sand	9, 408	2. 6	Parnell silty clay loam	5, 888	1. 6
Grimstad fine sandy loam	25, 984	7. 2	Alluvial soils, undifferentiated	7, 744	2. 1
Tanberg soils, undifferentiated	11, 328	3. 1			
Sioux loamy sand	7, 040	2. 0	Total	363, 520	
Foxhome sandy loam	6, 976	1. 9			

SOILS OF THE FARGO GROUP

The width of the belt comprising the first subdivision from west to east, the soils of the Fargo group, ranges from 5 to about 15 miles, except at two points where narrow projections of the second subdivision extend to the river banks. This belt comprises about 3,000 square miles, at least 2,500 of which are covered by heavy soils. The entire belt has a uniform plains relief and constitutes the flattest part of the area (fig. 11), its general westward slope being only a few inches a mile and its northward slope ranging from 6 inches to 1 foot a mile.

The natural drainage conditions of this strip divide it into two unequal parts. The smaller of these, which is fairly well drained, is composed of strips of land adjacent to the river channel and is drained directly into it or indirectly through the numerous coulees.

The surface drainage of the larger part recently has been improved by a system of artificial drains, before the construction of which this part was occupied by large marshes and sloughs. It is composed of several isolated tracts, the largest of which are in Kittson, Marshall, Polk, and Norman Counties.

The entire subdivision, in both well and poorly drained parts, originally supported a luxuriant cover of wild grasses, with forest vegetation occupying only narrow strips along the stream banks and bottom-land areas bordering the larger streams.

The soils of this subdivision are remarkably uniform, only two different types of soil occurring here, each of which occupies large continuous areas many square miles in extent, some of them several townships. These are soils of the Fargo series—Fargo clay and Fargo silty clay loam. The outstanding characteristics of the Fargo soils are the conspicuously heavy texture of both the soil itself and of

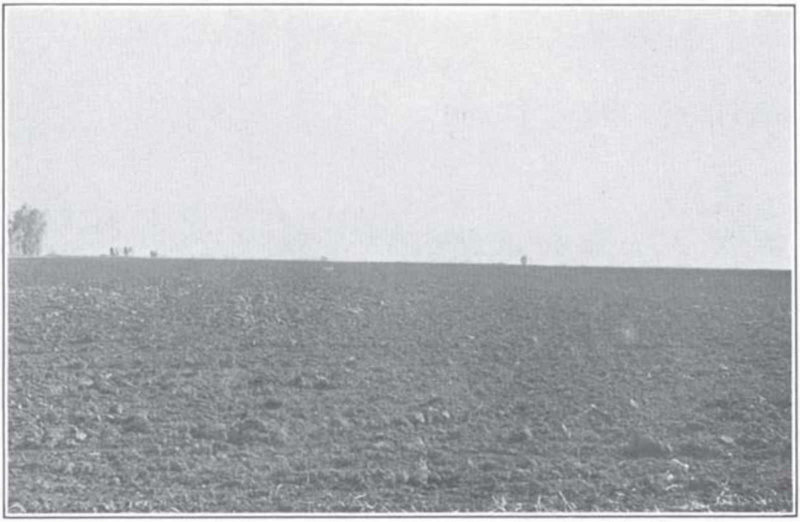

FIGURE 11.—Relief of the western belt of the area covered by the soils of the Fargo series. Note that the surface soil has been left in a cloddy condition as a precaution against soil blowing.

the material from which it is derived, and the typically black color of the surface soil, underlain by the gray or olive-gray clayey subsoil. Persons living outside this belt call it "gumbo" land, but the local farmers apply the name gumbo to the soil in somewhat depressed spots, scattered through their fields, which are occupied by extremely heavy and usually alkaline soil.

The surface layers of every Fargo soil are intensely black, because of the high content of organic matter. This black soil usually is very sticky when wet and breaks into large hard clods on drying. The upper subsoil layers in most places contain a considerable amount of lime. The heavy character of both the surface soils and the subsoils enables them to hold a considerable amount of moisture.

The soils of the Fargo group are those upon which the reputation of Red River Valley was built. The farming, in the earlier periods of agricultural development of the country, took place on the Fargo soils, and the reputation of the area, although somewhat exaggerated, was founded on the good crops of wheat produced after comparatively little preparation of the land. It must be pointed out, however, that this widespread reputation of the Fargo soils was established at a time when only the best sections of the area had been brought under cultivation. These constitute the better drained land bordering the rivers, occupied by the more perfectly developed or more mature soils.

Although not all soils of the Fargo group deserve the same high qualification, it is nevertheless true that, as a whole, they are the main agricultural soils of the region and are naturally rich in plant nutrients. Practically the entire area covered by these soils is under cultivation, and the naturally well-drained tracts, having been brought under cultivation more than 50 years ago, are in crops nearly

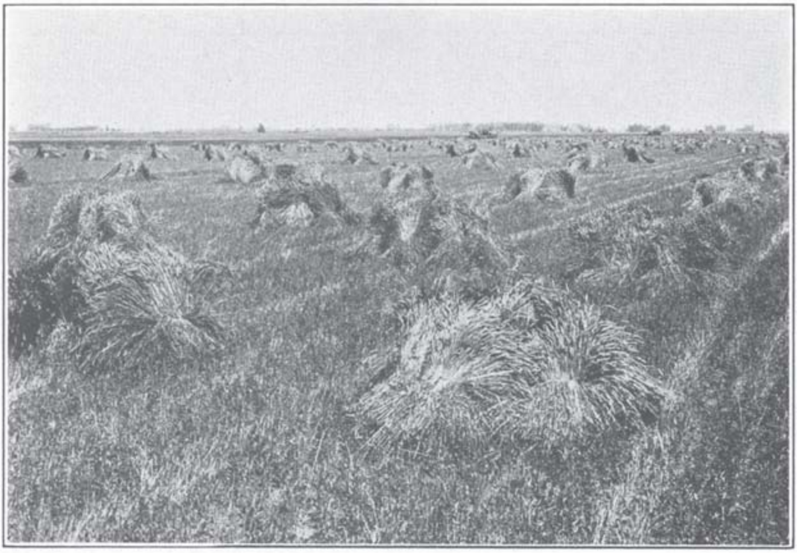

FIGURE 12.—Crop of wheat on Fargo soil. This is the principal crop and gives the Red River Valley the name of "the bread basket of the Nation." (Photo furnished by the Northwest Experiment Station at Crookston, Minn.)

every year and in normal years produce a good yield without the application of fertilizers. Even barnyard manure is not used by many farmers but is dumped on the river banks or in the barnyard.

The natural richness of the soils was an important factor influencing the development of the local systems of farming. The uselessness of manuring was a strong limiting factor for the growth of dairying. The monotony of the general landscape and, most of all, the uniformity of the soils encouraged a narrowly specialized kind of land utilization. The wide-open tracts, free from hollows, ravines, stones, or trees, were easily converted into continuous fields well adapted for growing grain on a large scale (fig. 12). Very little land, except the wet tracts, was left for pasture and hay production. General economic conditions and marketing problems, together with the example of the bonanza farms, were such that from the very beginning farming in this area developed along the line of commercial wheat growing. Relatively few dairy cattle were kept on the farms; on most farms only enough to provide for the home needs. Changes in economic conditions and in the availability of markets necessitated changes in farm practice, which are still in progress. Wheat continues to be the leading crop in the belt occupied by the Fargo soils, but considerable acreages are used for the production of oats and barley, which are the principal crops, in addition to wheat, grown on the heavy soils in the valley. Much of the recently drained land is devoted to flax. Practically no potatoes, no rye, very little corn, and very little sweetclover are grown in this belt, although sweetclover is becoming increasingly popular because of the common belief that it improves the physical condition of the exceedingly heavy gumbo soils.

Fargo clay.—Fargo clay is the most extensive soil and, agriculturally, one of the three most important soils in the area. The surface soil is typically black and ranges in thickness from 6 inches to about 2 feet. Its color depends on a rather high content of organic matter incorporated in the soil by decomposition of grass residues. The texture of this layer ranges from silty clay to clay, the clay being by far the most common. In some places this material breaks on drying into small sharp angular lumps, but in most places it has a rather compact and massive consistence and is broken into very large irregular clods. The subsoil is rather dark drab-gray or olive-gray compact clay. Because of the great contraction of the clay, both the surface soil and the subsoil crack on drying. The cracks, many of which are more than 1 inch wide at the surface, penetrate the subsoil to a depth of more than 3 feet. The black soil material from the surface, blown by wind and washed by rain, fills the cracks, producing characteristic narrow wedge-shaped but irregular tongues extending downward from the base of the surface soil layer.

The subsoil of Fargo clay is typically rich in lime, lime carbonate occurring at an average depth of about 20 inches below the surface, although in many large and rather inadequately drained areas it is much closer to the surface, and in some places the subsoil contains numerous more or less brittle nodules or concentrations of almost pure lime ranging in size from small grains to aggregates about 1 inch in diameter. In many places lime is disseminated more or less evenly throughout the subsoil in a layer 2 or 3 feet thick, the content gradually decreasing at the greater depth. Other salts, especially gypsum, occur in places at a depth of 3 or more feet, but these also may be much closer to the surface in the poorly drained areas. Both the surface soil and the subsoil of Fargo clay are typically free from stones.

Fargo clay covers large continuous areas, some of which extend for many miles, and is very uniform in its characteristics wherever it occurs. The surface of the areas is typically flat with a gentle slope that averages a few inches a mile.

By far the greater part of the area of Fargo clay occupies open prairie; only narrow strips along the stream banks, especially along Red River and its main tributaries, are under forest vegetation. Most of the original forest growth, consisting principally of oaks, has been cut, and the land has been brought under cultivation. Because of their location, close to the streams, these areas have better surface drainage than the areas lying at a greater distance, and the soil of these areas differs slightly from typical Fargo clay. It has a dark-gray color that is distinctly lighter than that of the typical soil and in many places shows a slight brown tint. In many places the soil in these areas is less compact, has a somewhat lighter texture, and breaks into small irregular lumps.

A number of large areas extending to some distance from the streams had, until recently, rather poor surface drainage, but this has been improved by the construction of an extensive system of deep ditches. The soil of these areas differs somewhat from typical Fargo clay, in that the black surface soil is rather thin, averaging about 6 inches, and the lime carbonate occurs in greater quantity and much closer to the surface, giving a much lighter color to the upper part of the subsoil.

Fargo clay is characterized by a rather frequent occurrence of spots of soil recognized as an "alkali" phase of Fargo clay but which are undifferentiated on the small-scale maps. The surface soil in such spots is characterized by a very compact or dense and somewhat waxy consistence that is especially pronounced in the lower part of the layer. The soil is exceedingly sticky and almost completely watertight when it is wet. On drying it becomes very hard and breaks into large solid clods separated from each other by wide irregular cracks. In many spots the upper part of the surface soil is somewhat lighter in texture and color, and in places is very light gray, soft and powdery, and of a light texture. It rests on a black very dense layer of material which breaks during the dry season into small irregular prisms. The spots of such soil are small, most of them ranging from 15 to 30 feet in diameter, and are scattered throughout the areas of typical soil.

Because of its fine texture, Fargo clay retains a considerable amount of moisture, dries slowly, and shows a strong tendency to clod. When wet, it is, as a rule, very sticky, and if plowed in such condition, forms coarse clods which become very hard when dry. In the preparation of this soil, better results are obtained if the soil is plowed when it is relatively dry. Fall plowing is commonly practiced.

Almost the entire area of this soil is under cultivation, most of which is planted to wheat. Other important, though less extensive, crops are barley and oats. Acre yields of wheat range from 10 to about 35 bushels, oats 30 to 70 bushels, and barley 20 to 60 bushels.

Fargo silty clay loam.—The surface soil of Fargo silty clay loam ranges in color from very dark gray to black, in thickness from 6 inches to about 2 feet, and in texture from silt loam to silty clay. The color of the subsoil is drab gray or olive gray, in some places having a pronounced yellow tint, and in most places is much lighter than the subsoil of Fargo clay.

Both the surface soil and the subsoil of Fargo silty clay loam are less dense than those of Fargo clay, although when thoroughly wet the soil is very sticky and breaks into coarse firm clods after drying. The cracks that separate the clods penetrate the subsoil to a depth of more than 3 feet and, being filled with dark soil from the surface layer, produce a fringe of dark streaks and tongues extending downward from the base of the surface soil layer, but these dark streaks are less conspicuous than in Fargo clay, and many of the streaks do not extend so deeply and are less sharp and distinct than those in the heavier soil.

Lime carbonate occurs at an average depth of about 15 inches, but in many places is much closer to the surface. In many places lime is accumulated in streaks or brittle concretions ranging in size from small grains to nodules more than 1 inch in diameter. The subsoil and the substratum are limy to a considerable depth with a more or less distinct zone of lime accumulation below the surface soil layer in which the streaks and concretions occur. This zone extends to a depth of 2 or 3 feet and in most places is characterized by a much lighter olive-gray color. Gypsum occurs in the substratum in many places, usually at a somewhat greater depth than that of the lime carbonate. Fargo silty clay loam is typically free from stones.

This soil occupies large tracts, but it is not so uniform as Fargo clay. Most of these tracts are along the eastern boundary of the belt occupied by the Fargo soils. Many of these tracts are associated with formerly poorly drained land, and a large part of this land is still characterized by rather slow and inadequate surface drainage, although the drainage has been greatly improved by the construction of deep ditches.

The soil of the poorly drained areas differs from the typical soil in that the surface soil is much thinner, in many places being less than 6 inches thick, and in many places contains a considerable amount of undecomposed or incompletely decomposed grass residues, which gives it a peaty character. The content of lime in the soil in such places is, as a rule, much greater than that in the typical soil, and the lime is much closer to the surface, in most places immediately beneath the black surface soil and in sufficient quantity to give the subsoil a very light gray or olive-gray color.

By far the greater part of Fargo silty clay loam is in cultivation, although a few insufficiently drained areas remain unbroken and are used for pasture and for wild hay.

All the crops commonly grown in the valley do well on this soil. Wheat is the principal crop, and oats and barley are next in importance. A relatively larger acreage than on Fargo clay is devoted to flax, corn, and potatoes, although all these crops are rather unimportant agriculturally.

SOILS OF THE BEARDEN GROUP

The second subdivision, comprising the soils of the Bearden group, lying just east of the belt of clay soils, extends in a north-south direction across Norman and Clay Counties, ranging in width from 2 to about 10 miles, and, entering Wilkin County, disappears about 10 miles south of the northern boundary of this county. In the southern half of Wilkin County and in Traverse County, it consists of several isolated areas, the largest of which is southeast of Dumont in Traverse County. In Polk County, also, several large isolated areas are occupied by the soils typical of this subdivision. Boundaries separating this belt from the neighboring subdivisions on the east and on the west and also the boundaries of the isolated areas are very irregular. The eastern boundary, which separates it from the section of sandy soils, is arbitrary because of the very gradual transition from one kind of soil to the other.

The relief of the soils of the Bearden group is essentially smooth and level, and differs little from the relief of the Fargo soils. Almost the entire area of this belt was open grassland (humid prairie), and the forest vegetation is confined to the narrow strips of bottom land bordering the main streams. The drainage conditions range from moderate to fair. Some areas which had inadequate drainage in the past have been improved by artificial drainage. The difference between the soils of the naturally well drained and the insufficiently drained land is not so marked as in the areas of heavy soils, although some rather small tracts still remain too wet for general farming and are used for pasture.

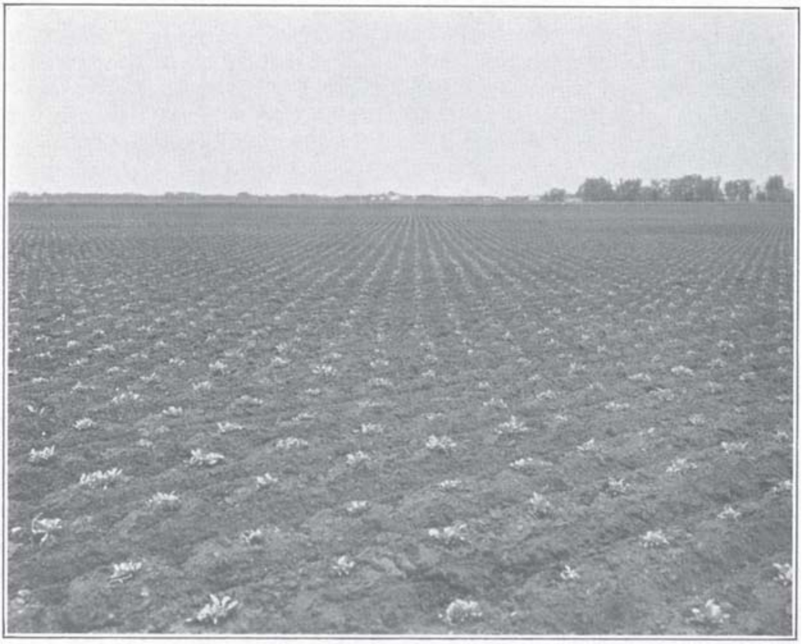

FIGURE 13.—Checkrowed sugar beets before being thinned, in the vicinity of East Grand Forks.

The soils of this belt are fairly uniform, and each type covers large areas several square miles in extent and shows remarkable uniformity and consistency in its features wherever developed. The outstanding features of the soils comprising the Bearden group are their black color, their high content of silt and very fine sand, and their high content of lime carbonate.

Having developed under a grass vegetation, the Bearden soils are rich in organic matter, although not so rich as the Fargo soils. Their surface soils are dark gray or almost black when dry and black when wet. The most typical texture of the Bearden soils is a loam; all of them are mellow soils, and their upper subsoil layers are, as a rule, perceptibly looser than are the dark-colored surface soils. These soils, unlike the Fargo soils, do not crack on drying, and they do not clod, but rather undergo pulverization upon drying, and under all circumstances are much softer and more easily worked than the Fargo soils. Care must be taken to prevent drifting of the freshly plowed dry soil by the wind. The Bearden soils have a lower moisture-retaining capacity than do the Fargo soils, and they dry and warm in the spring earlier than the Fargo soils under the same conditions.

As wheat is a leading crop on the Fargo soils, potatoes and sugar beets are the most typical crops on the Bearden soils. At least three-fourths of the potatoes grown in the area are grown on the soils of this group. The main potato-growing district of Clay County and a sugar-beet district of Polk County are on the Bearden soils (fig. 13). Oats, barley, wheat, corn, and tame hay are relatively less important crops, though the normal crop production is practically the same as that on the Fargo soils (fig. 14). By far the greater part of the area of Bearden soils is under cultivation, and the remainder, which consists mostly of insufficiently drained land, is used for wild hay and for pasture.

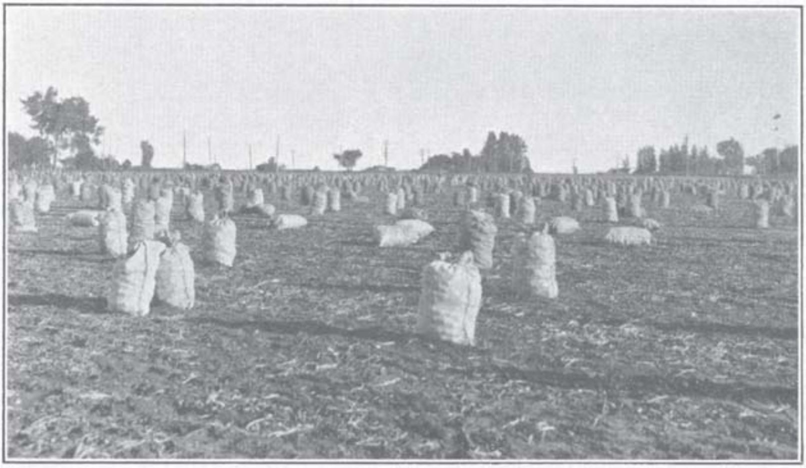

FIGURE 14.—Crop of onions on Bearden loam near Moorhead in Clay County.

The general agricultural landscape of these soils differs from that of the heavy soils chiefly in the overwhelming domination of potatoes. The general appearance of the farmsteads is about the same in both sections, but the windbreaks of planted poplars are more numerous and better cared for on the Bearden soils because of the looser character of these soils and their greater exposure to wind erosion. The eight-horse teams, which are used for plowing the heavy Fargo soils, give place on the Bearden soils to the four- and six-horse teams drawing the same-sized plow. The Bearden soils are naturally rich in lime. Applications of fertilizers, especially phosphates, show greater effect on the Bearden soils than on the Fargo soils. Barnyard manure is not wasted as a useless byproduct but is utilized for the enrichment of the soils.

The Bearden group includes Bearden loam and Bearden silt loam.

Bearden loam.—The surface soil of Bearden loam is dark gray or very dark gray and ranges in thickness from 8 to 18 inches. It consists of soft, mellow, and in some places floury loam, easily tillable under a wide range of moisture conditions and easily penetrable by cultivating implements. The soil does not clod and provides a good seedbed. This layer rests on a very light gray and somewhat more compact loamy subsoil which ranges in thickness from 4 to about 10 inches. When dry, the subsoil material is almost white because of an exceedingly high content of lime. The substratum below the very light gray subsoil consists typically of two layers which, in most places, are rather sharply separated from each other. The upper layer ranges in thickness from less than 6 inches to more than 3 feet and consists of mellow floury material composed of silt and very fine sand, the content of sand gradually increasing in the lower part of the layer. This material has a typical pale-yellow color mottled with numerous very fine dark-brown or black dots. The lower layer of the substratum consists of dark olive-gray compact clay. The boundary between the two layers in most places is rather clear-cut and occurs at a depth of not less than 30 inches from the surface of the ground.

Bearden loam is exceedingly rich in lime carbonate. Lime occurs in all layers from the surface downward and is accumulated in great quantity in the subsoil, that is, in the light-gray layer between the dark-colored surface soil and the pale-yellow upper layer of the substratum. In the upper substratum layer the content of lime noticeably decreases, especially where this layer is more sandy.

This soil is typically free from stones, although thin beds or lenses of fine gravel may occur in places in the substratum just above the lower or clayey layer, mostly in places where Bearden loam is associated with the Foxhome or Sioux soils.

The surface soil, the subsoil, and the upper layer of the substratum, being more or less free from excessive clay, do not contract on drying and do not cake or crack, and no dark streaks extend from the base of the surface soil layer into the subsoil. All boundaries between the different layers of the soil are smooth or gently wavy.

The surface drainage of most of the area occupied by Bearden loam is fair, although in some places it was not adequate for general farming and has been improved by the construction of deep ditches.

By far the greater part of this soil in the Red River Valley area occurs in a few large bodies, the largest of which extends north and south in Norman and Clay Counties. In Traverse County, Bearden loam covers about 55 square miles, forming one continuous body in the southeastern four townships. About 23 square miles of this soil are in the northern part of Wilkin County, and in the northern counties, Kittson, Marshall, and Polk, the areas are comparatively few and small.

Most of this soil is under cultivation. The ease with which the soil can be cultivated, its capacity for absorbing and holding moisture, its fair surface drainage, its comparatively high content of organic matter, and its excellent physical condition, make it most desirable for farming. All crops common to the area do well, but the soil is especially well adapted for corn and potatoes, both of which do remarkably well, because of the ease of cultivation and of maintenance in a proper condition. Potatoes are the leading crop on this soil in Clay and Norman Counties; acre yields range from 75 to 200 bushels, and the tubers are smooth, of uniform size, and of excellent quality. In Traverse County Bearden loam is devoted mostly to corn and small grains.

Bearden silt loam.—Bearden silt loam occupies an intermediate position between Bearden loam and Fargo silty clay loam. It differs from Bearden loam in texture, in its somewhat darker color, and in the slightly greater average thickness of its surface soil; and from Fargo silty clay loam in that the texture of the subsoil and of the upper part of the substratum of the Bearden soil is lighter than that of the surface soil, whereas the texture of the Fargo soil is typically rather uniform from the surface to a considerable depth.

The surface soil of Bearden silt loam ranges in thickness from 8 inches to about 2 feet and is very dark gray or black silt loam. In many places it is rather compact and cracks upon drying, but the cracks do not penetrate the subsoil very deeply and do not produce dark streaks like those in the Fargo soil. The surface soil grades into a light-gray or very light gray subsoil, ranging in thickness from 3 inches to about 1 foot, characterized by the increasing content of silt, which gives it a more mellow consistence and a loamy texture. The substratum consists of two layers. The upper layer is more or less mellow and in places is floury, pale-yellow or very light gray fine silty material. This rests on a layer of drab-gray or olive-gray compact clay. The boundary between the two layers in most places is very sharp, and ranges in depth from less than 2 feet to more than 5 feet. In many places this boundary is more or less smooth, but in other places the top of the clay layer is very uneven and causes sudden and sharp variations in the thickness of the upper layer, which ranges from a few inches to several feet within a relatively short distance.

Lime carbonate occurs throughout the entire soil mass and forms a definite zone of accumulation in the subsoil. The surface soil, subsoil, and substratum are typically free of stones, although some thin beds or lenses of fine gravel, which in few places are more than a few inches thick and usually occur where the Bearden soil is associated with the Sioux or Foxhome soils, may lie between the two layers of the substratum.

In general, the areas of Bearden silt loam are characterized by somewhat slower surface drainage than those of Bearden loam.

Bearden silt loam does not cover any large areas but occupies many small irregularly shaped areas, most of which are between areas of Bearden loam and the Fargo soils, or within areas of the Fargo soils, in association especially with Fargo silty clay loam. Such "islands" of Bearden silt loam are especially numerous in the western part of Norman County.

The greater part of Bearden silt loam is under cultivation. It is easily tilled under a wide range of moisture conditions and easily kept in good physical condition. It is rich in organic matter, which makes it one of the most highly prized soils in the area. All the staple crops common to the section are grown on this soil and do well. The land is well adapted for diversified farming. Dairying and hog raising are commonly combined with small-grain farming.

SOILS OF THE ULEN GROUP

The third division, comprising the soils of the Ulen group, occupies the most eastern portion of the open section of the valley. As far north as the southern part of Polk County it adjoins the upland section on the east, from which it is separated by the ancient shore line. It does not extend far into Traverse County, and in the southern half of Wilkin County it includes comparatively few isolated bodies. In the northern counties of the area this subdivision is bounded on the east by the forested section. It is a part of the great flat plain, but its relief is not so smooth and level as that of the first and second subdivisions. In many places the relief is very gently undulating, but having only very small differences in elevation, usually not exceeding a few feet, and most of the gravelly ridges heaped by the waves along the shore lines of ancient Lake Agassiz are in this subdivision. These ridges range in width from a few rods to nearly one-half mile and in height from 4 to more than 20 feet.

The northern part of the subdivision is divided by a terrace into upper and lower plains. A part of the upper plain, where it is crossed by the main tributaries of Red River, is intersected by deep ravines and has rough relief, such as that in the vicinity of Twin Valley in Norman County.

The drainage conditions of this subdivision range from poor to fair. The poorly drained areas are larger and more numerous near the eastern border, but they do not form a continuous wet section. The largest body of wet land is in the northern half of Wilkin County, extending in a north-south direction for more than 20 miles and ranging in width from 1 to almost 5 miles. It lies west of the upper shore line of Lake Agassiz. A considerable part of it, mostly in Tanberg Township, is covered with a thick layer of peat and muck. With some interruptions, the strip of wet land adjacent to the upper shore line on the west continues into Clay and Norman Counties, where it ranges from less than 1 mile to about 3 miles in width. Many springs are in this wet area, being especially numerous in Prairie View and Tanberg Townships in Wilkin County. Many of them form conspicuous peaty mounds with craterlike openings in the centers of their summits. The largest mounds may be more than 10 feet high and more than 100 feet in diameter at their bases. In addition to this main body of wet land, a number of smaller poorly drained areas, most of which are closely associated with the ridges which mark the consecutive lower shore lines of the ancient lake, occur throughout the entire subdivision. A considerable proportion of all these wet lands has been improved by the construction of deep ditches.

A large part of this subdivision was open grassland. The forested land and the prairie land are not separated by a sharp boundary, as a relatively narrow belt, where forest and grass vegetation are more or less intermingled, lies between them. This narrow belt in the four northern counties of the area is included in this subdivision.

The soils of this subdivision are much less uniform than the soils of the first and second subdivisions. A greater number of soil types are included, and the areas covered by each of these are smaller and more irregular in shape than those of the western subdivisions. The outstanding characteristic of the principal types of soil covering a greater part of this section is their looseness. This is predominantly a section of sandy soils. The surface layers of the soils of the open part are very dark gray, dark brownish gray, or even black, and range from about 8 inches to almost 2 feet in thickness. The content of organic matter here is smaller than that of either the Fargo or the Bearden soils. The subsoils are very light yellowish-brown or grayish-brown loose sand. Because of their friability and lack of cohesion, the soils do not crack in dry periods, and the general boundary between the dark-colored surface soil and the subsoil is not broken by tongues extending into the subsoil.

The moisture retention of these soils is rather low, and the crops here are relatively more often subject to injury from drought than are those in the more western subdivisions. Where unprotected, these loose soils drift easily in dry windy periods, and sandstorms, in which dense clouds of dust and finer sand are moved from the

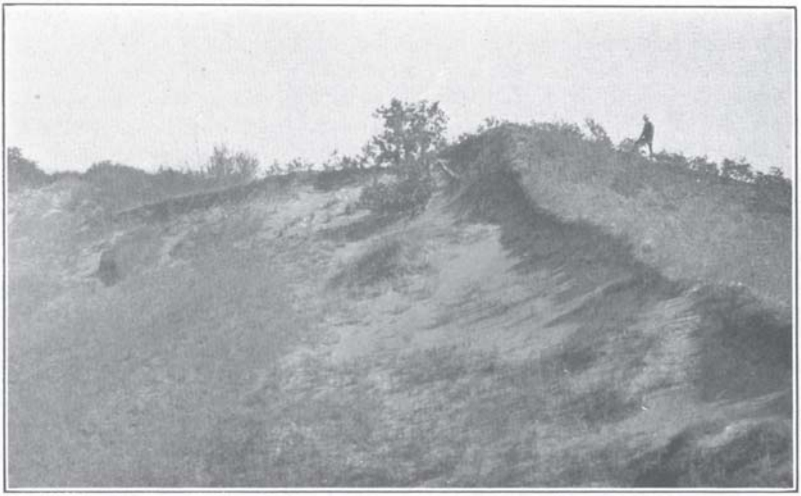

FIGURE 15.—Old sand dunes in Sundahl Township in Norman County.

fields, occur almost regularly twice a year, in the spring and in the fall. The shifting sand has resulted in the formation, in a few places, of typical dunes, the principal group of which is in Sundahl Township in Norman County where some of the dunes are nearly 40 feet high (fig. 15), and, more commonly, of a finely undulating microrelief.

The soils of this subdivision differ too greatly in their characteristics to be classed in one series, and seven series are recognized. The principal group is made up of loose sandy soils of the open grassland with moderate to good drainage. These are the Ulen and Grimstad soils. The sandy light-colored soils of the forested areas belong to the Poppleton series. The soils of marshy and swampy land within the sandy region of the prairie belong to the Tanberg series, whereas the corresponding soils associated with the Poppleton soils in the forest belt are recognized as Arveson soils. The soils of the gravelly ridges are included in the Sioux series. The Foxhome soils resemble the Grimstad soils.

The Tanberg and the Arveson soils are too wet to be farmed, and almost the entire area occupied by them is used for wild-grass hay. The wide wild-hay meadows with numerous haystacks scattered throughout in the fall are the most typical feature of the landscape of the areas of Tanberg soils. Some parts of these soils are pastured and others in places are sown to flax.

The Sioux soils occupy long narrow strips on the north-south ridges, which, because of their relief and physical composition, are too dry for most of the common crops and are devoted chiefly to rye, which matures before the moisture in the soil during spring and early summer is exhausted.

The greater part of the area of the Ulen soils and the part of the Poppleton soils cleared from woods are under cultivation. Potatoes, oats, barley, and tame hay are the leading crops. The Ulen and the Poppleton soils are less well supplied with plant nutrients than are the Fargo and the Bearden soils, and the application of barnyard manure produces a great response. Manuring for crop production of a considerable acreage of land, which could not be utilized otherwise than as pastures or for hay, favored the development of a more diverse system of farming in this section. This system is based on the raising of livestock which is accompanied by the home consumption of a large part of the farm crops for forage and feed.

Wheat is the typical crop of the first subdivision and potatoes of the second, but it is impossible to select only one crop as typical of the third subdivision because of a greater variety of local conditions. The third subdivision is a complexity of different physiographic landscapes rather than a uniform unit. Wild hay is the most typical product of the land lying along the eastern margin; and small grains, such as rye, oats, and barley, together with potatoes, tame hay, and flax, comprise a general combination of the crops throughout the better drained part of the sandy area. Very little, if any, wheat is grown here, but some corn is grown.

General farming in this subdivision faces several special problems, one of which is the drainage of the eastern part, where much of the land is wet, and the improvement of the hay meadows. In their present condition, these meadows produce on the average about one-half ton of low-grade hay an acre. The second problem is control of wind erosion. The seriousness of wind erosion is not fully realized by all farmers, as usually only the direct damage to some particular field, the filling of ditches and the burying of fences, or a general discomfort resulting from the duststorms, and not the impoverishment of the soil, which is perceptible even at the present time, are considered (fig. 16). Wind erosion of the Ulen and the Poppleton soils in the valley seems to be a result of cultivation. No doubt in former times these sandy areas which bordered the ancient lake supported only a scant grass vegetation, and wind erosion was very active. The sand dunes in the area were formed at that time. Gradually the grass vegetation became stronger and formed a continuous sod suffiicent to protect the sands from drifting. Under this protection the soils gradually incorporated a considerable amount of the organic matter after erosion ceased, as the formation of such soils would be impossible if drifting were not prevented by the sod. Recently, cultivation broke the sod and made possible a renewal of erosion. If some measures of control are not undertaken, erosion will increase and become a problem of first importance. The third problem is the reclamation and utilization of the soils containing soluble salts. In this subdivision the so-called "white alkali" salts are more common and are closely related to the poor drainage conditions.

The group of Ulen and associated soils includes Ulen loamy sand; Ulen sandy loam; Grimstad fine sandy loam; Poppleton loamy fine sand; Poppleton loamy fine sand, shallow phase; Tanberg soils, undifferentiated; Sioux loamy sand; Arveson sandy loam; Foxhome loamy sand; and Foxhome sandy loam.

Ulen loamy sand.—The surface soil of Ulen loamy sand ranges from very dark gray or brownish-gray to almost black loamy sand, from 8 inches to about 2 feet thick. It has a soft mellow or friable consistence and grades into light-brown or yellowish-brown loose

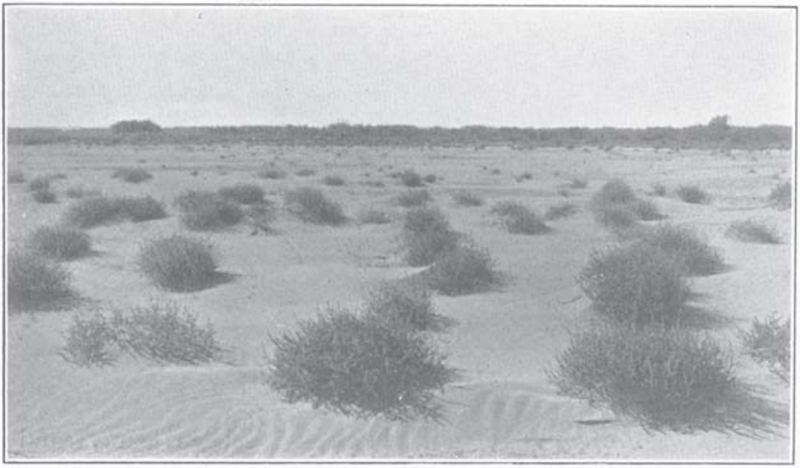

FIGURE 16.—Wind erosion of Ulen soil in Norman County. Ulen soils are peculiarly subject to serious soil blowing if unprotected by vegetation, and they are not suited to crops except in very small areas.

fine sand. This continues to a depth ranging from less than 2 to more than 5 feet, and rests on compact olive-gray clay, which in most places represents heavy lacustrine deposits and in other places is modified glacial till. The boundary between the sandy layer and the underlying heavy substratum in most places is very sharp.

Lime carbonate typically occurs in a rather large quantity in the clayey substratum but in very few places in the sandy material overlying the clay, but everywhere it occurs in the subsoil and in a few places even in the surface soil of areas with restricted surface drainage.

Both surface soil and subsoil of Ulen loamy sand are free of stones and gravel, but gravel may occur in thin beds in places where this soil is associated with the Sioux or the Foxhome soils. The gravel beds in most places are only a few inches thick and typically lie between the two layers of the substratum.

The largest area of Ulen loamy sand is in Norman and Clay Counties, where it occupies both the upper and the lower terraces of the valley. The areas are broken by long narrow strips of associated Sioux and Tanberg soils. In Wilkin County, Ulen loamy sand covers several irregularly shaped areas. A considerable area of this soil is in Kittson County extending in a north-south direction just east of the large section occupied by the Fargo soils. This belt extends south into Marshall and Polk Counties, where it forms several isolated islands.

The surface drainage of this soil is generally good, although the surface of the land itself is not so even as that of the Fargo or the Bearden soils, in many places consisting of a broad belt of very low and flat irregular waves and slightly depressed lowlands between them. In most places, the difference in elevation between these waves and depressions is not more than 4 feet, but the distance between the highest and the lowest points may be several hundred feet. These irregularities of the surface are hardly noticeable, but they are sufficient to cause a marked difference in soil characteristics due to retention of moisture in the depressions. The surface soil in the depressions is considerably darker, deeper, and richer in organic matter and has a finer texture than that of the more elevated parts, and the subsoil acquires a drab-gray or a light olive-gray color, in places slightly mottled with light iron stains.

Because of its texture, Ulen loamy sand dries rapidly, and the moisture-holding capacity of both the surface soil and subsoil is rather low. The loose consistence of the soil provides a condition favorable to drifting, especially during the spring and fall windy periods when the plowed fields are not protected by vegetation; therefore, great care is necessary in cultivation. A considerable number of areas markedly affected by wind erosion are in practically every locality where these soils occur.

The greater part of this soil is in cultivation. Small-grain crops (rye, oats, and barley) are generally grown, and a considerable acreage is devoted to potatoes, flax, and tame grasses.

The agricultural value and productivity of Ulen loamy sand is lower than that of the Bearden or the Fargo soils. The average yields of most crops are smaller, and the soil requires heavier manuring and more frequent applications of fertilizers than do the heavier soils.

Ulen sandy loam.—Ulen sandy loam is one of the less extensive soils of the area. It occupies an intermediate position between Ulen loamy sand and the soils of the Fargo series. Because it is a transitional soil, its characteristics are less constant than those of the other types and vary much more widely.

The surface soil of Ulen sandy loam is very dark gray and averages about 1 foot in thickness. The predominant texture of this layer is sandy loam, although it ranges from loamy sand to silt loam, but such extremes are rather rare and occur only in small spots and pockets scattered throughout the area occupied by the typical soil. The soil heavier than normal usually occupies slightly depressed areas, whereas that lighter than normal occupies relatively higher land. The content of sand gradually increases downward. The subsoil is brownish gray and grades into lighter brown or light-gray fine sand or loamy sand. This rests, at a depth ranging from about 2 to more than 5 feet, on a clayey substratum, which is usually drab gray or olive gray and very compact and contains considerable lime. As a general rule, lime carbonate does not occur in the sandy material overlying clay, although it does occur in the entire soil mass in many places characterized by restricted surface drainage.

The surface soil, subsoil, and substratum of Ulen sandy loam are free from stones, but some thin beds or lenses of fine gravel may occur in places where this soil is associated with the Sioux or the Foxhome soils. Such beds of gravel do not exceed 5 or 6 inches in thickness and usually rest on the surface of the clayey lower substratum.

The surface drainage is generally somewhat poorer than that of Ulen loamy sand. Because of its texture and consistence, Ulen sandy loam is not so easily drifted by wind as is the lighter soil, although care must be taken to prevent blowing, especially in early spring when crops are getting started and on the higher, more exposed, and drier areas.

This soil is used for practically every crop common in the area. Oats, barley, rye, potatoes, flax, and tame grasses do well in normal years.

Grimstad fine sandy loam.—Grimstad fine sandy loam may be regarded as an intermediate soil between the typical Ulen and Fargo soils. It differs from the typical Ulen soils in that the compact clayey substratum is nearer the surface, as the sandy material overlying the heavy substratum does not exceed 30 inches in thickness and in most places ranges from 10 to 20 inches. The wide range in thickness of this layer makes an accurate separation of the Grimstad and the Ulen soils impossible, and many small areas of each are mapped with the other.

The surface soil of Grimstad fine sandy loam ranges in thickness from 8 to about 20 inches. It is dark gray or nearly black and has a mellow to loose consistence. Its texture ranges from loamy sand to loam. Usually this material rests on the compact clayey substratum, which in most places is drab olive gray and contains numerous white nodules and streaks of lime carbonate. In many places, however, the lime is leached from the material to some depth, the leached part being very dark gray and in places almost black. This layer in few places exceeds 1 foot in thickness, in most places being 6 or 8 inches, and grades into the typical unmodified calcareous substratum. On drying, the material in the subsoil layer cracks into coarse firm clods. The loose sandy material just above the clay subsoil may be bleached in places and faintly mottled with pale iron stains. Such characteristics are associated with spots of rather restricted surface drainage and do not represent the normal profile. In the areas of better drained soil, the dark-colored surface soil of Grimstad fine sandy loam grades into light-brown or brownish-gray loose loamy sand similar to that in the subsoil of the Ulen soils.

Both the surface soil and the subsoil of Grimstad fine sandy loam are typically free of stones and gravel. Thin beds of gravel may occur, however, in places where this soil is associated with the Foxhome or Sioux soils. Most of the land is in cultivation. It has a tendency to drift, and care must be taken to prevent wind erosion.

This soil occurs in a number of small irregularly shaped bodies along the borders of the areas occupied by the Ulen soils or between the Ulen soils and the Fargo soils. Agriculturally it differs very little from Ulen sandy loam.

Poppleton loamy fine sand.—Poppleton loamy fine sand is a soil of the forested sandy areas, the forest vegetation being mainly aspen, mixed with birch and willow bushes. The forest did not cover the land entirely; the original vegetation consisted of groves of deciduous trees and of areas of open meadow that occupied more or less depressed wet spots. A considerable part of the original woodland has been cleared and is under cultivation.

Poppleton loamy fine sand is developed from deposits of loose sand, the thickness of the sand layer ranging from about 3 feet to more than 10 feet. This rests on the compact calcareous clayey substratum. In most places this material is a gray glacial till commonly known as boulder clay, although in a number of places the till is covered by an intermediate layer of lacustrine clay similar to that in the substratum of the Fargo, Bearden, Ulen, and some other soils.

The surface soil is gray, light gray, or light brownish gray and ranges from 2 to about 10 inches in thickness. It consists of a loose fine to medium sand colored with a relatively small amount of organic matter. The surface of the soil in its virgin state is covered by a thin mat of undecomposed organic residue consisting of dry leaves and grasses, in few places more than 1 or 2 inches thick. The subsoil is very light brown or light grayish-brown, loose, and in places somewhat coarser, sand. At various depths this is underlain by a heavy substratum, which, as a rule, is rich in lime, but in very few places does the sandy layer of the soil contain lime.

Because of its lack of cohesion, this soil is easily eroded by the wind, and no large continuous areas of it should be tilled. Even one-half section under tillage is wide enough to be impaired by wind erosion. In order to avoid this, it is necessary to limit the acreage of tilled land and to alternate the small fields with tracts left under forest cover, which are commonly used for pasture.

Poppleton loamy fine sand is poor in organic matter and nitrogen. It supports a fair growth of forest vegetation but is a poor soil for growing cultivated crops. Without manuring it does not produce even a scant yield, although under proper management and with a sufficient application of manure it produces normal yields of practically all the common crops grown in the area. (fig. 17.)

The need for barnyard manure, together with a considerable acreage of farm land left under forest cover and used for pasture, stimulates livestock raising and dairying and the growing of food crops for home consumption rather than cash crops. Rye, oats, barley, potatoes, tame hay, and sweetclover are the most common crops in the sections where Poppleton loamy fine sand is a dominant soil.

A considerable area of this soil is in the eastern part of Norman County, most of it is in Kittson and Marshall Counties, and none of it is in the southern counties—Clay, Wilkin, and Traverse.

Three important variations of this soil, not differentiated on the maps, are noted.

In Kittson County in the vicinity of Lancaster, Poppleton loamy fine sand is closely associated with Ulen loamy sand, and these soils merge into each other so gradually that accurate separation is impossible and the boundary between them is arbitrary. Poppleton loamy fine sand near this boundary has a considerably darker and deeper surface soil than typical, approaching that of the Ulen soil.

Another variation is in Marshall County in the section north and east of Thief Lake. Here, Poppleton loamy fine sand is characterized by stronger-than-average leaching, and its surface soil is much lighter in color than is typical and in places is bleached to a considerable depth. Several small areas of similar soil are in the extreme northeastern corner of Kittson County.

The third variation of this soil occurs wherever the Poppleton soil occupies areas having restricted surface drainage and may be regarded as a poorly drained phase of Poppleton loamy fine sand. This phase (undifferentiated on the maps) represents a transitional soil between the typical well-drained Poppleton soil and Arveson

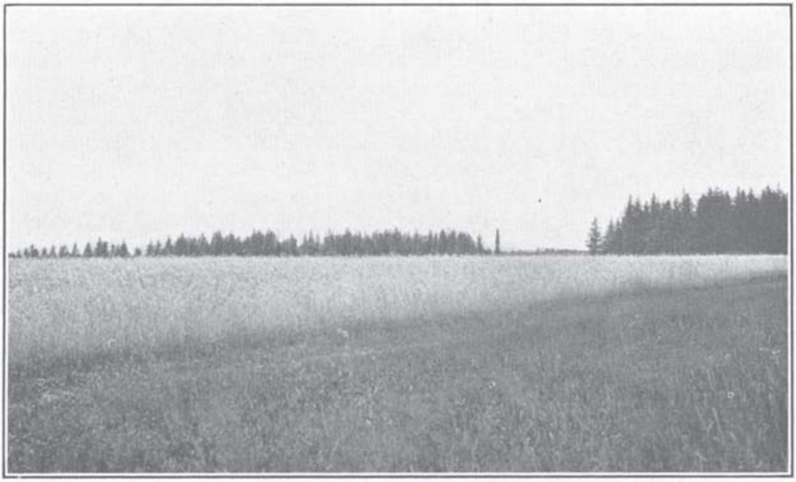

FIGURE 17.—Rye on Poppleton loamy fine sand in the eastern part of Marshall County. Such sandy soils may produce fair crops of rye, but they are unsuited to the principal cereal, wheat.

sandy loam. The surface soil of this phase is gray, dark gray, or in places black and ranges in thickness from a few inches to more than 1 foot. Its lower boundary is very irregular and indistinct. The subsoil is light drab gray mottled with rust stains. In many places the surface of the soil is covered by a thin mat of undecomposed vegetable residue. As a rule, the soil in the poorly drained areas is richer in lime than is the typical soil. Very little of this soil is under cultivation, the greater part being used as pasture, although, if the drainage conditions were improved, it could be used for the same crops as those commonly grown on the typical Poppleton soil.

Poppleton loamy fine sand, shallow phase.—Poppleton loamy fine sand, shallow phase, differs from typical Poppleton loamy fine sand in that the compact clayey substratum lies at a depth not greater than 30 inches from the surface. In most places, the thickness of the sandy material overlying the heavy lower substratum ranges from about 10 to 20 inches. In other characteristics the surface soil of the shallow phase is similar to that of the typical soil.

The soil in most places is free from stones, but the heavy substratum is formed by clayey glacial till in which are embedded small boulders, cobblestones, and gravel; and in many places, where the sandy mantle spread over the till by wind or water is rather thin, the boulders and other stones may appear on the surface. Their number, however, is nowhere so large as to cause much difficulty in the cultivation of the land.

This soil occupies a number of small areas adjacent to areas of typical Poppleton loamy fine sand.

Tanberg soils, undifferentiated.—Tanberg soils, undifferentiated, include marshy or depressed land occupied by sloughs in the sandy areas of the open part of the valley. The surface layer of these soils is black under moist conditions but changes to gray or light gray on drying. It ranges in thickness from 5 inches to almost 2 feet and in texture from loamy sand to silty clay loam. The boundary between this layer and the subsoil is usually more or less irregular and rather sharp. The subsoil of the typical Tanberg soils is loose sand underlain at various depths by compact clay. The layer of sand ranges in thickness from less than 1 foot to several feet and usually is light olive gray or bluish gray mottled with rust-brown or dark-brown stains.

The surface layer of the Tanberg soils in most places is not uniformly colored but has a cloudy appearance with darker and lighter spots intermingled. In places it has a mucky or peaty character in the upper part, the thickness of the peaty layer ranging from a few inches to 1 foot. Most of the Tanberg soils are rich in lime, and in some places the surface soil is underlain by a bed of pure white marl ranging from several inches to nearly 2 feet in thickness.

The largest area of Tanberg soils, undifferentiated, is in the northeastern quarter of Wilkin County, and some smaller areas are in Clay and Norman Counties. In Norman County the areas are closely associated with the gravelly ridges, which prevent the excess moisture from running off.

By far the greater part of the area of the Tanberg soils is free of stones and gravel, though beds of gravel may be present in places where these soils are associated with the Sioux or the Foxhome soils.

Only a small part of the Tanberg soils is cultivated to grain and other crops, among which flax occupies the largest acreage. By far the greater part of the area of these soils is used for pasture or for wild hay meadow.

Sioux loamy sand.—Sioux loamy sand is a soil of the gravelly ridges. The surface layer ranges from 4 inches to about 2 feet in thickness. Usually it is black or very dark grayish brown. Its most common texture is loamy sand, but the sand, as a rule, is less uniform than that of the other sandy soils in the area, as it contains a considerable proportion of coarse sand and some fine gravel. In many places the material in this layer forms into a compact mass difficult to crumble. The black surface soil rests on a layer of stratified and assorted gravel, ranging in thickness from about 2 to many feet, some deposits being more than 50 feet thick and some being interbedded by strata of outwashed sand. As a rule, the change from the black surface soil to the gravelly substratum is sharp. The gravel in turn rests on compact clay.

Because of the sloping relief of the ridges and the texture of the soil, Sioux loamy sand is rather excessively drained and not infrequently is subject to drought. The content of lime in this soil is much smaller than that of the other soils of this group. Lime occurs in the gravel layer.

The ridges occupied by Sioux loamy sand are very popular for the location of farmsteads. In a number of places the gravel is excavated for the construction of roads, but the greater part of the soil is under cultivation. Rye is the most common and the best adapted crop grown.

The principal limiting factor in crop production is the inability of the soil to hold moisture, hence the productive capacity and the crop yields differ with climatic conditions to a greater extent than on other soils. In dry years the crops are subject to more damage by drought than on any other soil, but when the spring is abnormally wet, better yields are produced on the Sioux soil than on other soils which are more productive in years of normal rainfall.

Typical Sioux loamy sand, like the other soils developed under a natural grass vegetation, is characterized by a dark-colored surface layer. A variation of this soil is in the northeastern corner of the area, in the eastern parts of Kittson, Marshall, and Polk Counties, where the gravelly ridges enter the forested region of Red River Valley, and here a large part of these ridges remains open or occupied by a sparse cover of trees, mostly scrub oaks. The sandy surface soil here is thin—in many places not more than 3 or 4 inches thick. Its color is lighter than that of the typical Sioux soil. Most of this soil is too gravelly and droughty for use as cropland and is used for pasture, although some of it is cultivated and sown almost exclusively to rye.

Arveson sandy loam.—The Arveson soils, among which the predominant type is Arveson sandy loam, include the soils of the wet sloughs in the forested part of the sandy belt of the valley. Arveson sandy loam is closely associated with Poppleton loamy fine sand.

The surface soil ranges from dark gray to black and from a few inches to more than 1 foot in thickness. The lower boundary of this layer is very irregular. In many places the material has a mucky or peaty character due to the large content of undecomposed or incompletely decomposed organic residues, and in places a peaty mat, ranging from 2 to about 8 inches in thickenss, is on the surface of the virgin soil. The texture of this layer ranges from loamy sand to silty clay loam, but in most places it has a rather mellow consistence. The subsoil has a typical drab-gray or bluish-gray color richly mottled with rusty iron stains. In most places the material consists of incoherent sand underlain at some depth by a compact clayey substratum. The thickness of the sandy layer ranges from less than 1 foot to many feet, and in many places the dark surface soil rests directly on the heavy substratum.

Typical Arveson sandy loam does not contain stones in the sandy subsoil layer, but stones of different sizes, from fine gravel to medium-sized boulders, are in the lower glacial till layer. In places where the sandy layer is not sufficiently thick to cover the boulders, however, stones may be in the surface soil and even on the surface. Arveson sandy loam is relatively rich in lime, although the distribution of lime is very uneven and irregular.

Practically none of the area occupied by this soil is used for cultivated crops. Most of the depressed and wet areas are occupied by a dense willow and aspen growth and are used for pasture.

Foxhome sandy loam.—The surface soil of Foxhome sandy loam is about 10 or 12 inches thick, is black or very dark gray, and has a mellow or moderately compact consistence. In places it contains a considerable amount of incompletely decomposed grass residue and in a virgin state is covered by a thin peaty mat. The surface layer rests on a layer of gravel, pebbles, and cobblestones, ranging from a few inches to about 2 feet in thickness but in most places not exceeding 1 foot. The gravel layer rests on a light olive-gray clayey substratum in which a few stones of various sizes are embedded. The heavy substratum is rich in lime.

This soil does not cover any large tracts of land, and most of it is in the southeastern part of the lake-bed region in Wilkin County. A large part of this land has rather inadequate drainage and is used for pasture or wild hay.

Foxhome loamy sand.—Foxhome loamy sand is very similar to Grimstad fine sandy loam, that has beds of gravel in the subsoil. It differs from Grimstad fine sandy loam in that the clayey substratum of the Grimstad soil is a compact and stone-free lacustrine clay, whereas that of Foxhome loamy sand is a heavy unassorted glacial till. Both may have the same texture, consistence, and color, and they differ only in the occurrence of stones. The stony layer under the surface soil of the Grimstad soil usually consists of fine or medium gravel, but that of the Foxhome soil consists of unassorted stones of different sizes from fine gravel to cobblestones. Nevertheless, in many places where these soils are closely associated, they may be easily confused, and their separation is difficult unless they are thoroughly examined.

The surface soil of Foxhome loamy sand averages about 10 inches in thickness, is dark gray to brownish black, is soft and mellow, and has an increasing content of sand in the lower part of the layer. It is relatively rich in organic matter and in places is covered by a soft mat of undecomposed grass residue. The surface soil rests on a layer of gravel, pebbles, and larger stones, ranging in thickness from a few inches to about 1 foot, and is underlain, in turn, by a compact clayey substratum, which has a typical light olive-gray color and a high content of lime.

This soil usually is closely associated with Foxhome sandy loam, and in general it occupies areas relatively higher and better drained than those occupied by the heavier soil. Much of it is in cultivation and is sown to oats, barley, flax, or tame grasses, especially sweetclover.

SOILS OF THE PELAN GROUP

The fourth subdivision, comprising the soils of the Pelan group, occupies the northeastern part of the area, embracing the eastern parts of Kittson, Marshall, and Red Lake Counties and several townships in the northeastern part of Polk County.

The surface is generally level, and the surface drainage of a considerable part of the land is rather poor. The most striking features are a number of wide, open, perfectly flat peat bogs scattered throughout the country, most of which are covered with grasses; a thick second growth of aspen mixed with shrubs of willow over the greater part of the mineral soils; wide muskegs, or dense tamarack, spruce, and balsam fir forests on peat in the extreme eastern townships, especially in Marshall County (fig. 18); a predominance of poorly drained lands everywhere; plenty of boulders scattered on the surface and of gravel and pebbles in the soil; relatively few roads, most of which are rather poor; relatively few farmsteads; flocks of sheep; stacks of wild hay on the open meadows; and a relatively small proportion of land in crops.

This subdivision is the youngest in the area in agricultural development. The settlement of the valley began from the banks of Red River and gradually spread eastward into the woodland. The natural conditions of the new area were responsible for the development of a general system of farming somewhat different from that which was practiced in the open parts. Everywhere here the land was covered with shrubs or trees or was wet and was unsuitable for growing the common crops, at least until it was properly improved, but provided wild hay and good pastures. The large areas of peat and, in some places, of stony and sandy land could be better used for wild hay and pasture, as the potential cropland originally was occupied by forest vegetation. The soils of such land are poorer in their content of the mineral plant nutrients required by the common crops, and they require the application of fertilizers, especially of barnyard manure, in order to produce a normal crop. All these factors determined, from the very beginning, the development of livestock raising, which required the growing of more feed crops rather than cash crops. Practically no wheat is grown on this land, but it is used for the production of oats, barley, and rye, and the freshly cleared forest land is sown to flax. A considerable acreage is devoted to tame hay, chiefly sweetclover, and to timothy alone or

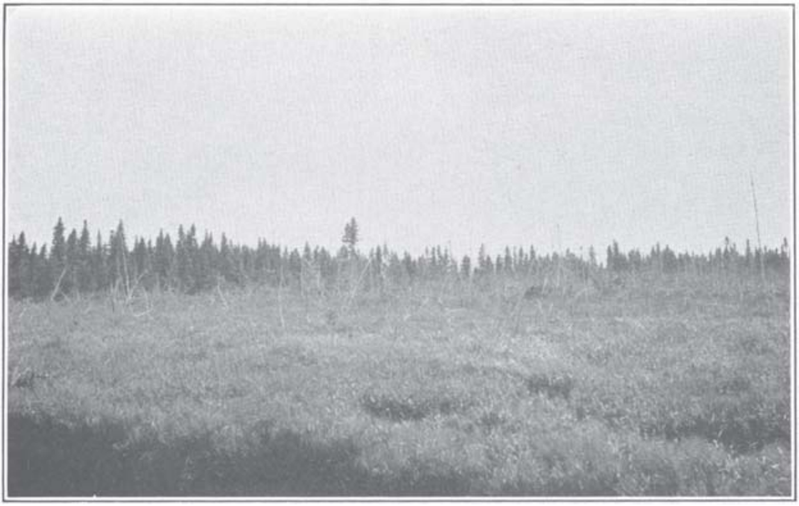

FIGURE 18.—Typical muskeg in the eastern part of Marshall County.

mixed with clover. Some districts with sandy soils, such as Jupiter and Norway Townships in Kittson County, specialize in potato growing. The livestock, in addition to dairy cattle, include many sheep.

The soils of this subdivision are much less uniform than the soils of the western three subdivisions. A greater number of soils are mapped here, and the areas covered by each are smaller and are very irregular in shape.

As these soils developed under forest conditions, all of them are lighter in color than the soils of the open prairie. This is especially pronounced in the extreme eastern townships in Marshall, Red Lake, and Polk Counties. All these soils are rather poor in organic matter and in most places are slightly acid in their upper layers. The different soils are rather intricately mixed. They do not occupy large areas, and the boundaries that separate the different soils are

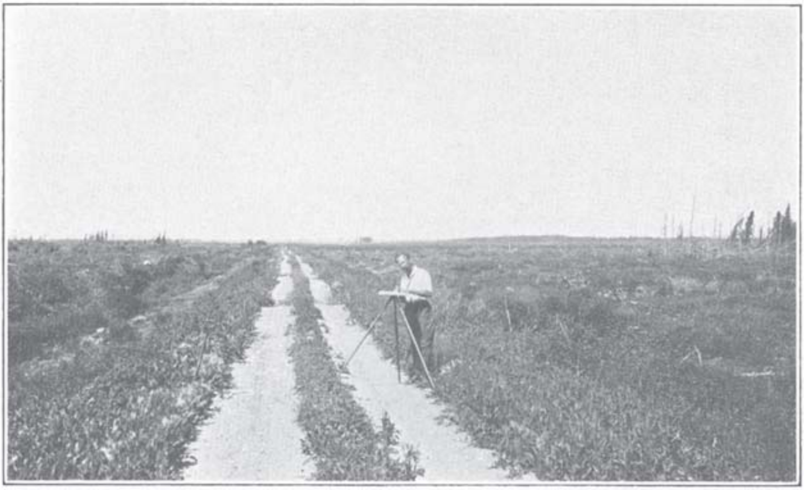

FIGURE 19.—General character of the landscape of the area occupied by the soils of the Pelan group. These soils are little used for crops.

very irregular. The dense forest vegetation and the scale of reconnaissance mapping did not allow an accurate separation of all individual soil types, and many of them are shown on the maps as groups of undifferentiated soils. These groups are composed of soils which are recognized as members of the Pelan, Gatzke, Kittson, and Nereson series and are described separately in the text but are not shown separately on the soil maps. These soils or undifferentiated groups are associated with the soils of the Poppleton, Sioux, and Taylor series and with the numerous areas of peat land (fig. 19).

Pelan sandy loam.—The Pelan series includes several types, of which Pelan sandy loam and Pelan loamy sand, especially the former, are agriculturally the most important. As these types are not shown separately on the maps but are included with Pelan and Kittson soils, undifferentiated, and as they differ from each other, mostly in the texture of the surface soil, only the predominant type is described.

The surface soil of Pelan sandy loam, ranging in thickness from 4 inches to about 1 foot, is dark brownish gray, which appears almost black when wet and becomes rather light gray on drying. In many places the upper part of this layer is more or less peaty because of the high content of undecomposed vegetable remains, and in some places a layer of dark-brown peat, ranging from 2 inches to about 1 foot in thickness, is on the surface of the mineral soil. The lower part of the surface soil is, as a rule, much lighter in color and coarser in texture, in some places being composed of rust-brown mixed sand. In most places this layer rests on a layer of unassorted cobbles and gravel, ranging from 1 inch to more than 2 feet in thickness, but in some spots gravel is absent entirely. In many extensive areas such a layer of stony material is more or less uniform in thickness and composition, but more commonly the gravel and cobblestones are distributed in beds and irregular thin separate lenses. The coarse material ranges in size from fine gravel to small cobblestones. The stony layer rests on the compact clayey substratum formed by a bouldery glacial drift. This material is very rich in lime, which in many places is concentrated near the surface of the drift layer or just below the stony layer. This limy layer is almost white and averages about 1 foot in thickness. The drift beneath this has a typical light olive-gray color.

This soil, in general, is more or less stony, and some stones, ranging in size from cobblestones to medium-sized boulders, are commonly present on the surface in various quantities. In several areas in the vicinity of Halma in Kittson County the stones on the surface are exceptionally large and plentiful.

A large part of the area of Pelan sandy loam has rather slow and inadequate surface drainage. Only a small part of this soil is under cultivation. In most fields the stones have been removed from the surface, and drainage conditions have been improved by ditches. If properly managed and fertilized this soil gives fairly good yields. The most common crops grown are oats, barley, flax, sweetclover, and tame grasses, but the greater part of the land is used for pasture.

Gatzke clay.—An area of Gatzke clay is shown on the soil map in the northwestern part of Kittson County. It also occurs in the Kittson, Gatzke, and Nereson soils, undifferentiated, but is not separated on the soil maps. The Gatzke series includes several soil types, among which Gatzke clay and Gatzke loam are the most important agriculturally. As these types are not differentiated from each other over most of their area and differ only in the texture of their surface soils, only the predominant type is described as representative of the entire series.

The surface soil of Gatzke clay ranges in thickness from about 4 inches to more than 1 foot, in most places not exceeding 8 or 9 inches. Its color is dark gray or almost black with a distinct brown tint in the lower part of this layer. The material is compact, is sticky when wet, and has a strong tendency to clod and crack on drying. The cracks penetrate the subsoil to a depth of about 1 foot and result in the development of a fringe of irregular black streaks extending downward from the base of the surface soil layer. The boundary between the surface soil and the subsoil in most places is rather sharp but very irregular. The subsoil and the substratum consist of a stone-free lacustrine clay similar to that from which the soils of the Fargo series are developed. This material is dark drab gray or olive gray and is very dense and heavy textured. Lime carbonate lies at a depth of about 18 or 20 inches below the surface.

In a virgin state the area occupied by the Gatzke soils was covered by forest vegetation, consisting mostly of aspen, and the surface soil has been covered by a layer of incompletely decomposed vegetable residues or in places by a thin layer of peat, ranging from 1 to about 6 inches in thickness, which has accumulated where the surface drainage is restricted. In many places this peat layer has been burned.

Much of the forest vegetation has been cut or burned off, and the land has been brought under cultivation. Oats, barley, flax, and sweetclover are the most common crops. Most of the Gatzke soils are in the eastern parts of Marshall, Red Lake, and Polk Counties, and are closely associated with the Nereson and the Pelan soils and with the areas of peat.

Nereson silty clay loam.—Nereson silty clay loam is not indicated separately on the soil map but is included with the Kittson, Gatzke, and Nereson soils, undifferentiated. This is the predominant type of the Nereson series in the Red River Valley area. All the soils of this series are similar to the Gatzke soils, from which they differ in that they are developed from a moderately stony and clayey unmodified glacial till, whereas the substratum of the Gatzke soils is formed by the stone-free lacustrine clay. The Nereson soils are also related to the Pelan and the Kittson soils. They differ from the Pelan soils in that the Pelan soils are characterized by an accumulation of gravel and stones in a conspicuous layer under the surface soil due to the modification of the original till. This layer is absent in the Nereson soils.

The surface soil of Nereson silty clay loam is very dark gray or black silty clay loam, ranging from 4 to about 10 inches in thickness. This grades into a drab-gray or grayish-brown subsoil, which in few places is more than 4 or 5 inches thick and which passes into the drab-gray or olive-gray substratum. Lime carbonate occurs at a depth of about 20 or 30 inches from the surface.

The surface soil is sticky when wet and tends to crack and clod on drying. Small boulders, cobblestones, and gravel occur on the surface, in the soil mass, and in the substratum, although in very few places are they so numerous as to be a serious hindrance to cultivation, and they are not accumulated at any definite depth in the soil mass.

The land occupied by the Nereson soils originally was in forest, most of which has been cut or burned off and the land brought under cultivation (fig. 20). Oats, barley, flax, hay, sweetclover, and red clover are the most common crops, and all do well under normal conditions.

Most of the Nereson soils are in the eastern part of Marshall County and are intricately associated with the Gatzke and the Pelan soils.

Kittson silty clay loam.—Kittson silty clay loam commonly occurs in combinations with other soils. It is not mapped separately but is included with Kittson, Gatzke, and Nereson soils, undifferentiated, and with Pelan and Kittson soils, undifferentiated. This soil is representative of the Kittson series, which is composed of the soils developed from unmodified glacial till in the open areas of the northern part of the valley. These soils are closely related to the Nereson, Fargo, and Foxhome soils. They differ from the Nereson soils in being developed under a different type of vegetation; from the Fargo soils in being developed from a different substratum (glacial till and lacustrine clay); and from the Foxhome soils in the absence of an accumulation of stony material in any layer of the soil mass.

The surface soil of Kittson silty clay loam, ranging in thickness from 5 inches to about 1 foot, is very dark gray or black silty clay loam, which has a tight consistence. The soil is sticky when wet and has a strong tendency to crack and clod on drying. A fringe of sharp black streaks extends down from the base of the surface soil

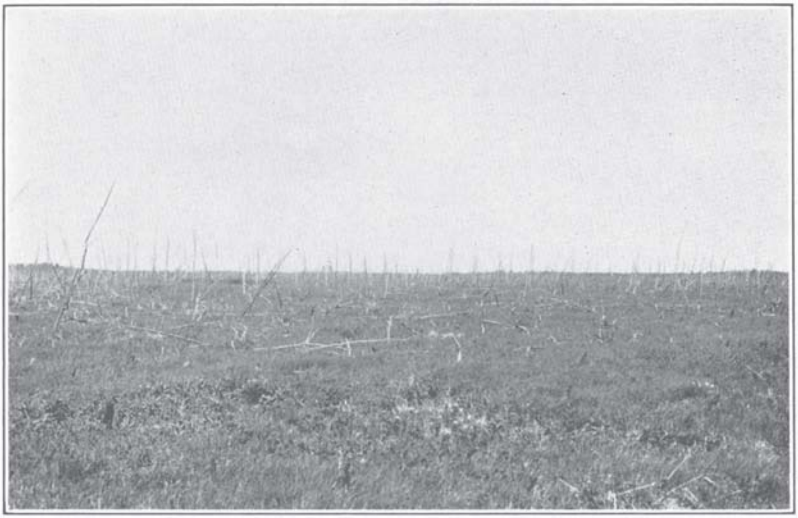

FIGURE 20.—Burned-off area of shallow peat land associated with the Pelan, Gatzke, and Nereson soils in the eastern part of Marshall County.

layer and penetrates the subsoil and substratum for about 1 foot. The subsoil is dark drab gray and about 4 or 5 inches thick. The substratum is a moderately stony unmodified glacial till, of an olive-gray or drab-gray color. Lime carbonate lies at an average depth of about 18 inches from the surface, in many places being accumulated in the upper part of the substratum, which has, as a result, a very light gray color and a crumbly structure.

This is an agriculturally unimportant soil occurring in the eastern parts of Kittson and Marshall Counties. Several small areas of different types of the Kittson series occur in combination with other soils, some of which are indicated separately on the soil maps.

Kittson silt loam.—Kittson silt loam differs from Kittson silty clay loam in the texture of the surface soil and in the less dense consistence of the surface soil and subsoil. The zone of lime accumulation is somewhat nearer the surface of the soil and the lime has accumulated in greater quantity in the silt loam than in the silty clay loam; consequently, the upper part of the substratum is of a very light, almost white, color and is very crumbly. The soil does not crack so much as do the heavier types of the Kittson series, and the cracks do not penetrate the substratum so deeply as in the heavier soils.

Kittson gravelly silt loam.—An area of Kittson gravelly silt loam is indicated on the soil map in the southeastern part of Kittson County. Numerous other small areas occur within the areas of Pelan and Kittson soils, undifferentiated, but these are not separated on the soil maps.

This soil is distinguished from Kittson silt loam by its larger content of unassorted gravel in the surface soil, subsoil, and substratum. Like the other Kittson soils, it varies in texture and stone content within short distances. The surface soil may range from very fine sandy loam to silty clay loam, but the predominating texture is silt loam. The value of this soil for cropping is considerably lowered by the high content of gravel, and the greater part of it is used for pasture.

Kittson clay loam.—The surface soil of Kittson clay loam, ranging in thickness from 4 to 10 inches, is very dark gray clay loam. This grades into a dark drab-gray subsoil, which, in turn, passes, at a depth of about 16 inches, into the heavy substratum. The soil is very sticky when wet and breaks into coarse firm clods on drying. Lime carbonate occurs at an average depth of about 20 inches from the surface, but the quantity is smaller than in the lighter Kittson soils. A moderate quantity of medium-sized boulders, cobblestones, and gravel is on the surface, in the surface soil and subsoil, and in the substratum, but in few places is the quantity large enough to cause difficulty in the cultivation of the land. Most of the stones have been removed from the cultivated fields.

By far the greater part of the areas occupied by the Kittson and the Gatzke soils and all of the areas occupied by the Pelan, Gatzke, and Nereson soils are indicated on the maps in groups of undifferentiated soils.

Kittson, Gatzke, and Nereson soils, undifferentiated.—In Kittson, Gatzke, and Nereson soils, undifferentiated, the Nereson soils are by far the most extensive, whereas the Gatzke soils occur in a number of small irregular isolated tracts. Moderately stony soils developed from heavy glacial till are, therefore, the more common. The amount of stones on the surface is nowhere so great as to make cultivation of the land impossible. Most of the larger stones have been removed from the fields.

Originally all this land was occupied by a dense forest of deciduous trees and was characterized by rather slow surface drainage. Much of the forest has been cut or burned off and the drainage improved by ditching.

The land is not extensively cultivated. Oats, barley, hay, flax, and tame grasses, especially sweetclover, are the common crops grown, but most of the land is used as pasture.

Pelan and Kittson soils, undifferentiated.—By far the largest part of the areas of Pelan and Kittson soils, undifferentiated, are occupied by the Pelan soils, whereas the Kittson soils occur on small tracts separated from one another and scattered throughout the entire area occupied by these soils. With the exception of the bodies of the Kittson soils, the entire area of these soils was covered originally by a mixed deciduous forest of aspen, birch, willow, alder, and other trees, and a considerable part was characterized by slow and inadequate surface drainage, which has since been greatly improved. The soils are moderately stony, but the larger stones have been removed from many fields.

A considerable part of this land has been cleared and cultivated. Oats, barley, hay, flax, sweetclover, red clover, alfalfa, and some potatoes are the usual crops and all do well. Much of the land is used for pasture and wild hay.

A number of areas occupied by Poppleton sandy soils and broad areas of open peat are very closely associated with the Pelan soils.

Barnett clay loam.—Barnett clay loam is a very unimportant soil agriculturally, a few small areas of which are located in the eastern part of Marshall County. It is closely related to the Nereson soils, from which it differs mainly in that it has poor surface drainage.

The surface soil of Barnett clay loam in many places has a mucky character and is covered by a thin layer of peat. Under this the mineral soil is very dark gray to black clay loam, averaging about 5 inches in thickness. This grades into a light-gray subsoil, which passes, without any sharp changes, into an olive-gray or bluish-gray compact, heavy, and moderately stony till substratum. Lime usually occurs in the subsoil and the substratum.

Willow bushes or mixed deciduous forest constitute the most typical vegetation on this soil. By far the greatest part of the land is used as pasture or for wild hay of rather poor quality.

Taylor silt loam.—Taylor silt loam is a soil of small extent occurring in several of the most eastern townships of Red Lake and Polk Counties. It is developed under a forest vegetation. It consists of a thin layer of peaty material made up of undecomposed vegetable residues—dead leaves, grasses, and moss—from 2 to 4 inches in thickness. This overlies a strongly leached surface soil, of a very light gray color, which ranges in thickness from 2 to about 8 inches and in texture from fine sandy loam to silt loam. The subsoil is tough and compact and ranges in color from drab gray to grayish yellow or grayish brown, and in thickness from a few inches to about 1 foot. This grades into the light olive-gray or bluish-gray substratum of heavy and limy glacial till. A small quantity of stones, ranging in size from fine gravel to small boulders, is embedded in the till and in places lies on the surface of the soil.

The natural surface drainage of Taylor silt loam ranges from poor to fair. This soil is less productive than the closely associated Gatzke soils, but if properly managed and sufficiently fertilized, especially with barnyard manure, it produces fairly good crops. Sweetclover, oats, barley, and rye are the chief crops, but most of this land is still unbroken and is used for pasture.

SOILS OF THE BARNES GROUP

The fifth subdivision, comprising the soils of the Barnes group, consists of the open prairie part of the upland lying around the lake-bottom section. It embraces the southern part of Traverse County, the northeastern part of Wilkin County, the eastern part of Clay County with the exception of the forested land, and the southeastern corner of Norman County. Several isolated areas in the southeastern part of Polk County also belong to this subdivision. The surface is more or less rough, its relief ranging from gently undulating to hilly. A typical feature is the numerous pot holes or circular depressions of various sizes (fig. 21).

The drainage conditions are generally fair, although many of the depressions are occupied by sloughs, some being covered by peat, and most of them remain wet until late spring or early summer.

Being developed under grassland conditions, all soils of the Barnes group are rich in organic matter. Their surface soils are very dark brownish gray to almost black and range from a few inches to almost 2 feet in thickness, averaging about 1 foot. The most typical texture of these soils is loam, but this also differs widely,

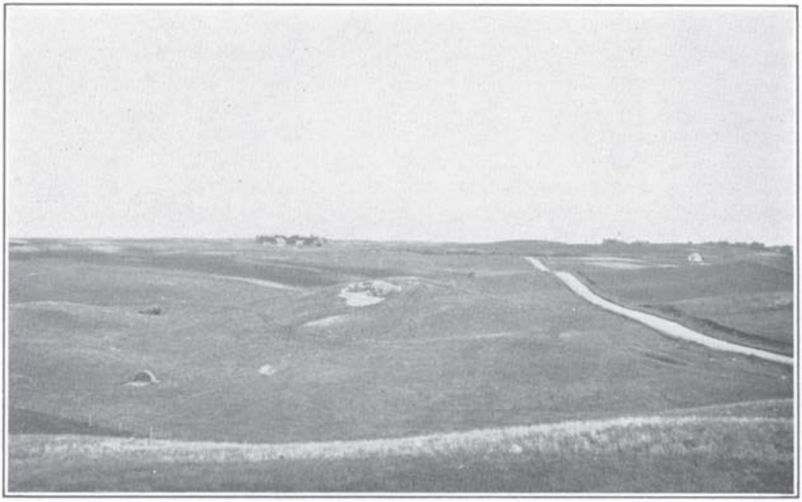

FIGURE 21.—General character of the landscape of the upland occupied by the soils of the Barnes group. Contrast this landscape with that shown in figure 11, characteristic of the Fargo soils.

ranging from loamy sand to heavy silt loam. The subsoil of nearly every Barnes soil is a very light brown or brownish-gray "boulder clay."

A few kames, or small knolls, composed of unassorted gravel, pebbles, and larger stones occur in some places which have a rougher relief than normal. These are especially prominent in the extreme northeastern corner of Wilkin County and in the southeastern parts of Clay and Norman Counties. On the kames, the thin dark-colored surface soil, which in some places is only a few inches thick, is underlain by very stony and gravelly deposits. Such soil does not cover any considerable area but occurs in scattered spots only a few rods in diameter.

Boulders, either on the surface or embedded in the soil and subsoil, are a typical feature of the Barnes soils, but in few places are the boulders so numerous as to be an obstacle to the cultivation of the land by ordinary implements. In most fields the larger stones have been removed.

In only a few places in the areas of Barnes soils are the slopes steep enough to make plowing impossible. In Traverse County, a narrow strip of such land faces Lake Traverse. It is a rather strongly eroded cliff bordering the glacial till plateau. In both Norman and Clay Counties, such rough lands are along some especially deep ravines which dissect the upland adjoining the lake-bottom plain. Most of these are narrow strips along the water-courses and do not extend very far from the main cliff. In the extreme northeastern corner of Norman County, such steep slopes border the valley of Sandhill River. Besides these, many smaller strips of steep slopes border the most prominent depressions. All these lands are pastured.

Generally speaking, the Barnes soils rank among the best agricultural soils, as they are naturally rich in plant nutrients. Their relief promotes early and rapid drying and warming of the soil in spring, and the physical structure of the surface soils provides an excellent seedbed. Most of these soils are neither so loose as to be subject to wind erosion nor so heavy as to clod, but some protection against surface erosion by run-off must be afforded hilly areas.

Spots of soils containing an excess of soluble salts are almost unknown in this section. The general farming seems to be the best organized and most stable in the entire area surveyed. The percentage of farms operated by tenants is lower than that for land in the valley, and a great number of farms are operated by their original owners, many of whom have continued successful farming for more than 50 years.

The typical crop is wheat in the first subdivision, potatoes in the second, and a combination of hay and the small grains other than wheat in the third. The most typical crop grown in the fourth subdivision is corn, although the general system of farming in this subdivision is closer to a well-balanced, diversified, self-supporting system than in any other part of the Red River Valley area. Among the small grains, oats and barley are the leading crops, although the acreage sown to wheat is fairly large. The crops of tame hay are headed by sweetclover and alfalfa. Many farmers have silos. Dairying and the raising of hogs and poultry constitute important sources of revenue on almost every farm.

The Barnes group includes Barnes loam, Barnes silt loam, Barnes sandy loam, Barnes stony loam, Barnes silt loam, slope phase, Parnell silty clay loam, and Pierce gravelly loamy sand.

Barnes loam.—The surface soil of Barnes loam is very dark grayish-brown or black loam, ranging in thickness from about 4 inches to almost 2 feet. In most places this is underlain by a distinctly brown layer which averages about 6 inches in thickness and grades into the subsoil. The subsoil is very light brown or yellowish brown, and its texture is somewhat heavier than that of the surface soil. It grades into the substratum of typical glacial drift. Boulders of medium size, cobblestones, and isolated pieces of gravel, either on the surface or embedded in the soil and substratum material, are of common occurrence, but practically nowhere are they so numerous as to be a serious obstacle to the cultivation of the land, and most of them have been removed from cultivated areas. The substratum is rich in lime, which occurs at an average depth of about 20 inches.

The surface soil of Barnes loam is somewhat compact in the virgin condition, but it can be easily reduced to a soft mellow mass which does not cake or become hard and is easily penetrated by plant roots. This soil dries and warms in the spring soon after the thawing of the snow, which makes possible the beginning of field work earlier than on most soils in the lake-bed section.

The wide range in the thickness of the dark surface soil on rolling and hilly land is due mostly to surface erosion and the washing away of the dark-colored material from the slopes. The thickness of this layer is more or less uniform throughout the flatter areas, where it averages about 10 inches.

Barnes loam occupies by far the greater part of this subdivision of the area. All the other types of this series occur mostly in isolated areas irregular in outline and ranging in size from less than 1 acre to several square miles, scattered throughout the area occupied by Barnes loam.

Nearly all this soil is under cultivation and is equally suitable for all common crops—small grains, corn, potatoes, and tame grasses.

Barnes silt loam.—The surface soil of Barnes silt loam is a very dark gray or black silt loam ranging in thickness from about 8 to 24 inches. The average thickness is greater and the color is darker than in Barnes loam, and both the color and the thickness of the surface soil of Barnes silt loam are more uniform than those of the surface soil of Barnes loam, probably because of the more level relief. The brown layer underlying the surface soil of Barnes loam is absent or only slightly developed in Barnes silt loam. Where this layer is slightly developed, the dark-colored surface soil is rich in organic matter and grades rather quickly into a light-brown or light grayish-brown subsoil composed of weathered glacial drift. A moderate quantity of small boulders, cobblestones, and smaller stones is on the surface of the soil and in the parent material. A considerable amount of lime is typically present in the substratum.

This soil does not cover any large areas but occurs in numerous small isolated areas throughout the areas of Barnes loam. These isolated bodies almost everywhere are somewhat lower and smoother than the surrounding land.

The surface of this soil in most places is nearly flat or gently undulating, and the surface drainage is not so good as that of Barnes loam and in some spots is rather poor.

Practically all Barnes silt loam is under cultivation, and all the common crops grown on the other Barnes soils are grown on this soil.

Barnes silt loam, slope phase.—The areas of Barnes soil which are too steep for cultivation are mapped as a slope phase of Barnes silt loam. In most places the steepness of slope is such that sheet erosion prevents the normal development of the surface soil and continually denudes the land. Many of these areas are very stony, and a great number of boulders are scattered over the surface. Some of the areas are covered by forest in which oak trees predominate. At the bases of some slopes are small areas of springy, slough land.

Areas of the slope phase are mostly in Traverse County along the bluffs on the eastern shore of Lake Traverse. In Clay and Norman Counties they border the ravines which have been eroded through the gentle slopes of upland toward the lake bottom. All this land is used for pasture.

Barnes sandy loam.—A large proportion of mixed sands, in many places coarse sand, in both surface soil and subsoil is the principal characteristic distinguishing Barnes sandy loam from the other Barnes soils. The surface soil is dark brownish black, about 6 or 8 inches thick, and in most places is more or less sharply separated from the rust-brown subsoil. The soil is slightly compact and cakes on drying but can be reduced to a mellow mass with little difficulty. Pieces of gravel, cobblestones, and a few small boulders are common in the surface soil, subsoil, and substratum. The substratum consists of weathered glacial drift which is rather compact and contains a considerable amount of lime.

Barnes sandy loam occupies small scattered areas adjacent to areas of more sandy soils. Several local variations are included with this soil as mapped that differ considerably from the typical soil. Barnes sandy loam in the northeastern quarter of Prairie View Township in Wilkin County is composed chiefly of very fine sand. Such a texture characterizes not only the surface soil, but also the subsoil and substratum to a depth ranging from a few feet to more than 6 feet. The surface soil of this variation is brownish gray, is uniformly mellow, contains no gravel or larger stones, and merges gradually with a light yellow-brown mellow subsoil. The soil is poorer in organic matter than typical Barnes sandy loam.

Another variation occurs in places adjacent to the upper shore line of the ancient lake bed on the east, where the Barnes soil is closely associated with the sandy soils of the Ulen group. The Barnes soil here occupies several narrow strips extending north and south directly east of the boundary which separates the upland from the lake-bed flat. A small body of this soil is in the extreme southwestern corner of Traverse County, and several larger areas are in the northeastern townships of Wilkin County. This soil differs from the other types of the Barnes series in that the boulder clay, which is the typical material from which the Barnes soils are developed, is covered with a layer of sand ranging in thickness from about 2 to more than 6 feet. In many places this layer of sand rests on the unmodified glacial drift, but in many other places lenses and beds of mixed gravel separate these two strata. The surface soil of this variation is dark grayish brown and ranges in thickness from about 8 to 20 inches. It is mellow and uniform, contains a considerable amount of organic matter, and passes gradually into a light-brown sandy subsoil.

Barnes stony loam.—Barnes stony loam is one of the less extensive soils of the area. It occurs in the eastern part of Clay County, the largest tract being in the extreme southeastern córner of the county, in the area occupied by the hilly belt of the terminal moraine. Several other much smaller tracts are scattered throughout the territory north of this area.

A great number of large boulders on the surface and in the soil make cultivation of a large part of this land impossible, and it is used for pasture. The boulders, however, do not cover the entire area, but are more numerous on the steeper parts of slopes, whereas a number of small irregular tracts between the stony areas have virtually no stones on the surface and are planted to various crops. These areas are too small and too irregular to be shown on the map separately. As a general rule, they occupy the low-lying land among the stony hills, and the stone-free soil material is accumulated here from sheet erosion of the surrounding hillsides (fig. 22).

Parnell silty clay loam.—Parnell silty clay loam occupies the wet marshy areas on the bottoms of numerous depressions scattered throughout the upland section. Some of these depressions represent the dried basins of small lakes, and some are still submerged and overgrown by reeds.

The surface layer, ranging in thickness from less than 1 foot to about 2 feet, is black when wet and becomes much lighter gray after drying. In many places the upper part has a mucky or peaty character and contains much undecomposed grass residues. The sub-

FIGURE 22.—Stony land in the southeastern corner of Clay County. The rounded boulders are characteristic of the stones found on terminal moraines. Such land is, of course, unsuited to crops.

soil is heavy sticky dove-gray or bluish-gray clay, usually richly mottled with rust-brown iron stains. The surface soil is compact, becomes hard after drying, and cracks into large irregular clods.

Parnell silty clay loam, which, in older surveys, was included with the soils of the Fargo series, covers no large areas but is scattered in a number of small areas, only a few of which are tilled. Most of this land is used for pasture or for wild hay of a rather poor quality. The small spots scattered throughout the fields, if not occupied by stagnant water, are tilled and sown together with the surrounding land.

Pierce gravelly loamy sand.—The only considerable body of Pierce gravelly loamy sand is in the extreme southeastern corner of Clay County. The relief is gently rolling. The outstanding characteristic of the soil is a high content of gravel, pebbles, and cobblestones in both the surface soil and the subsoil.

The grayish-brown or brown surface soil is about 6 or 8 inches thick and consists of unassorted sand mixed with cobblestones and gravel, which is colored and in places is somewhat coherent as a result of the rather small content of organic matter. This grades into a layer of unassorted stony and gravelly sandy material which in places is distinctly stratified.

Pierce gravelly loamy sand is a rather poor soil. A considerable part of it is used for pasture, but the greater part is cultivated. Rye, oats, and potatoes seem to be the crops best adapted to this soil.

SOILS OF THE WAUKON GROUP

The sixth subdivision, comprising the soils of the Waukon group, consists of the forested part of the upland surrounding the ancient Lake Agassiz plain. It occupies about two townships in the southeastern part of Clay County and most of the upland in the southeastern part of Polk County. The relief is predominantly rolling or gently rolling. The drainage of the entire subdivision is good, with the exception of a number of rather small isolated depressions occupied by peat and small sloughs. Small shallow lakes, some of which are now dry, are scattered throughout this section. The virgin vegetation was a dense deciduous forest, although some coniferous trees grow in the southeastern two townships of Polk County. The forest covering the greater part of the subdivision is composed chiefly of aspen, birch, maple, oak, elm, and other hardwoods.

The soils of the Waukon group are developed from the same parent material as that of the soils of the Barnes group, but differ in the manner of their formation because of the forest vegetation. The surface layers of these soils are much lighter gray and are considerably thinner than the corresponding layers of the Barnes soils. The soils of the extreme southeastern corner of Polk County are strongly leached.

A large part of the land of this subdivision is under cultivation, but a considerable acreage still remains in a virgin condition. The common crops here are nearly the same as those grown on the Barnes soils, consisting of corn, small grains, tame hay, and potatoes. The natural supply of plant nutrients provided by these soils is poorer than that of the Barnes soils, and the yields of all nonleguminous crops grown on the soils of the Waukon group are dependent upon fertilization and proper manuring.

The Waukon group includes Waukon loam, Waukon silt loam, Waukon loamy sand, Nebish loam, and Mahnomen loamy sand.

Waukon loam.—The surface soil of Waukon loam is gray or dark-gray loam ranging in thickness from a few inches to about 1 foot, in many places being only 1 or 2 inches thick. The subsoil is light brownish gray or very light brown, and grades into the substratum of typical glacial drift. This drift is very light olive gray or gray, very compact, and well supplied with lime. Small boulders, cobblestones, and gravel are on the surface and throughout the surface soil, subsoil, and substratum.

The original vegetation under which Waukon loam has been developed is a rather dense deciduous forest composed of aspen, birch, maple, oak, elm, and other species. In a virgin condition the surface of the soil is covered with a thin matlike layer of an undecomposed residue of dead leaves and grasses, about 1 or 2 inches thick.

Waukon loam is mapped in the northeastern corner of Norman County and in the adjacent southeastern corner of Polk County and is intricately associated with Waukon silt loam. The relief is mostly gently rolling to rolling, and typical Waukon loam, as a rule, occupies the relatively higher and better drained positions. The surface drainage is generally good, but in a number of scattered depressions, which have a flat surface, drainage conditions are less well developed.

The greater part of this land has been cleared of its forest vegetation and brought under cultivation. It is rather easily tilled and does not bake and harden on drying. The content of organic matter is rather small. The soil responds readily to fertilization, especially to manuring. Oats, barley, rye, potatoes, corn, tame grasses, and occasionally some wheat are grown. The uncultivated areas still under forest cover are used for pasture.

Waukon silt loam.—Waukon silt loam is closely associated with Waukon loam. As a rule it occupies the more or less depressed or relatively flatter areas and is interspersed with areas of more restricted surface drainage than that of the areas of Waukon loam. The largest body of Waukon silt loam is in the eastern half of Waukon Township in Norman County, but a number of small irregular areas are scattered throughout the entire section occupied by the Waukon soils. The lowest portions of these areas are usually occupied by small bodies of peat. Many of these areas are not, and apparently never were, entirely covered by forest vegetation, but they include areas of grassland among groves of deciduous trees covering the relatively drier and more elevated land.

The surface soil is dark gray and in places almost black and is about 8 or 10 inches thick. The subsoil is light gray or somewhat bluish gray, slightly mottled with rust-brown iron stains.

A considerable part of the area occupied by Waukon silt loam is used for wild hay and for pasture, but the better drained areas are cropped.

Waukon loamy sand.—Waukon loamy sand occurs in several isolated bodies scattered over the southeastern part of Polk County. Most of these areas are along the upper shore line of the ancient lake and are associated with the sandy soils of the lake bed.

Waukon loamy sand is a light brownish-gray loose soil originally covered by forest. The gray or brownish-gray surface soil is about 8 or 10 inches thick and grades, without any distinct line of demarcation, into the light-brown loose sandy subsoil. The thickness of the sandy layer ranges from 1 to more than 5 feet. It rests on light-gray compact glacial drift.

Nebish loam.—Nebish loam occurs in the southeastern corner of Polk County. Its surface soil consists of two distinct layers. The upper layer is very thin in most areas, about 2 or 3 inches thick, in places being less than 1 inch thick. It is dark gray or nearly black and in many places contains a considerable amount of undecomposed or incompletely decomposed vegetable residues. The soil material is soft and rather mellow. The second layer of the surface soil ranges from 3 to about 8 inches in thickness, has a very light gray (bleached) color, and usually is more or less friable. The texture of this layer in most places is somewhat coarser than that of the substratum and especially that of the immediate subsoil. The surface soil is underlain by a heavy layer which is rather dark brown or dark brownish gray and ranges in thickness from 1 to more than 2 feet. The material of this layer is usually broken into roughly cubical, sharp-angular lumps of different sizes. As a rule, these lumps are relatively small in the upper part of the layer and gradually become larger in the lower part, and most of them are covered by a very dark brown glossy film. This layer grades into very light grayish-brown unassorted glacial drift, which is everywhere very rich in lime carbonates, whereas the surface soil and the brown layer underlying it are strongly leached and are usually acid in reaction.

Small boulders, cobblestones, and gravel are scattered over the surface and in the surface soil, subsoil, and substratum, but the quantity of stony material is nowhere sufficient to be an obstacle to cultivation.

The native vegetation on Nebish loam was composed of mixed forest, predominantly of deciduous trees, such as aspen, oak, birch, maple, and elm. In a virgin state the surface of the soil is covered by a mat of undecomposed forest debris from 1 to 3 inches thick.

The relief is rolling to undulating, and surface drainage is generally good, but a number of small depressions scattered throughout the area of this soil have no drainage outlets and are occupied by small bodies of peat.

Nebish loam, being strongly leached, naturally is less productive of nonleguminous crops than are the Waukon soils, with which it is closely associated, and is still less productive than are the Barnes soils; it requires more manuring than any of these soils. Where the soil is properly treated, all common crops, such as small grains, corn, alfalfa, and potatoes, give very good returns. About one-half of this soil is in crops, and the remainder is still unbroken, being covered by the mixed forest, and is used for pasture.

Mahnomen loamy sand.—Several small bodies of Mahnomen loamy sand are in the southeastern part of Polk County. The surface soil is gray or grayish-brown loose mixed sand, ranging in thickness from 3 inches to about 1 foot, and rests directly on beds of gravel. The layer of gravel ranges in thickness from 3 to many feet and is underlain by glacial till.

MISCELLANEOUS LAND TYPES

Alluvial soils, undifferentiated.—Alluvial soils, undifferentiated, include soils which are widely different in their characteristics but which are so intricately mixed that separation of the different types was impractical. These soils occur throughout the entire area. They do not cover any continuously large or broad areas but occur in long narrow strips along the channels of streams which traverse the area.

These soils range in texture from clay to almost pure outwash sand; in color from black to very light grayish brown; and in stoniness from a complete absence of stones to very stony and gravelly areas. Most of this land is subject to floods, and many areas are composed of poorly drained wet land, as a result of which only a small part of the land is under cultivation, and by far the greater part of it is used for wild hay in the open sections of the area and for pasture in the forested sections. By far the greater part of the bottom land is forested (fig. 23), but narrow strips along the small streams in the prairie portion of the area are open. Most of the soils of the bottoms are heavy, are rich in organic matter, are very dark, and have thick surface soil layers. These soils occupy positions below the average level of the surrounding country and are subject to floods. Where the banks of the ravines are not too steep and the ravines themselves are not too deep, the bottom land is cultivated.

Most of the soils along the larger streams are lighter in texture, ranging from loamy sand to silt loam, are rather loose, and are light gray. In places they are interbedded with streaks of gravel, but in most places they are rather uniform to a depth of several feet. The surface of these areas is usually broken by abandoned stream channels, and most of them support a cover of willow shrubs and mixed forest and are used for pasture.

FIGURE 23.—Forest on alluvial soils along Buffalo River in Clay County. The streams in Red River Valley are characteristically sluggish.

In places along the smaller streams the flat bottom land was too narrow to be indicated on maps of the scale used in this survey, and some areas of these soils indicated on the soil maps include slopes partly covered by alluvial material.

Dune sand.—Only a few small areas of dune sand are in the area, one of the largest being in sections 5 and 6, T. 146 N., R. 44 W., in Norman County and in the adjacent part of Polk County. A smaller development is in sections 3, 10, and 15, T. 160 N., R. 46 W., in Kittson County. The hills rise from 20 to 40 feet above the surrounding country and consist of loose sand heaped by the wind. They are partly covered by open oak groves and are used for pasture (fig. 24).

During dry seasons in recent years a number of small dune areas have been started in the sandy soils, where fields have been plowed in dry windy seasons or allowed to become bare of vegetation, and the sand, whipped by the wind, has formed into ridges. These areas range in size from less than 1 to more than 200 acres. Such wind erosion has been especially severe in areas of Ulen loamy sand in Clay and Norman Counties (fig. 25) since the completion of this survey.

FIGURE 24.—Old sand dunes in Norman County.

Peat.—Peat deposits ranging in thickness from less than 1 foot to more than 6 feet cover large parts of the area (fig. 26). The largest deposits are in the eastern half of Marshall County around Mud Lake, and in the northeastern corner; and in the eastern part of Kitt-

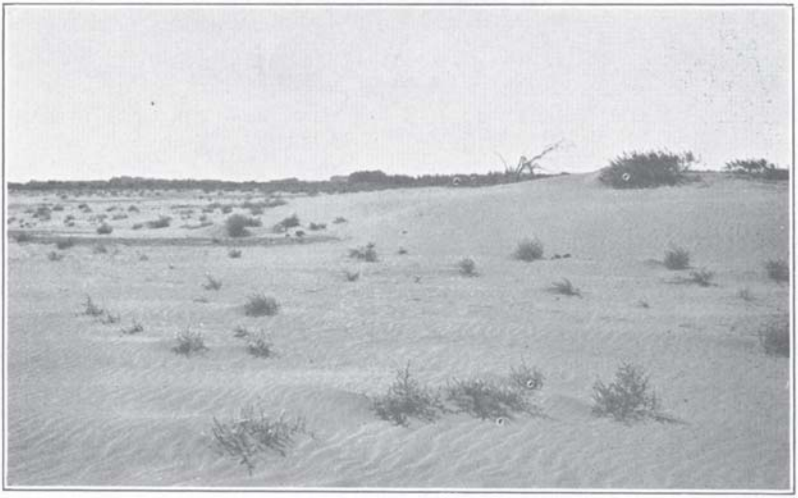

FIGURE 25.—Recent dunes on Ulen loamy sand in Norman County. When these soils are cultivated in large fields, great care must be taken to prevent serious soil blowing.

son County in Ts. 161 and 162 N., R. 45 W. In addition to these, many smaller bodies, ranging in size from less than 1 acre to several square miles, are scattered throughout the entire forested part of the ancient lake bed, including the eastern parts of Kittson, Marshall, Red Lake, and Polk Counties. In the upland section a great number of isolated and relatively small areas of peat land occupy depressions in the eastern parts of Polk, Norman, and Clay Counties. Only a few isolated areas of peat are in the prairie portion of Red River Valley proper.

The peat layer consists of undecomposed vegetation (mainly grass), is brown, and differs greatly in thickness. In places where peat is associated with the Pelan or the Sioux soils it is underlain by a layer of gravel resting on glacial drift, but in many other places the peat rests directly on clayey glacial drift.

Much of the peat land is open or partly covered by marshy shrubs, but in eastern Marshall, Red Lake, and Polk Counties there are several large muskegs.

FIGURE 26.—Peat deposits in the eastern part of Marshall County. Under present conditions such land is unsuitable for crops.

A large area of peat land has been burned over, and peat fires continue to denude the country each year. In many places the peat has been burned completely, exposing the underlying substratum covered by ash. A large acreage of peat (fig. 27) has been burned since the field work of this survey was completed.

By far the greater part of the peat land is used solely for pasture, and only a small part of it is in cultivation. Oats, barley, and sweetclover are the most common crops.

Alway reports [7] that peat of the sedge-covered bogs of northeastern Minnesota has been found very unproductive when treated like the ordinary or mineral soil:

> The unproductivity of this peat is due to a lack of available phosphate. When this is supplied, good yields of most crops adapted to that section of the state are obtained, except as they happen to be destroyed by summer frost or flood. When phosphate is not supplied, only flax, of all the crops tried, has given satisfactory yields. * * * Among the grains, the most promising are flax as

[7] ALWAY, F. J. REPORT OF GOLDEN VALLEY PEAT EXPERIMENTAL FIELDS, 1918 AND 1919. Minn. Agr. Expt. Sta. Bull. 194, 116 pp., illus. 1920.

a first crop, oats, winter rye, and field peas. Wheat is the least satisfactory, and flax fails on burned peat. A mixture of alsike and red clover with timothy, and also brome grass are advised for hay and pasture. Corn, millet, and various other crops which do well on adjacent mineral soils, are not suitable for the peat because of summer frosts, which may be expected in some seasons to ruin even flax and potatoes. The grasses and ordinary clovers are uninjured by summer frosts and are well adapted to the conditions in general.

The danger of summer frosts, the threatened potash exhaustion, and the good growth of grasses and clovers combine to make the production of milk, beef, mutton, and wool the most promising use of these peat lands when properly fertilized.

Rough broken land.—Rough broken land is shown on the maps of Norman and Clay Counties in narrow strips along Wild Rice and Buffalo Rivers. It occupies the steep and, in many places, severely eroded slopes. It includes also some narrow areas of bottom land and riverwash at the bases of cliffs. Virtually all this land is covered

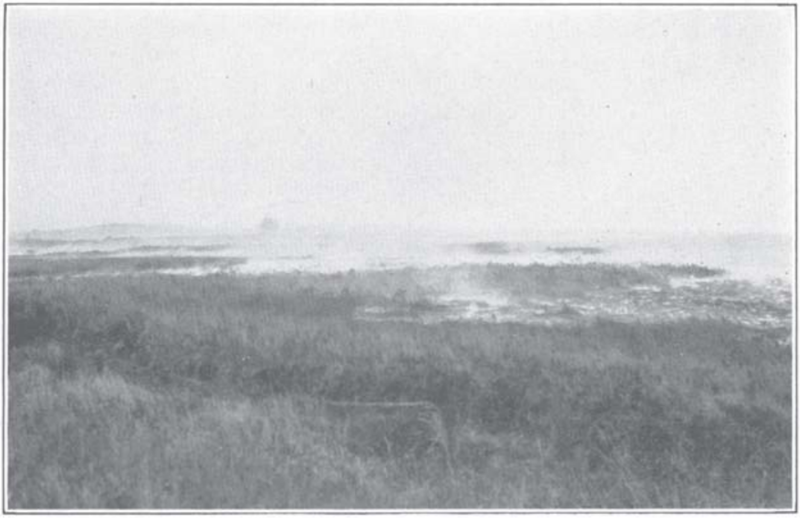

FIGURE 27.—Peat fire in Marshall County. Such fires may continue for several months, or even years, and become serious hazards to the area.

by a thick growth of willow and alder bushes and by mixed aspen and birch forest. None of it is cultivated for crops, and it is used entirely for pasture.

LAND USES AND AGRICULTURAL METHODS[8]

In spite of the recent increase in the acreage of corn (about 170,000 acres), potatoes (about 100,000 acres), legumes and other tame hay (about 260,000 acres), and some other crops, the usual cropping practice in Red River Valley continues to be primarily a combination of

[8] The greater part of this section is compiled from Bulletins 282, 283, and 284 of the Minnesota Agricultural Experiment Station.

POND, G. A., SALLEE, G. A., and CRICKMAN, C. W., See footnote 6, p. 15.

SALLEE, G. A., POND, G. A., and CRICKMAN, C. W. AN ECONOMIC STUDY OF LIVESTOCK POSSIBILITIES IN THE RED RIVER VALLEY OF MINNESOTA. Minn. Agr. Expt. Sta. Bull. 283, 58 pp., illus. 1931.

POND, G. A., SALLEE, G. A., and CRICKMAN, C. W. PLANNING SYSTEMS OF FARMING FOR THE RED RIVER VALLEY OF MINNESOTA. Minn. Agr. Expt. Sta. Bull. 284, 84 pp., illus. 1931.

the spring grains. No definite system of crop rotation has been worked out, the sequence of crops is very irregular, and practically every crop may follow itself a second year or may follow any other crop with no definite regularity. Lack of rotation results in unbalanced ratios between crop and livestock production and between cash crops and feed crops. A crop rotation, as a definite program extending over a series of years, provides for the growing of an approximately equal acreage of a given crop, or groups of crops, each year and for the shifting of these crops each year from one field to the other, so that the entire cultivated area of the farm is used for each crop at least once during the cycle of rotation.

The Northwest Agricultural Experiment Station of the University of Minnesota, located at Crookston, recommends four different crop rotations. Two of these four are for the large farms and provide 7-year rotations, and the other two are for the medium-sized farms and provide 5-year rotations. In each group one rotation is for the farms raising much livestock and the other for the farms raising less livestock. All four contain at least one field of legumes and one field of cultivated crops. Of the legumes, sweetclover is recommended chiefly for pasture, and alfalfa, for hay. These recommendations, however, are made for the main physiographic section of the area—Red River Valley proper—or the open part of the lake-bottom plain.

The introduction and wider application of any system of crop rotation undoubtedly will add extensively to the solution of the main cropping problems in the valley, such as weed control and disease control.

Sowthistle, Canada thistle, and quackgrass are the most widespread and the most destructive weeds. The ordinary wild oats, kinghead, wild mustard, wild garlic, and several others are of relatively less importance, but in some places may become a great nuisance. The first step in the eradication or control of weeds is ordinarily a season of summer fallowing. If the season is not too wet, summer fallowing, if properly done, is effective. Continued control is accomplished by seeding sweetclover in the grain in spring; plowing the meadow the following year after the first crop, or in July if pastured; keeping the new weed shoots from becoming established by cultivation until the ground freezes in the fall; and the following year planting to a cultivated crop. It is necessary to rotate sweetclover and a cultivated crop regularly with the grain crops and to plow the grainfields immediately after the crop is removed from the land.

The diseases attacking the various crops present a problem of no less importance. The annual damage by black stem rust to wheat is as high as 30 percent in seasons favorable to rust development. Early seeding to bring about ripening ahead of weather conditions favorable to rust development and the use of rust-resistant varieties are the most effective methods of combating the disease. Wheat root rot, crown rust of oats, the smuts of wheat, oats, and barley, and barley stripe are listed among the other diseases which take a heavy annual toll from the crops in the valley. Crop rotation, proper seed treatment before planting, and the sowing of resistant varieties are the means of control.

A proper maintenance of the soil condition is another problem. Results obtained at the Northwest Experiment Station show that for the 17-year period 1910–1927, wheat grown continuously averaged only 14.7 bushels as compared to 22.8 to 24.9 bushels in a rotation. Rotation experiments at the same station, as well as the experience of the farmers themselves, have demonstrated that the turning under of a legume, especially sweetclover, once in each rotation period is very beneficial to the yields of following crops because of its loosening effect on the heavy soils.

Other problems, which have rather regional or local character, are drainage control, control of wind erosion on the sandy areas, and excessive soil alkalinity in some places in the southern part of the area. The drainage problem has not yet been satisfactorily solved, notwithstanding the fact that a great mileage of deep principal and shallow lateral ditches has been opened throughout the extensive poorly drained districts. Probably this is not so much the result of a deficiency of drainage ditches or their size, as their failure to carry off the surface water at the time when this is most urgent. The main problem is the drainage of the water from melting snow in spring. Many of the main ditches are filled with ice and snow in spring, which thaw more slowly than the snow cover on the land surface; consequently water submerges the large flat areas for considerable periods, preventing the early start of field operations and not infrequently forcing the farmers to change their plans for the year by seeding late crops. Probably the widening of some of the principal ditches would be a practical solution of part of the problem. These should be constructed in a shape more or less similar to natural gullies; this will prevent them from filling with drifting snow during the winter. Wind erosion is an important problem in the sandy districts of the valley, especially in Norman County, and the soils containing soluble salts are locally important in Traverse and Wilkin Counties.

MORPHOLOGY AND GENESIS OF SOILS

The character of the parent material, the manner in which this material has been modified by the soil-forming agencies, and the length of time during which these agencies have acted upon the parent material are the three principal factors which determine the character of the soil.

The parent material from which all soils of the Red River Valley area are developed is a glacial drift deposited during the last, or late Wisconsin, glaciation.[9] The entire area is covered by a sheet of this drift, known as Young Gray or Keewatin drift, ranging in thickness from less than 100 to several hundred feet. This glacial drift, however, is not a single uniform type of parent material. From the melting of the ice to the beginning of the formation of the existing soils, the surface of the drift deposits was modified by geological agencies other than ice, and the work of these agencies produced several distinct types of parent material; consequently over only a relatively small part of the area has the original drift been virtually unaltered. This so-called unmodified drift consists of clay, silt, sand,

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[9] LEVERETT, F. QUATERNARY GEOLOGY OF MINNESOTA AND PARTS OF ADJACENT STATES. U. S. Geol. Survey Prof. Paper 161, 149 pp., illus. 1932.

gravel, and boulders mingled indiscriminately in an unstratified mass. The parent material represented by the unmodified Young Gray drift covers the extreme southern and eastern portions of the area described as an upland section.

By far the greater part of the entire area, namely, the part that forms the plain of Red River Valley and is known as the bed of glacial Lake Agassiz, was covered with a great body of water for a long period of time following the recession of the glacier.

Lake Agassiz dried gradually, and its dimensions and its depth decreased little by little. The configuration of its flat bed is such that at nearly every stage of its history wide stretches of shallow water were along its margins, where wave action affected the bottom, muddied the bottom material, and gradually washed out the finer constituents, which were carried away by the lake currents and deposited on the bottom of the deeper portions of the basin. Thus, step by step, in the course of the gradual diminishing of the lake, the superficial section of the glacial drift was completely reworked, sorted, and redeposited throughout the entire area occupied by the lake. Not all sections of the lake bed, however, experienced an equal force from the wave action, as the outer belts of the bottom adjacent to the highest shore line were affected during the earliest stages of the lake, when both the depth and the dimensions of the lake were the greatest in its history and naturally provided the strongest wave action. From then on, the extent and the depth of the water gradually decreased, and at the same time the strength of the waves gradually weakened; consequently the consecutive inner belts of the lake bottom underwent final reworking by gradually weaker wave action.

The waves of the earliest stages, when the lake was largest, were strong enough to wash away the entire mass of drift with the exception of the larger stones, and produced the steplike escarpments by removal of the earthy constituents of the drift and left the areas with a great number of boulders and other stony material accumulated on the land surface. Many areas in the outer belt of the lake bed are covered with a layer of smaller stones—gravel, pebbles, and cobblestones, depending on the content of stones in the original drift. This layer ranges in thickness from a few inches to several feet, but in only a few places is its thickness more than 2 feet, and in many places it is very thin. Originally these stones and gravel were distributed proportionally through the mass of drift and were dropped and accumulated on the surface because of the complete removal of the earthy material. This layer usually rests upon the till which was not modified mechanically. Later the stony layer was covered with a new layer of fine earth material, mostly sand, of an average thickness of about 1 foot. This material was brought in and spread over the area partly by wind and partly by run-off water from the surrounding higher land.

The fine earth material removed from the surface layer of the outer belt was transported by the water in the lake and deposited over the unassorted drift on other parts of the bottom. This fresh deposit apparently did not contain any coarse stony ingredients and consisted of clay, silt, and sand. The next belt of the lake bed, inside of the first belt, was affected by weaker wave action. The depth and dimensions of the lake were already considerably diminished as compared with those of the earliest stages, and the winds could not develop such strong wave action as before. These waves stirred the material on the bottom of the second belt and removed the silt and clay but left the outwashed sand. Thus, a sandy mantle has been assorted and spread over the surface of the second belt, and the finer material composed of silt and clay was removed still farther into the inner section of the lake bed.

In just the same way, the third belt of the lake bottom, inside the second belt, was covered with a mantle of assorted silt, and the finest ingredient of the original till, the clay, was removed still farther and finally deposited on the bottom of the deepest portions of the drying lake. This material occupies the axial depression of the original bed and forms the fourth and innermost belt (fig. 28).

The lake in the last stage, especially its southern fingerlike extension, was a narrow and very shallow reservoir. A great part of this was undoubtedly of a marshy character and was overgrown with reeds, sedges, and aquatic grasses. It is doubtful whether any strong waves could be developed in this lake, and the sediments on its bottom must have accumulated in a more or less quiet environment. These sediments included very fine materials brought in by the tributary sloughs of the lake during flood periods, which were not able to carry into the inner belt anything coarser than clay particles and finer silt, because they passed through the wide flat outer belts before they reached the remaining part of the lake and dropped the coarser ingredients of their burden far away from the quiet water of the disappearing lake. The tributaries had not yet carved out any adequate channels and during flood periods spread over wide areas; consequently it is evident that their currents could not have been very strong. The gradual accumulation of such fluvial material produced a conspicuous stratification of the lacustrine deposits in many sections of the inner belt, and in many places thin layers or lenses of nearly pure clay are interbedded with thin layers of floury silt and very fine sand. In some places the fluviolacustrine deposits buried the unde-

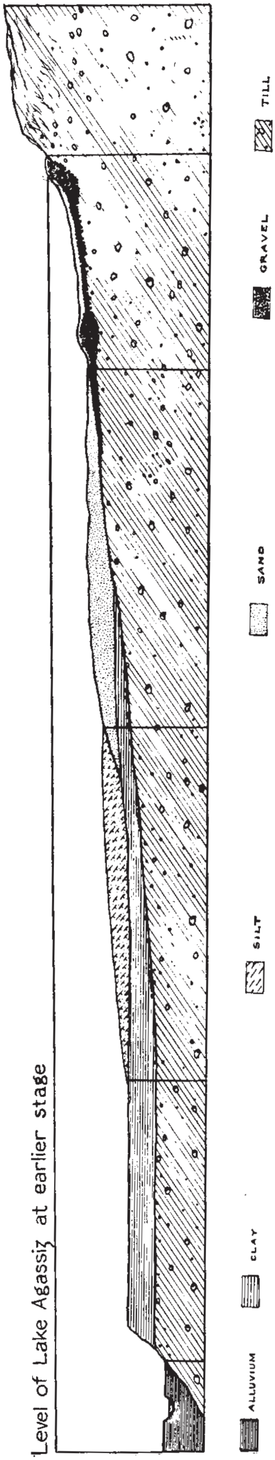

FIGURE 28.—Cross section of the lake-bed area showing distribution of different types of parent materials.

composed residue of aquatic grasses, and layers of these organic materials occur in places at various depths in these sediments. In some places such layers include fragments of wood probably brought into the lake by its tributaries.

Thus, four belts with their corresponding four types of lacustrine deposits were formed, although none of them is sharply defined. Especially is this true of the inner three belts, the boundaries between the sandy and the silty belts and between the silty and the clayey belts being rather indistinct. The change from a relatively coarse textured deposit to a consecutively finer one is rather gradual, the sands of the typical sandy areas being gradually replaced by fine sands, then by very fine sands, which in turn, without a sharp break, pass into silts, and then into clays.

The thickness of the lacustrine deposits differs widely. The layer of assorted lacustrine clay of the inner belt in some places is more than 50 feet thick and rests upon the unassorted till. The silty and the sandy mantles of the third and second belts range in thickness from a mere film to more than 10 feet, and both may rest upon the unassorted original till or upon the earlier lake deposits which are usually heavier in texture than the superficial covers.

Still other types of deposits, such as the accumulations of gravel and sand on the so-called beaches of Lake Agassiz, were produced by wave action. In different stages of the successive recessions of the water of the lake, the waves piled up sandy and gravelly ridges along its temporary shores. Ordinarily, these rise from 5 to more than 20 feet above the surrounding land, range in breadth from a few rods to almost one-half mile, and have smoothly rounded slopes and tops. The typical beaches are built from assorted and stratified gravel and sand, the thickness of the layer of gravel ranging from about 2 to more than 20 feet and resting upon the unassorted till. In many places such ridges have been piled up not along the actual shore lines, but at some distance from them, where, with the decreasing depth of the water, the more or less sharp friction of the bottom retarded the main mass of rolling water and broke the strength of the waves. Thus the shallow lagoons, which were overgrown with grasses and became marshes, were separated from the main body of the lake by the beaches.

Further modification of the surface formations occurred during the post-lake period and was due to either water erosion or wind erosion, but neither of these agencies has imposed any considerable modification upon the surface of the area, because of the relatively short duration of their action, and nearly all the products of their work are restricted to the lake-bed section.

The principal surface formation produced by water erosion is the alluvium which covers the areas of bottom land and is indicated on the soil maps as alluvial soils, undifferentiated. Small narrow areas of such land border the channels of the main streams which drain the area.

The most conspicuous products of wind erosion are the dunes, which occur in only a few places in the lake-bottom section. Wind, however, undoubtedly played a prominent role during the formation of the loose lacustrine deposits, although there is not sufficient evidence that any of the silty cover was removed by the wind. On the contrary, there are some evidences that the areas covered by silty material have remained wet until the present time, and the excessive moisture would protect the surface from blowing away or drifting. The sandy cover of the second belt of the lake bed, however, underwent strong wind erosion after recession of the water. The bare sandbanks and the recently exposed section of the bottom near the shores underwent drifting, and much sand was spread over areas larger than those left by the waves. The sandy mantle over the stony layer of the first belt apparently has been formed mostly in this way, and in other places a similar sandy cover has been spread over some other lacustrine deposits. In some places this occurred immediately after recession of the water of the lake, and in some other places, considerably later, which is clearly proved by the frequent occurrence of fossil soils buried under the recent mantle of wind-blown sand.

In rather rare instances the erosion of the lake bed resulted in a complete removal of the lacustrine deposits and in the exposure of the unassorted glacial drift within the border of the lacustrine region. Such exposures and outcrops occur on the slope and along the crest of the terrace crossing the area and also along the bluffs of the ravines and valleys deeply cut through the body of the upper terrace. An example of this is near Twin Valley, in Norman County.

The recent surface formations include also the deposits of peat and muck accumulated on the bottoms of depressions in the drift area and also covering some spots of the lake-bed area.

Each of the surface formations discussed represents an independent type of parent material. They include parent materials of glacial origin, formed in the prelake period, consisting of (1) unassorted Young Gray, or Keewatin, drift; parent materials of lacustrine origin, formed in the Lake Agassiz period, consisting of (2) a stony mantle over the lake-washed till, (3) a sandy mantle over the till or over the other earlier lacustrine deposits, (4) a silty mantle over the till or earlier lacustrine deposits, (5) lacustrine clay over till, (6) stratified gravel of the shore ridges; and parent materials of recent origin, formed in the postlake period, consisting of (7) stream deposits or alluvium, (8) wind deposits or dune sand, and (9) organic deposits, peat and muck. To this list may be added (10) a glacial till which was covered by the waters of the glacial lake but was left mechanically unmodified, that is, without differentiation of any particularly assorted mantle on its surface. This strictly local type of material is combined with the material produced by the leveling of the terminal moraines which are supposed to have been formed under the water of Lake Agassiz. The different types of parent materials are described as follows:

(1) The Young Gray, or Keewatin, drift consists of clay, silt, sand, gravel, and larger stones mingled indiscriminately in an unstratified mass. The proportion of the stony ingredients is rather small, and only a few boulders of any considerable size are scattered on the surface or embedded in the mass. The approximate thickness of the drift is from 150 to 200 feet. It is dark bluish gray and is very compact. The surface layer, which ranges from 15 to 30 feet in thickness, is modified by general weathering, the color being changed to light yellowish brown and its consistence becoming mellower.

The unassorted drift found within the boundaries of the area is considered as a unit, but this is not entirely correct. The area covered by the glacial drift includes some tracts of morainic sand, morainic gravel, and other stony deposits; some tracts covered by the fluvioglacial sediments; and the belts of terminal moraines (fig. 29). Some portions of the drift area adjacent to the upper shore line of Lake Agassiz are covered by a mantle of sand, which was evidently drifted from the lake shore by the wind. This mantle ranges from less than 1 foot to several feet in thickness and in some places covers an area more than 4 miles wide, back from the shore line. The soils developed over these variations are undifferentiated on the soil maps because of the small scale used, but each of them would be recognized as an individual soil type in a more detailed survey.

(2) The stony mantle over the lake-washed till consists of three layers. The upper layer is composed mostly of sand, but other fine

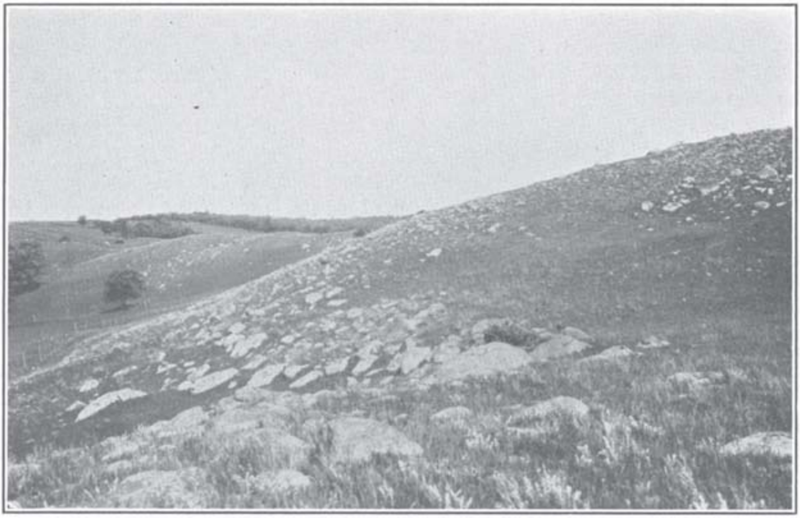

FIGURE 29.—Terminal moraine in Clay County. Soils on the terminal moraines are usually stony and suited only to pasture or forestry.

earth materials (silt, clay, muck) may constitute variable proportions of its mass. The thickness of this layer averages about 1 foot. Where not colored by organic matter, it is light brown. It has been deposited by the wind and by flood waters mostly during the postlake period. The second layer consists of stones. These may be gravel, pebbles, cobblestones, or even larger stones, which are not assorted by sizes and are not stratified. The average thickness of this layer is about 1 foot. In many places the stones lie upon the surface of the underlying material in a very thin layer, but this stone covering is not everywhere continuous. In places this layer is composed of coarse sand or fine gravel. This layer has been produced by the waves of the lake. The third and basal layer is unassorted till deposited by the glacier during the prelake period (fig. 30).

(3) The sandy mantle over the till or over the other earlier lacustrine deposits consists of two layers. The upper layer is composed of

loose outwash sand partly reworked by the wind. It is very light brown or grayish brown and ranges in thickness from a mere film to more than 10 feet. This layer has been produced partly by the undulating action of waves and partly through modification by wind. The second layer, underlying the sandy mantle, may consist of unassorted till or of the earlier lacustrine deposits that in most places consist of lacustrine clay. This layer is compact and usually is dark gray, bluish gray, or olive gray. The boundary between the two layers is usually very sharp, and the sand, as a rule, rests directly upon the surface of the clay or drift, although in some places an intermediate layer of gravel or of stones coarser than gravel separates the two strata. This gravel layer usually does not exceed a few inches in thickness. In those places where this layer rests upon the unassorted drift its origin apparently is the same as that of the stony mantle,

FIGURE 30.—Parent material with a stony layer. The Foxhome soils in the grassland and the Pelan soils in the forest are developed from this type of parent material.

and in such places the type of parent material differs from the preceding only in the relative thickness and the purity of the superficial mantle; but in other places, especially where the lower layer is a lacustrine clay free from any stony ingredients, the gravel apparently has been spread by the waves.

In some places the boundary between the sandy mantle and the underlying lacustrine clay is not so sharp, and the one passes into the other through a stratified zone composed of beds and lenses of sandy material and strata of clay, which gradually increase downward in both number and thickness.

(4) The silty mantle over the till or over the other earlier lacustrine deposits in many respects is similar to type 3 and consists of two principal layers. The upper layer, composed of silt and very fine sand, in most places is of a conspicuous light-yellow color and of a soft floury consistence. Its thickness which ranges from 3 to 6 feet, is somewhat less than that of the sandy mantle. In most places the texture of this layer gradually becomes somewhat coarser

with increasing depth. The second, or lower, layer, the general character of the boundary between the silty mantle and the basal layer, and the occurrence of the intermediate layer of gravel or of the stratified zone are very similar to those described in connection with type 3 except that the occurrence of the stratified zone between the silty mantle and the clay is considerably more frequent under the silty mantle than under the sandy mantle.

(5) The lacustrine clay, if considered as a parent material, consists of one layer; but it may be considered as a clayey mantle spread over the unassorted till. This layer is composed of the well-assorted bedded clay. It is typically dark olive gray or bluish gray and of a waxy and compact consistence. On drying it breaks into thin plates. The thickness of this layer ranges from several feet to more than 50 feet.

In many places the deposits of clay are interbedded by thin horizontal layers and lenses of silt or very fine sand. These are usually very light in color, in some places almost white, have a floury consistence, and range from a small fraction of an inch to several inches in thickness. In such places the lacustrine clay has a stratified character, but its superficial layer is everywhere composed of clay and is rather thick.

(6) The stratified gravel of the shore ridges consists of three layers. The first layer is composed of mixed sand containing a noticeable proportion of coarse sand. This layer ranges in thickness from several inches to about 2 feet and was formed by the waves during a relatively short time immediately before the completion of a given ridge. The second layer consists of well-assorted and horizontally stratified gravel. This may be interbedded by lenses and layers of outwashed sand, but the gravel in any particular layer is composed of grains of approximately the same size. The size of the grains may differ from one layer to another according to the relative strength of the waves at different periods during gradual building of the ridge. The thickness of the gravelly layer as a whole ranges from about 2 to more than 20 feet. The third layer underlying the gravel may consist of unassorted drift or of some of the earlier lacustrine deposits, in most places lacustrine clay.

(7) Recent alluvium is not uniform in composition. It consists of clay, silt, sand, and in places gravel. In some places all these components are well assorted and stratified, and in other places they are thoroughly mixed. The most typical alluvium consists of stratified outwashed sand. This is light brownish gray and usually has a considerable content of organic materials brought in by the muddy flood waters from the surrounding slopes. The thickness of the alluvial sediments covers a wide range.

(8) Dune sand consists of well-assorted extremely loose sand of a very light yellowish-brown color. The sand is heaped into conspicuous asymmetric hills.

(9) Peat consists of undecomposed vegetable remains, mostly of mosses or aquatic grasses. It usually is dark brown and ranges in thickness from a few inches to several feet. Peat, or an organic mantle, may be developed on every parent material already described, and it may rest upon the unassorted drift, upon lacustrine clay, or upon the sandy mantle, or it may be underlain by a layer of gravel and stones.

(10) Glacial till in the lake-bed area has not been modified mechanically by wave action; therefore, mechanically, this till does not differ from that found in the upland. The submerging, however, prevented oxidation and normal weathering of the drift, thus producing a noticeable difference between these two types of parent material. The till within the lake bed consists of but one geological layer composed of unassorted clayey and moderately stony material. The color is dull bluish gray or olive gray, becoming darker as the depth increases.

Each of the different types of parent material described occupies a certain area limited by more or less distinct geographical boundaries. As previously stated, in the lake-bed area these types form a series of successive belts from the ancient shore line to the axial depression. These belts, however, are not continuous, neither are they defined by straight boundaries, as many of the belts occupy a number of areas separated from one another and having very irregular outlines, and in places islands of one type occur within the area occupied by another type. The succession of belts as outlined is, therefore, only a general scheme and not a precise expression of the geographical relationships.

The geographical boundaries which separate the areas occupied by different formations should coincide with the morphological boundaries that separate one formation from the other according to their individual characteristics. The morphological boundaries, however, are nowhere sharp, and the individual characteristics of any one type disappear gradually, giving place to an increasingly clear formulation of the characteristics that are peculiar to another type. In nature, therefore, a complete change from one type to another occupies certain spaces or transitional belts, the width of which may range from a few to several hundred rods.

The transitional belts are of particular importance in areas where the types of parent material composed of one particular layer, such as unassorted glacial till or deep lacustrine clay, came in contact with the types made up of several layers, for example, of a sandy or silty mantle underlain by till or lacustrine clay. In this area, not less than four different forms of gradual change from a homogeneous parent material to one composed of different layers occur. The first and commonest form consists of a gradual diminishing of the thickness of the upper mellow layer and its final disappearance. The second form occurs where the thickness of the mantle remains practically the same but where its mechanical composition or texture gradually becomes heavier and less distinct from that of the underlying layer, which shows less complete assorting during deposition. The third form is represented by a fine stratification of the material of which the different layers are composed; that is, by an interbedding of a thin layer of sand or silt with thin lenses or layers of clay. The fourth form is represented by a very uneven or irregular surface of the lower layer. Usually the boundary that separates the two layers is more or less smooth and parallel to the surface, but in some places, it is extremely irregular. The surface of the clay is composed of innumerable small prominences and hillocks separated by hollows or depressions from 2 to 4 feet deep. These hollows are filled by the material of the upper layer which smooths the general surface of the land; therefore, the mellow mantle is characterized by a very uneven thickness, and the hollows, in places where the underlying layer is exposed on the surface, are small isolated spots. Gradually the number and the size of these spots decrease, decreasing the area covered by the mantle, which finally disappears.

The transitions from the parent material having a layer of accumulated gravel or stones to that in which such a layer is absent, are more or less similar to those previously described (fig. 31).

Not all these intermediate forms are recognized as independent types of parent material; therefore the soils developed from them do not constitute independent soil types but are recognized as transitional phases of the principal types.

Many different soils can be developed from each given type of parent material according to the local combination of the soil-form-

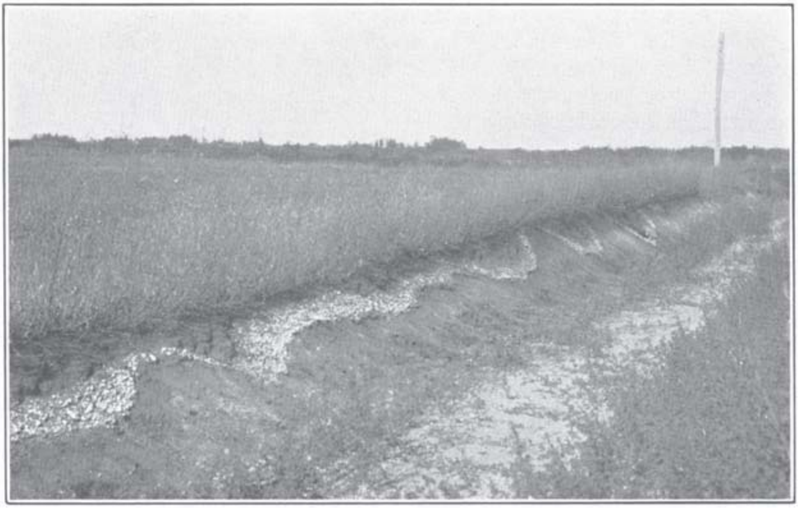

FIGURE 31.—Uneven surface of the lower layer of parent material covered with a thin layer of gravel.

ing agencies, the most important among which are vegetation, climate, and relief.

The eastern part of the valley, including the adjacent areas of the upland surrounding the lake bed, lies in the belt of forest vegetation, whereas the western part extends into the open prairie (figs. 32 and 33). Between these two sections is a relatively narrow transitional belt where both forest and grass vegetations are intermingled. Thus the entire area comprises three different belts, or sections, each of which has its own combination of soil-forming factors.

With a few exceptions, all types of parent material previously described, occur in each of these three belts, and these parent materials naturally undergo modifications into soil in different ways. Three parallel groups of the soils, therefore, have developed from each type of parent material; namely, one formed under the influence of grass vegetation, one formed under the influence of forest vegetation, and one formed under the combined influences of both.

The main distinction of soil formation in the grassland from that in the woodland is due to a specific arrangement in each case of the turn-over of certain compounds between the soil and living matter.

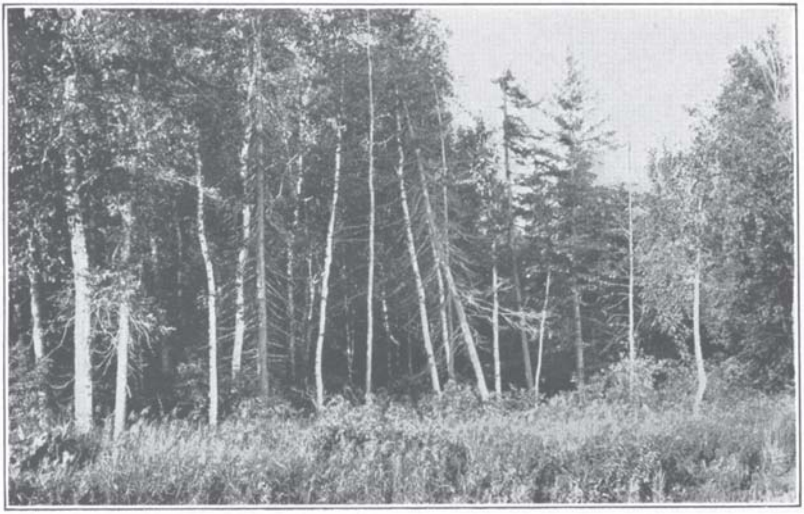

FIGURE 32.—Forest vegetation, predominantly birch, aspen, and balsam fir, of the eastern part of the area.

In the grassland the entire amount of vegetable matter produced by a yearly crop is turned over to the soil in the form of organic residues and undergoes a rather slow process of decomposition which leads to

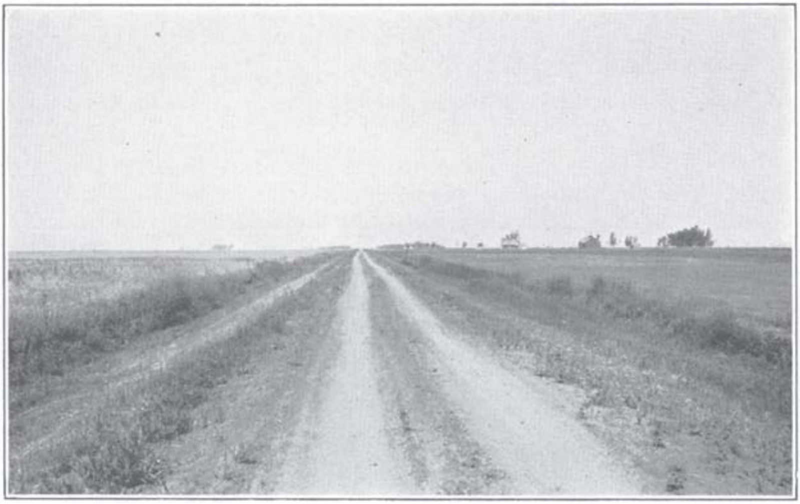

FIGURE 33.—Prairie of the western part of the area.

the accumulation of a large amount of humus. In woodland only a part of the vegetable matter is returned to the soil each year, and this undergoes rather fast decomposition that prevents an accumulation of humus. The organic material of a grassland soil usually is in the form of well-decomposed amorphous humus, whereas that of a forest soil is predominantly in the state of "raw" humus or of a semidecomposed forest litter.

The greater part of the roots of grasses are in the A horizon of the soil, whereas most of the tree roots are distributed in the B horizon. An exchange of material between the living matter and the soil in a grassland occurs, therefore, in the uppermost part of the soil; whereas in the woodland its functions extend into the subsoil, and the plant nutrients must be leached through the A horizon before they can reach the roots and be consumed by the plants.

The climatic conditions of the open western part of Red River Valley do not differ materially from those of the forested eastern part; therefore, climatic conditions and their variations cannot be held primarily responsible for the development of strikingly different

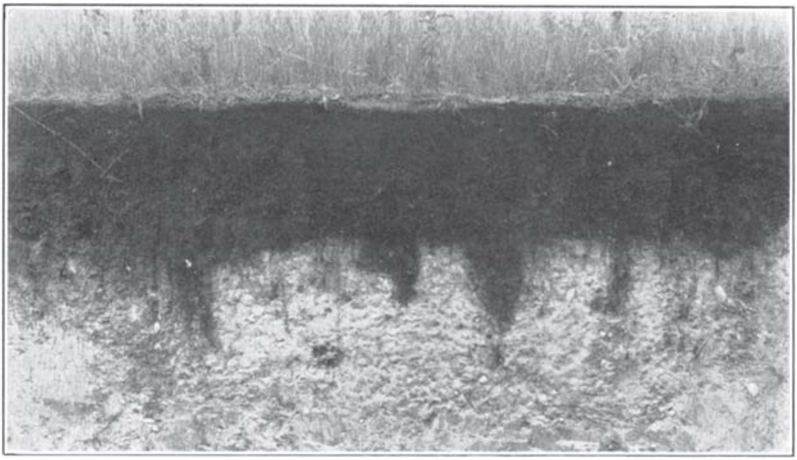

FIGURE 34.—A profile of Barnes loam representing the group of Chernozem soils in the area. Note the deep black surface soil.

soils in each section. Soil differences, apparently, must be attributed principally to the influences of different types of vegetation.

The outstanding characteristic of the soils of the grassland is an accumulation of a large amount of humus in the A horizon which acquires a dark-brown, dark-gray, or black color according to the content and, probably, to the composition of the humus. The soils of the woodland, on the contrary, are characterized by a thorough leaching of the A horizon and by the removal of most of its soluble compounds.

Many of the dark-colored soils of the open part of the valley and the surrounding area belong to or are closely related to the Chernozem group of soils, whereas the most strongly leached and light-colored soils of the extreme eastern part of the area are perfectly developed Podzols. Both the Chernozems and the Podzols occur in the lake-bed area and in the surrounding upland (figs. 34 and 35). The soils of the transitional belt are neither true Chernozems nor true Podzols.

The transitional belt in itself is not so distinct a geographical entity as are the belts between which it extends. The geographical boundaries that separate this belt from the prairie and the forest belts are exceedingly irregular and indistinct. Ecologically, this belt represents an intricate combination of the areas of virgin prairie and the areas occupied by forest. The ecological boundaries, however, that separate the forested and the open areas are not the precise boundaries that separate the typical soils of the forest from the typical soils of the grassland. Many of the soils of the forested areas in the transitional belt are decidedly different from the soils developed under the same vegetation inside the forested belt, and the same thing is true in regard to the soils of the grassland. In many places this is due to the instability of the ecological boundary which is determined by the never-ending biological battle between the grass and the tree vegetation. In many places the forest advances into the prairie, or, vice versa, retreats from certain areas. The changes of vegetation may

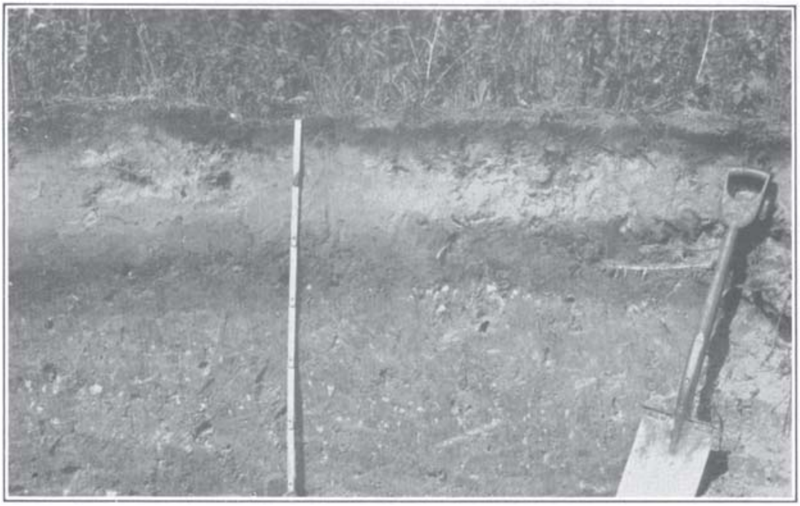

FIGURE 35.—A profile of Nebish loam representing the group of Podzol soils in the area. In contrast to the soil shown in figure 34, note the very thin dark-colored surface soil underlain by light-gray leached soil.

be caused by preliminary changes in the soil, or they may be caused by changes of climate and will be followed by changes of the soil characteristics. It is not definitely known whether the forest advances into or retreats from the prairie in Red River Valley. Because of such conditions, the characteristics of the soils of the transitional belt differ more widely and are less stable than those of the adjacent stabilized natural regions.

Within the borders of any given natural land division, several different soils can be developed from any one parent material according to the local relief, which is a factor controlling distribution of surface moisture. Three principal types of relief are developed: (1) the steep slopes; (2) gently undulating, gently sloping, or level well-drained plains; and (3) poorly drained flats and depressions. The run-off from the steep slopes leaves only a small fraction of the rainfall that may be absorbed by the soil and may act upon it as a soil-forming factor. The land surface having relief of the second type retains most of the meteoric moisture. The land characterized by the third type of relief receives moisture from the adjacent elevated areas in addition to the moisture supplied by the normal rainfall.

According to these types of relief not less than three different soils can be developed from any kind of parent material. These three are as follows: (1) Oromorphic (or orogenic) soil—characterized by a slight modification of the parent material by the constructive soil-forming factors and dominated by the characteristics of the preexisting material—developed under the predominant influence of surface erosion; (2) phytomorphic (or phytogenic) soil—characterized by a normal modification of the parent material—developed under the predominant influence of vegetation; (3) hydromorphic (or hydrogenic) soil developed under the predominant influence of excessive moisture. The soils of the second group represent the most typical soils and are usually spoken of as the normal soils of any given region. The normal soils of the valley and of the surrounding upland, and their classification according to the types of parent material and the natural land divisions, are shown in table 20.

TABLE 20.—*Classification of the normal soils in the ancient lake-bed area of Red River Valley, Minn.*

Type of parent material	Grassland	Transitional belt	Forest
Unmodified glacial drift	Barnes	Waukon	Nebish.
Glacial drift in the ancient lake-bed area	Kittson	Nereson	Not known.
Stony mantle	Foxhome	Pelan	Do.
Sandy mantle	Ulen	Poppleton	Hiwood.
Silty mantle	Bearden	Not known.	Baudette.
Lacustrine clay	Fargo	Gatzke	Taylor.
Stratified gravel on ridges	Sioux	Sioux	
Alluvium	Alluvial soils, undifferentiated		
Dune sand	Dune sand, undifferentiated		
Organic deposits	Peat		

Because of the character of the relief of the area, only the Barnes soils have their oromorphic associate. The hydromorphic associates are more numerous, although an effective improvement of the natural conditions of surface drainage greatly reduced the area originally occupied by these soils, as the establishment of artificial drainage changed natural conditions of soil formation. Sufficient time required for a complete readjustment of the soil characteristics to the new conditions has not yet elapsed since the old and natural conditions were altered. Therefore, the soils of most of these areas can be recognized as immature phases.

The Parnell soils are recognized as the hydromorphic associates of the Barnes soils; the Tanberg soils as the hydromorphic associates of the Bearden and Ulen soils, undifferentiated; and the Arveson soils as the hydromorphic associates of the Poppleton soils. The entire area of the hydromorphic associates of the Fargo soils, which originally was very extensive, is drained artificially, and the immature soils of this area are included with Fargo silty clay loam. The areas which could be occupied by the hydromorphic associates of the Pelan, Kittson, Gatzke, and Nereson soils are occupied by peat land.

The Barnes series includes the Chernozem soils developed from unassorted Young Gray glacial drift under open grassland conditions. The principal types of this series are sandy loam, loam, and silt loam. The A horizon is very dark gray or black and ranges in thickness from about 4 inches to nearly 2 feet. The A horizon of Barnes silt loam and of types of still heavier texture in many places shows a well-developed granular structure. The transitional B horizon is grayish brown or reddish brown and averages about 6 inches in thickness. The horizon of carbonate accumulation is very light brown and averages about 8 inches in thickness. The C horizon is light yellowish brown, which gradually passes into gray mottled with rust-brown stains. The relief ranges from gently undulating to hilly; the drainage is generally good; and the stoniness is moderate. The average depth to effervescence with acid is 20 inches from the surface, in most places directly below the B horizon.

The Foxhome series (fig. 36) includes the soils developed from lake-washed till covered by a stony or gravelly mantle under grassland conditions. The principal types of this series are sandy loam and loamy sand. The A horizon is usually confined to the uppermost fine earth layer covering the stony mantle. It is black or very dark gray and averages about 1 foot in thickness. Beneath the A horizon is a stony layer ranging in thickness from a few inches to almost 2 feet. The B horizon is commonly associated with this layer; its fine earth component is gray or light gray. The carbonate horizon is in the upper part of the unassorted till immediately beneath the stony mantle. It is very light gray and averages about 1 foot in thickness. The C horizon is gray or light olive-gray unassorted till. The relief is flat to very gently undulating; the drainage is moderate to poor; and the stoniness ranges from scant to abundant. The average depth of effervescence is about 1 foot from the surface, usually in the stony layer or immediately beneath it.

The Ulen series (fig. 37) includes the soils developed from loose sandy material assorted by wave action, partly reworked afterward by the wind and deposited over the unassorted till or the earlier clayey lacustrine sediments. The thickness of the sandy layer of the typical Ulen soil is not less than 2 feet. All the members of this series are grassland soils. The principal types are loamy sand and loamy fine sand. The A horizon is very dark gray or almost black and ranges in thickness from about 8 inches to nearly 2 feet. The material of the entire horizon is uniform, friable, and structureless. Its lower boundary is smooth or gently wavy and very indistinct; it grades without any sharp change into the subsoil. The transitional layer is the B_1 horizon, the approximate thickness of which is about 8 or 10 inches. The C_1 horizon is a loose uniform light-brown or yellowish-brown sand, which ranges in thickness from about 1 to more than 10 feet and rests upon gray or olive-gray clay. Because of its loose sandy character, the horizon of lime accumulation is very indefinite. Effervescence with acid appears in the lower part of the B_1 horizon or immediately beneath it and disappears in the lower part of the C_1 horizon. The C_2 horizon is everywhere very rich in lime and in many places contains numerous white concretions. The relief ranges from flat to very gently undulating, and drainage is mostly fair but in some places is only moderate or even insufficient. Typically, all the soils of this series are entirely free from stones.

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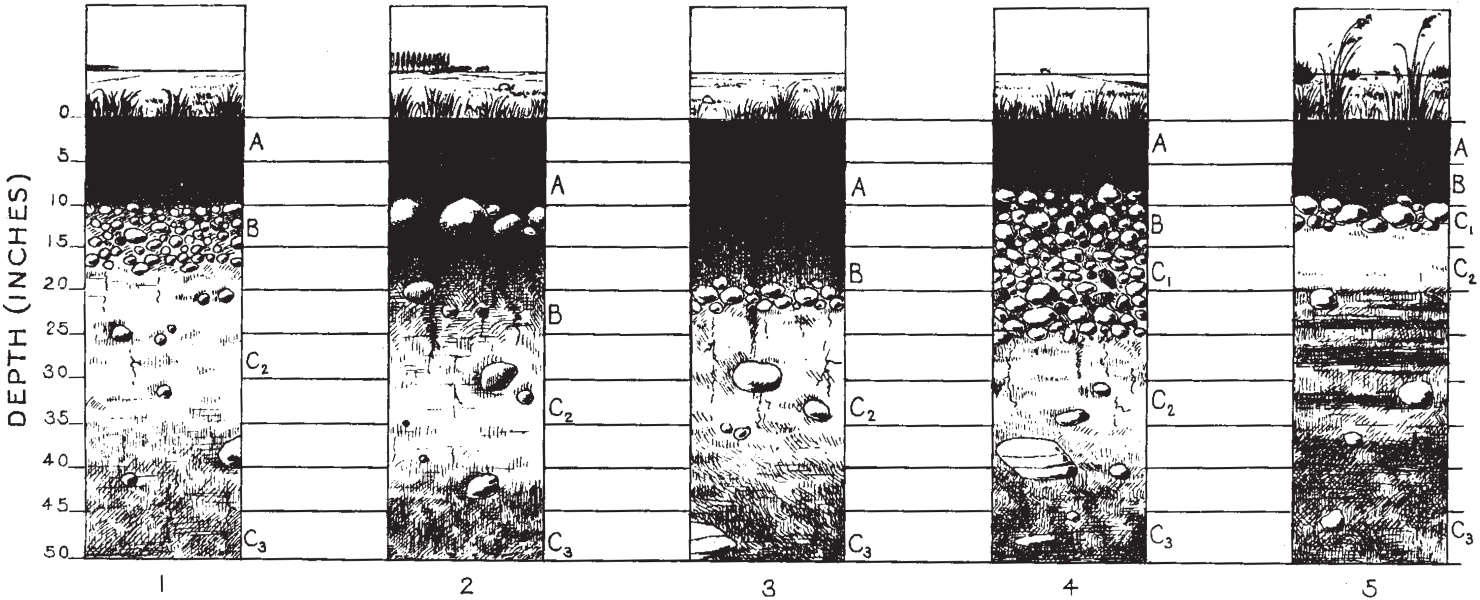

FIGURE 36.—Typical profiles of the Foxhome soils: Profiles 1, 2, 3, and 4, local variations of the normal Foxhome soil; profile 5, poorly drained phase with a layer of marl in horizon C_2.

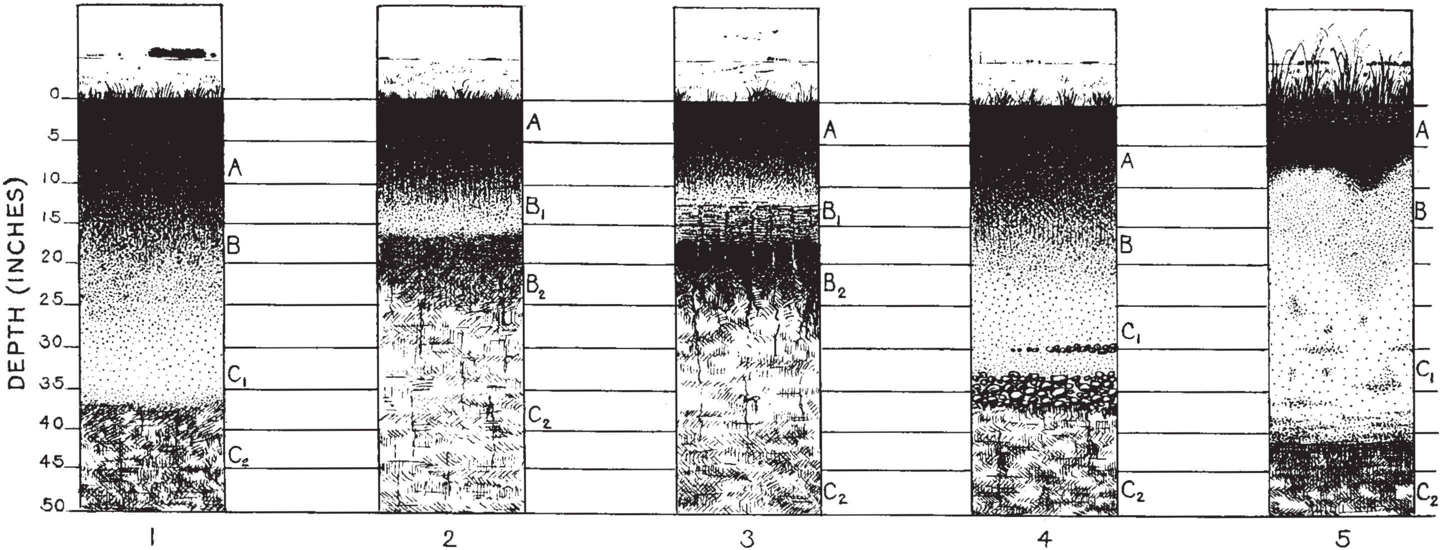

FIGURE 37.—Typical profiles of the Ulen and related soils: Profile 1, normal Ulen loamy sand; profiles 2 and 3, shallow phase of Ulen loamy sand (recognized as Nereson loamy sand); profile 4, gravelly phase of Ulen loamy sand; profile 5, poorly drained phase of Olen loamy sand.

The Bearden series (fig. 38) includes soils developed under grassland conditions from the silty or very fine sandy mantle assorted by the waves of the lake and deposited over the unassorted till or over the earlier clayey lacustrine sediments. The thickness of the silty mantle of every typical Bearden soil is not less than 2 feet. The principal types of this series are loam and silt loam. The A horizon is very dark gray and ranges in thickness from 8 to 18 inches. The material of the entire horizon is homogeneous, mellow, and structureless, only the silt loam type in places showing a medium-fragmental structure. The lower boundary of this horizon is usually more or less sharp, and the transitional horizon, B_1, in most places is absent but where present is seldom more than 2 or 3 inches thick. The horizon of carbonate accumulation is almost everywhere very well developed. It is very light gray and averages about 8 inches in thickness. In most places it lies directly beneath the A horizon and is more or less distinctly, if not sharply, separated from the horizons above and below it. The C_1 horizon is a friable very fine sand or silt, which is of a typical floury or loesslike consistence and a conspicuous pale-yellow or straw-yellow color, almost everywhere mottled with small dark-brown, black, or rust-colored specks. Where the drainage is less perfect, the yellow color changes to light gray. The C_2 horizon is dark-gray or olive-gray clay. All boundaries between the horizons of Bearden loam are typically smooth and clear-cut, but in the silt loam type the dividing line between the A and B horizons is rather irregular, wavy, or even sharply broken.

The relief is typically flat, and the drainage is moderate rather than fair. All Bearden soils are free from stones. Effervescence typically occurs in the surface soil and in the B horizon and is rather vigorous, but in the C_1 horizon, just above the boundary between it and the clay, effervescence is lacking in places, showing a lime-free zone. The C_2 horizon is everywhere strongly calcareous.

The Fargo series (fig. 39) includes soils developed under grassland conditions from lacustrine clay. The principal types of this series are clay and silty clay loam. The A horizon of all Fargo soils is black and ranges in thickness from about 6 inches to almost 2 feet. In places this horizon, especially the upper part, shows a well-developed granular or medium-fragmental structure, but by far the greater part of the Fargo soils breaks on drying into large irregular lumps with sharp edges. The narrow vertical cracks separating them penetrate the B and C horizons about 2 or 3 feet below the surface. Filling of the cracks by the infiltration of material from the A horizon produces black wedge-shaped tongues, typical of every Fargo soil. The B_1 horizon is rather indistinct and ranges in thickness from one-half to 1 foot. The horizon of carbonate accumulation is better developed in the lighter types. It is light gray, in places shows a fine fragmental structure, and averages about 1 foot in thickness. This horizon can seldom be distinguished in the profiles of the heavier types. The C horizon is dark olive-gray compact and usually bedded clay, in many places mottled with crumbly concretions of lime. The surface is exceedingly flat, and the drainage ranges from good to insufficient. The principal types of the series are entirely free from stones. The average depth of effervescence is about 20 inches from the surface.

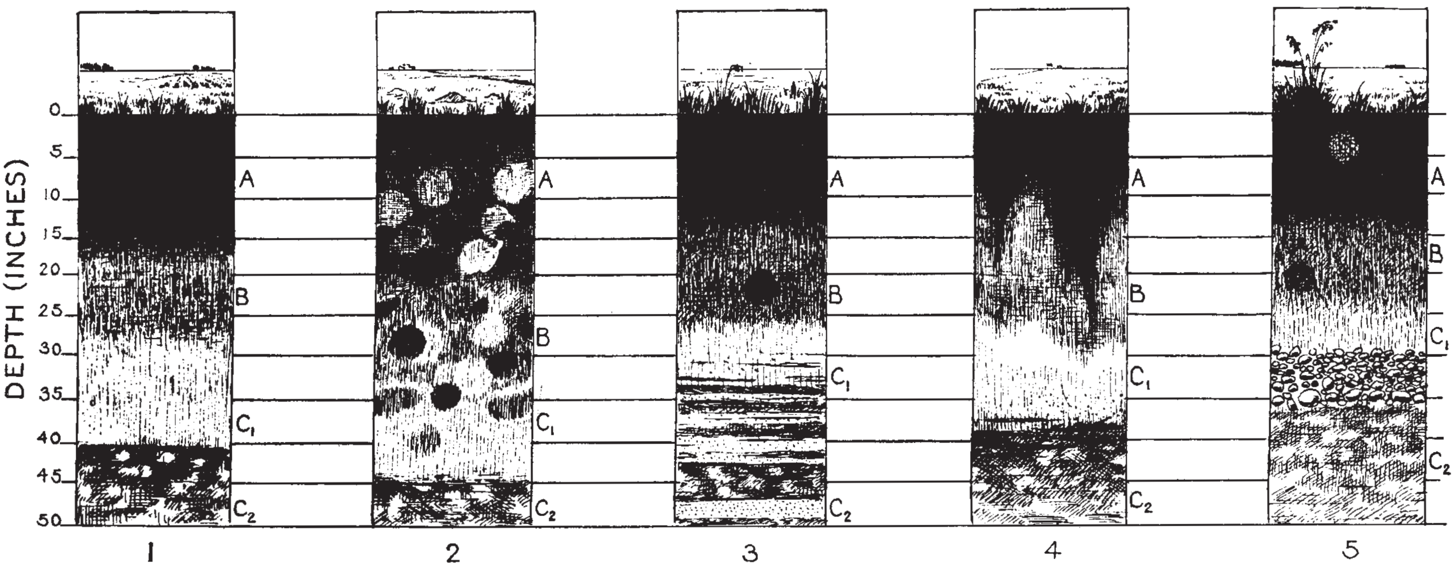

FIGURE 38.—Typical profiles of the Bearden soils: Profile 1, normal Bearden loam; profile 2, Bearden loam reworked by rodents and showing a number of krotovinas; profile 3, Bearden loam on stratified parent material; profile 4, poorly drained phase of Bearden loam; profile 5, poorly drained gravelly phase of Bearden loam.

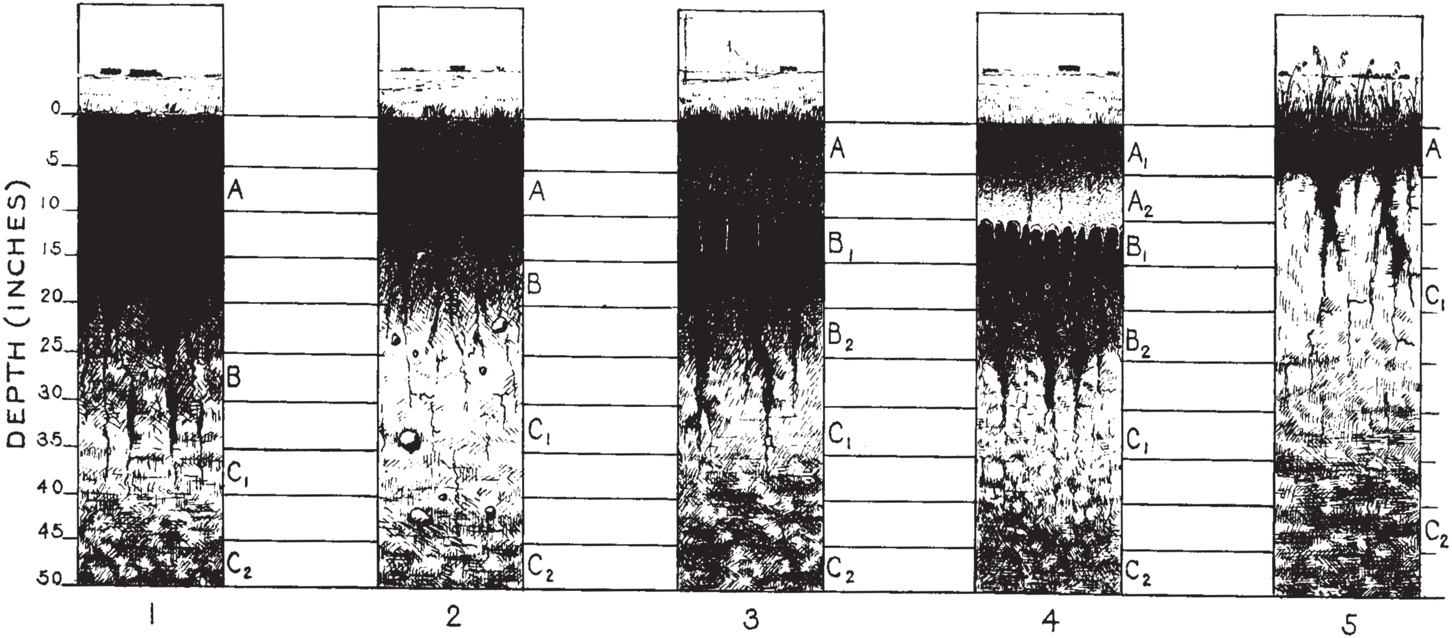

FIGURE 39.—Typical profiles of the Fargo and related soils: Profile 1, normal Fargo clay; profile 2, normal Fargo silty clay loam; profile 3, alkaline phase of Fargo clay; profile 4, columnar Solonetz; profile 5, immature, poorly drained phase of Fargo clay.

The Sioux series (fig. 40) includes soils developed under grassland conditions from the parent materials piled by the waves into littoral ridges. The principal types of this series are loamy sand and sandy loam. The A horizon is very dark gray or, more commonly, black and ranges from about 4 inches to nearly 2 feet in thickness, in most places being about 1 foot. This horizon is confined to the uppermost sandy or fine-earth layer of parent material lying over the gravel. It is a structureless mass of mixed sand colored by humus. In dry seasons it bakes to a solid mass, which cracks and breaks into large irregular crumbly lumps. Below this the material changes sharply to gravel, which is not differentiated into horizons. These soils occur on long narrow ridges which have a rounded configuration. Drainage, in most places, is excessive. Large boulders and stones coarser than gravel occur only where the ridges are piled on the sloping surface of the unassorted drift or its lake-washed modifications. Effervescence usually occurs in the gravelly layer beneath the A horizon.

The Waukon series includes soils developed from the Young Gray drift in the transitional belt between the open prairie and the forest. The principal types of this series are loamy sand, loam, and silt loam. The A horizon of the Waukon soils is gray or dark gray and ranges in thickness from a few inches to about 1 foot. Some spots of the Waukon soils show the result of podzolization of the lower part of this horizon. Horizon B is grayish brown, but is usually very indistinct and obscure. This rests upon the light grayish-brown highly calcareous substratum. The relief ranges from gently undulating to rolling, the drainage ranges from rather slow to good, and the stoniness is moderate. The average depth of effervescence is between 15 and 20 inches, in most places immediately below the B horizon.

The Pelan series (fig. 41) includes soils developed from lake outwashed till covered by a stony or gravelly mantle under the influence of a forest cover. The predominant types of this series are light loam and sandy loam. The A_1 horizon of the Pelan soils is gray or dark gray and ranges in thickness from about 3 to more than 8 inches. The A_2 horizon is not everywhere distinctly developed but in most places is shown by the somewhat lighter color of the lower part of the A_1 horizon. The B horizon is usually much more definite; in many places it is brown or brownish gray and is of a texture heavier than that of the A horizon. In most places the development of the B horizon occurs within the stony or, more commonly, the gravelly layer of the parent material, but it is not unusual for it to be located entirely above the gravel. This is most common in the types which are relatively lighter in texture. The clayey material of the third layer is everywhere very rich in carbonates, especially immediately beneath the gravel. This layer of the profile, which averages about 1½ feet in thickness, may be almost white. Effervescence very seldom occurs above the gravelly layer.

The most common position of the stony layer is between the till and the fine-earth surface layer, although in many places the stones are embedded in the clayey underlying layer, and in a few places this layer is underlain by sand.

The surface of the Pelan soils is flat, and natural surface drainage is rather slow and in many places inadequate. Boulders and some

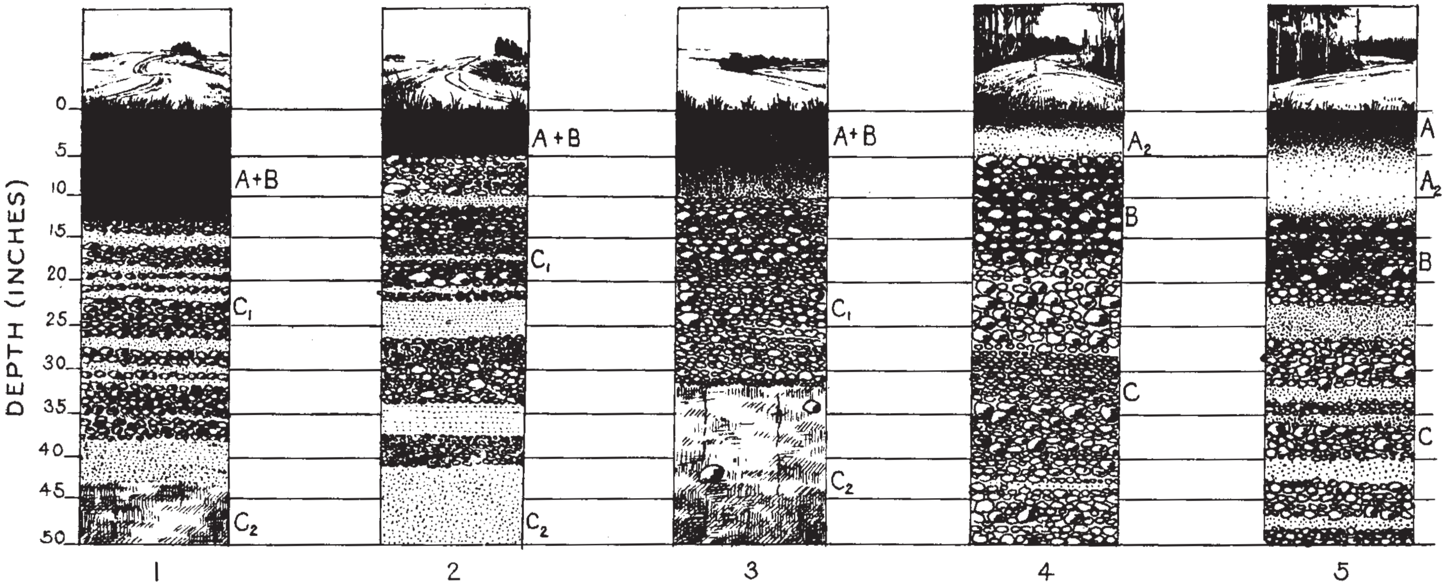

FIGURE 40.—Typical profiles of the Sioux and related soils: Profiles 1, 2, and 3, local variations of the typical Sioux soil in the prairie; profiles 4 and 5, strongly leached (podzolized) phase of Sioux soil in the forest belt.

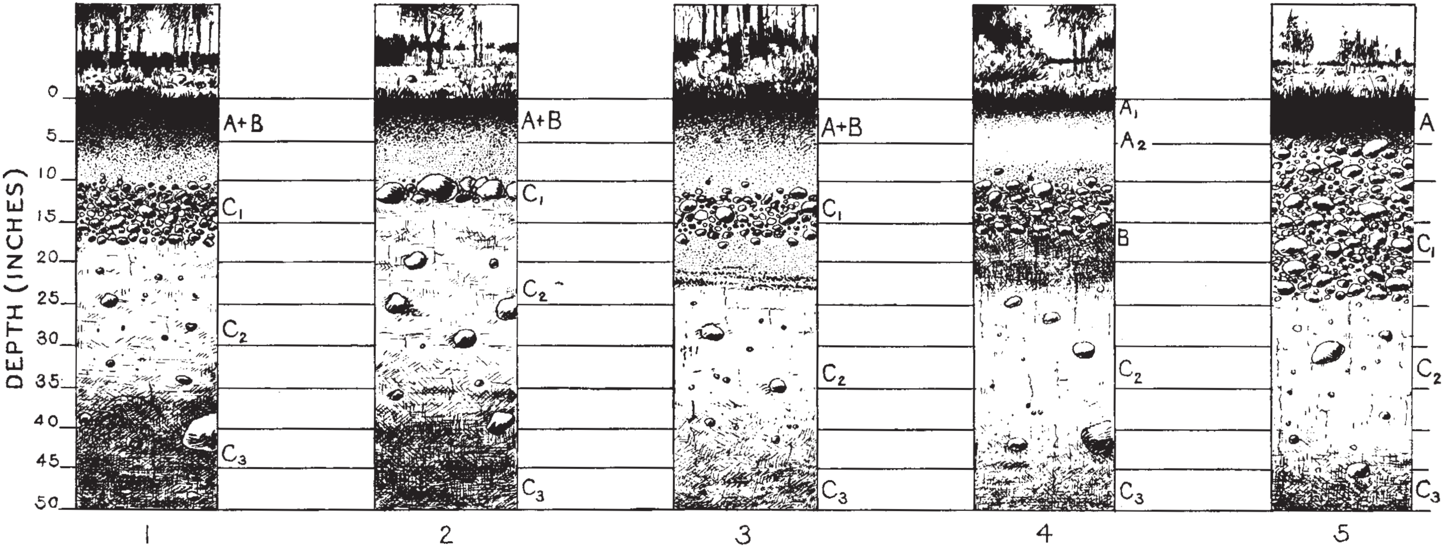

FIGURE 41.—Typical profiles of the Pelan soils: Profiles 1, 2, and 3, local variations of normal Pelan sandy loam; profile 4, podzolized phase of Pelan sandy loam; profile 5, poorly drained phase of Pelan sandy loam.

smaller stones on the surface and in the soil mass are typical of the Pelan soils.

The Poppleton series includes soils developed from the loose sandy material which was assorted by wave action, afterward partly reworked by wind, and deposited over the unassorted till or over the earlier lacustrine deposits. In other words, the Poppleton soils are developed from the same parent materials as the Ulen soils but under the influence of a deciduous forest of the transitional belt. The principal types of this series are sand and loamy sand. The A horizon of the Poppleton soils is gray or light gray and ranges in thickness from about 2 to 12 inches. It is friable structureless sand slightly colored with a small content of humus. Horizon B is usually very weakly developed and has practically no stable characteristics. The C_1 horizon is light-brown or grayish-brown loose sand, in some places mottled with rust stains. The relief is very gently undulating to flat, and drainage ranges from fair to insufficient. Stones are present where the sandy cover is thinly spread over the lake-washed till or morainic till. The lower, or clayey, C_2 horizon is commonly rich in lime, but a slight effervescence may occur in the sandy layer where the drainage is slow and poor.

The Gatzke and Nereson soils have similar profiles in most respects and differ from each other mainly in the character of their parent materials. Both series include soils transitional between the Chernozems and the Podzols, developed from lacustrine clay and glacial till, respectively. The A horizon of each series is very dark gray or black and ranges in thickness from 4 to 10 inches. In a virgin condition the soil is covered with a fibrous A_0 horizon ranging from 1 to about 3 inches in thickness. The lower part of the A horizon in many places has a brown tint, which probably indicates an embryonic development of the illuvial B horizon, but this is nowhere very distinct. The very weak podzolization shown by a slight bleaching of the lower part of the A horizon is more pronounced in the eastern part of the area. The forest vegetation of the area occupied by these soils is composed almost entirely of aspen. The surface is flat, and the surface drainage is insufficient and in many places poor. Stones of various sizes from boulders to fine gravel are a typical feature of these soils, but are nowhere numerous. The subsoil is very rich in lime carbonate.

The Nebish series includes the most western Podzols developed from the Young Gray drift. In this area they occur on the upland in the southeastern corner of Polk County. The principal types of this series are loam and silt loam. The profile of Nebish loam has the following characteristics:

A_0. A forest floor, almost black, averaging 2 inches in thickness and consisting chiefly of undecomposed vegetable debris.

A_2. Very light ash-gray friable material ranging from 3 to 8 inches in thickness. The material in some places shows a fine or very fine lamellar structure, but the lamellae are so crumbly and fine that they cannot be separated from one another. This structure may become rather fragmental in the lower part of the horizon.

B. Dark-brown or chocolate-brown heavy compact clay, ranging from about 8 inches to almost 2 feet in thickness, and usually showing a sharply angular blocky structure. The aggregates are smaller in the upper part of the horizon and gradually become larger near the lowest part. These blocks have somewhat shining surfaces and usually have a dark surface coating which is especially pronounced in the lower part of the horizon.

C. Light-brown or yellowish-brown calcareous drift. Boulders and smaller stones occur in places on the surface and in the soil mass. The relief ranges from rolling to gently undulating, and drainage is good. Effervescence with acid occurs below the B horizon.

The Taylor series includes the heavy Podzols developed from lacustrine clay or lake-washed till in the forested sections of the bed of ancient Lake Agassiz. In general, the profile of the Taylor Podzol is less perfectly developed than that of the Nebish Podzol, although they have many characteristics in common. A mature profile of Taylor silt loam is as follows:

A_0. The forest floor, which is almost black and ranges from 1 to 3 inches in thickness.

A_2. Very light ash-gray material, usually somewhat sandy and friable, ranging in thickness from 3 to 6 inches, and in some places showing a slight fine lamellar structure.

B. Dark-gray or brownish-gray heavy and compact material which, in the best drained places, shows a coarse blocky structure and ranges in thickness from about 6 inches to more than 1 foot.

C. A light-gray or olive-gray clayey till or lacustrine clay, rich in lime carbonate. The surface is flat, and the drainage ranges from fair to moderate. In places boulders and smaller stones are on the surface and in the soil (fig. 42).

FIGURE 42.—A new field showing an ash-gray A_2 horizon of the Taylor soil exposed by turning over the sod.

The Parnell series is a hydromorphic associate of the Barnes series. It includes the soils developed under grassland conditions from the unassorted Young Gray drift. The A horizon is black when moist and becomes gray or light gray on drying. It ranges in thickness from 1 to 2 feet. The upper part of this horizon in many places is somewhat mucky. The B horizon usually is very indistinct and variable in all its characteristics—color, thickness, and texture. The C horizon is dove gray or bluish gray, usually mottled with rust stains. These soils occur in depressions, pot holes, and other low and wet land. Drainage is poor, and many depressions have no drainage outlets. Some areas are free from stones, but some are extremely stony. The depth of effervescence differs widely, in some places occurring at the surface but in most places not higher than the bottom of the A horizon.

The Tanberg series (fig. 43) is a hydromorphic associate of either the Bearden or the Ulen series. It includes the soils of the marshy areas traversed by sloughs scattered through the area covered by either a sandy or a silty mantle. The principal types of this series are loam, silt loam, and silty clay loam. The A horizon is black and changes to gray on drying; it ranges in thickness from 5 to more than 20 inches. The B horizon is gray or cloudy dark gray and ranges from one-half to 1 foot in thickness. The upper part of the subsoil of the typical Tanberg soil is light-gray loose outwashed sand which rests on clay. In places where the upper mantle is very thin, especially where it is thinner than the combined thickness of the A and B horizons, the sandy layer of the subsoil disappears. The boundary between the horizons usually is irregular. The surface is flat, and drainage is poor. Stones occur only where a thin mantle is spread over the lake-washed till. Effervescence occurs below the A horizon and in many places at the surface.

The Arveson series is a hydromorphic associate of the Poppleton soils. It includes the hydromorphic soils developed from sandy parent material in the transitional belt of deciduous forest. Its relation to the Poppleton soils is similar to the relation of the Tanberg soils to the Ulen soils. The principal types are Arveson sandy loam and Arveson sandy clay. The A horizon is black and becomes gray or light gray on drying. Usually it is very sharply separated from the underlying horizon, and its lower boundary is extremely irregular. The surface layer of the horizon in many places is peaty or mucky. Horizon B has no definite or stable characteristics, as it is merely a transitional layer from the A horizon to the C horizon and is not of uniform color. The C_1 horizon is dove-gray or bluish-gray loose sand mottled with rust stains. The C_2 horizon is gray compact clay. The Arveson soils occur only in depressions or flats, and drainage is poor. A greater number of stones are on the surface than are common in the Poppleton soils. The soil material effervesces with acid from the surface downward. In places the lenses of marl are below the A horizon.

The most numerous and striking deviations from the normal profile characterize the soils developed from a parent material composed of several dissimilar layers. It is recognized that the normal profile of such soils is the one developed from a parent material, the upper layer of which is sufficiently thick to allow the full development of the entire solum from homogeneous material. For soils like those of the Bearden, Ulen, and Poppleton series, this layer should be not less than about 30 inches thick. In such places the second layer of parent material is not affected materially by the soil-forming processes. Where the thickness of the upper layer of parent material is less than the average thickness of the solum, however, the entire B horizon, or part of it, is developed from material originally different from that from which the upper part of the solum is developed.

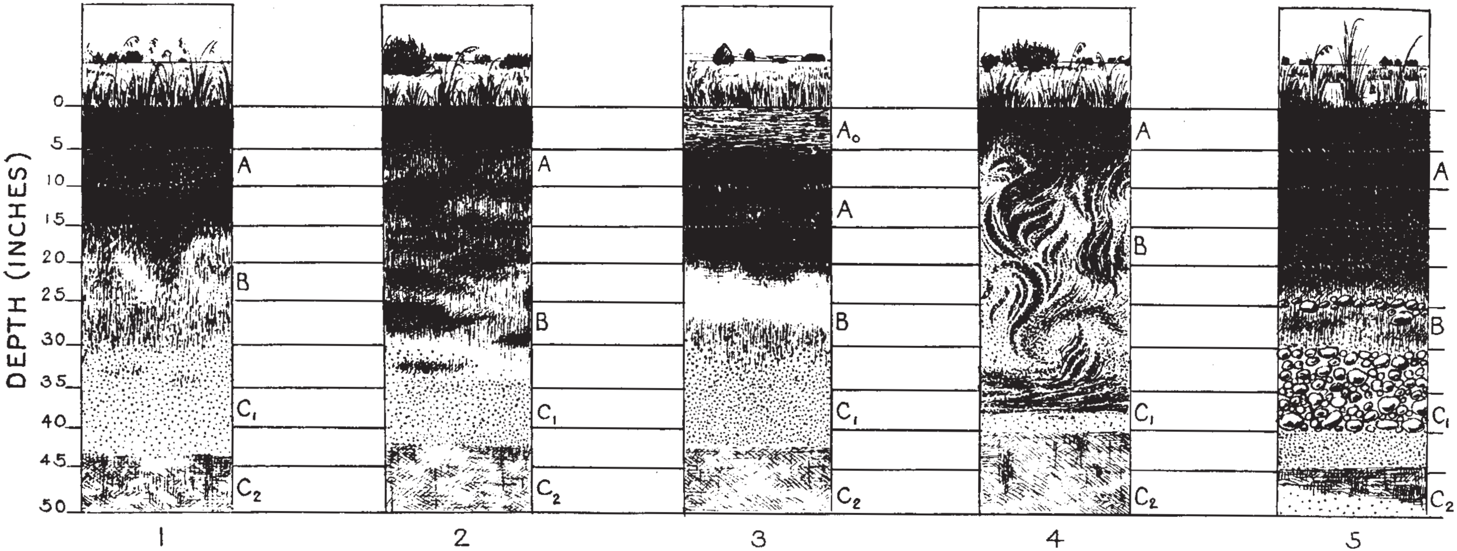

FIGURE 43.—Typical profiles of the Tanberg soils: Profile 1, typical Tanberg silt loam; profile 2, unevenly colored Tanberg silt loam; profile 3, peaty phase (A_0) of Tanberg loam with a layer of marl in the B horizon; profile 4, infiltration of organic material into the subsoil in Tanberg sandy loam; profile 5, gravelly phase of Tanberg silt loam.

The lower layer of a parent material in most places is formed by either lacustrine clay or heavy glacial till, both of which are characterized by a rather high content of lime, a drab-gray or olive-gray color, and a more or less massive structure. Where this material is close to the surface, its modification into a B horizon, or into the lower part of a B horizon, is expressed in several ways. Lime carbonate undergoes leaching to a depth ranging from a few inches to about 1 foot below the surface of this layer. The leached layer acquires a color considerably darker than that of the original material. On drying, the material in this layer cracks and breaks into coarse irregular roughly prismatic clods. In wet seasons the cracks close, and the upper layer becomes waterlogged and subject to anaerobic conditions. This, in turn, leads to bleaching and occasional mottling with iron stains. All of these changes create a great number of local modifications of the normal or typical profiles.

Parent materials characterized by the presence of a gravelly layer, like those of the Foxhome and the Pelan soils, usually have an upper layer less than 1 foot thick. The A horizon of these soils, therefore, is usually developed from this layer, whereas the B horizon in most places coincides with the stony layer. Neither of these layers has any genetic relation to the third layer, or C horizon, underlying the gravel, or to each other. Moreover, the stony or gravelly layer itself may be accumulated on the surface of clay, it may be partly or entirely buried in clay, or it may be separated from the surface of clay by an intermediate bed of sand.

The clay itself usually contains a large quantity of lime carbonate, especially near the top of this layer, where, in many places, a zone of lime accumulation is formed. This zone may lie immediately under the stony layer or even within this layer; or the lime may be leached to some depth from the top of the clay layer. These conditions create another series of local deviations from the normal profiles.

It has been pointed out that the soils of the Bearden and the Ulen series and some of the Poppleton soils are normally free of stones or gravel but that thin beds and lenses of gravel may occur between the two layers of parent material in many places where these soils are associated with the Foxhome, the Pelan, or the Sioux soils. Local formations of the Bearden, the Ulen, and the Poppleton soils containing beds of gravel may be considered as gravelly phases of these soils. These phases differ from the normal Foxhome or Pelan soils mainly in the thickness of the upper layer or in the depth at which the stony layer is situated. The soil may be considered as a gravelly phase of either the Bearden or the Ulen soil where its solum (A and B horizons) is developed from the uniform material of the upper layer, that is, where the thickness of the mellow mantle is not less than 20 or 30 inches.

A slight variation of the drainage conditions causes a development of a so-called poorly drained phase. The profile of this phase differs from the normal soil in several respects. The A horizon of the poorly drained phase usually contains more organic matter, and consequently its color is darker, its texture is somewhat heavier, and its consistence is more compact, as compared with the same characteristics of the normal soil. The A horizon is thinner than that of the normal soil, and the boundary between it and the B horizon typically is sharper and more irregular than that of the normal soil. The topmost part of the A horizon in places may be mucky or peaty. The B horizon acquires a dove-gray or light olive-gray color and in some places is mottled with iron stains. In many places a large amount of lime carbonate accumulates in the B horizon, and the lime in the poorly drained soils, as a rule, appears closer to the surface than in the normal soil.

The saline phase is rather unimportant in the area. Most of this phase occurs in the northeastern corner of Traverse County and in the eastern part of Wilkin County. Most areas of such soils are recognized as phases of rather light normal soils, such as those of the Bearden, Ulen, and Foxhome series. The spots of the saline phase of the Fargo soils are few and small. The saline phases of the Bearden, Ulen, and Foxhome soils belong to the soil group designated as the wet Solonchaks. They occur in poorly drained areas, usually east of gravelly ridges which block the surface drainage and cause a drying of the land after the wet seasons, mainly through evaporation, which brings the soluble salts close to the surface. The salts are mostly carbonates and sulphates of calcium and magnesium. Gypsum is one of the commonest salts in these soils and in many places is accumulated in the B horizon in great quantity. Occasionally the salts appear on the surface following the wet seasons. Except for the incrustation and efflorescence of salts, the morphological profile of the saline phase is similar to that of the poorly drained phase.

The most significant phases of the Fargo soils are the immature, the alkaline, the degraded, the columnar Solonetz, and the stony.

The immature phase of the Fargo soil is a product of the artificial drainage of the naturally poorly drained areas. This phase differs from the normal soil in that its A horizon, as a rule, is much thinner, ranging from 3 to 8 inches in thickness. It is black, its surface layer in places has a mucky or even peaty character, and its lower boundary is very irregular. The B horizon almost everywhere is saturated by lime carbonate; is very light gray, almost white; has an average thickness of about 1½ feet; and grades into the underlying material without any sharp line of demarcation. The abundance of lime makes the consistence of this horizon considerably mellower, less compact, and less solid than that of the normal soil. Effervescence generally occurs in the surface soil or immediately below the A horizon.

If alkalinity can be measured by certain physical characteristics of the soil, then most of the Fargo soils are in some degree alkaline and may be designated as an alkaline phase. This alkalinity is shown by the conspicuous compactness of the lower part of the A horizon and, in some places, of the upper part of the B horizon. The zone of compactness ranges in thickness from several inches to nearly 2 feet. It is typically black and very dense. When wet, it is exceedingly sticky and almost watertight; on drying, it becomes very hard and in places forms a firm crust, more commonly breaks into large sharp-edged solid lumps. The thickness of the upper mellow part of the A horizon is about 6 or 8 inches, and in very few places is the compact horizon exposed on the surface. The upper part of the A horizon also is black, but is somewhat lighter in color than the compact zone. The lightness, which may change the black color to gray, is especially pronounced in the lower part of the A horizon directly above the surface of the compact zone. The effervescence in the alkaline phase never occurs in the compact zone or above it, but the subsoil commonly is very rich in carbonates.

A soil is said to be degrading when it is growing old. A gradual replacement of one particular type of soil by another must be considered as a degradation of the former, but degradation usually is regarded as an impoverishment and is considered only where some particular soil is replaced by a new type of soil that is agriculturally poorer than the original.

The degraded phase of the Fargo soil differs from the normal soil in a general lightening of the color of the A horizon, which becomes gray or brownish gray as a result of the impoverishment in humus. The B horizon also becomes more brown, even somewhat reddish brown, and develops a typical fragmental or blocky structure. A typical white floury coating appears in the lower part of the A horizon and in the cracks separating the structural fragments of the B horizon. The upper limit of the zone of effervescence is at a deeper level than in the normal soil.

Columnar Solonetz is a peculiar soil formation associated with the Fargo soil, although it cannot be considered as a mere phase of this soil. It occurs mostly in Traverse and Wilkin Counties in a number of small spots scattered throughout the areas of normal or slightly alkaline Fargo clay. The morphological profile of the columnar Solonetz is as follows:

The A_1 subhorizon is from 3 to 6 inches thick, is very dark gray or black, and in most places has a fine lumpy structure.

The A_2 subhorizon, which ranges in thickness from 2 to about 8 inches, is very light gray, usually has a finely laminated structure with a typical difference in color on the upper and lower sides of each plate (when in a natural position), the upper side being considerably lighter than the under side. The texture of the material in this subhorizon is coarser and has a more friable consistence than that of the A_1 subhorizon. The change from the A_2 to the B horizon is very sharp.

The B horizon ranges from 5 to 15 inches in thickness, is black, has an exceedingly dense or compact consistence, and is of a heavy texture. It is very waxy and sticky when wet and hard when dry. The upper part of this horizon has a conspicuous prismatic or columnar structure. The columns are pentagonal or hexagonal and range from less than 1 inch to more than 2 inches in diameter and from 3 to 5 inches along the vertical axis. The tops of some of the columns are flat, but most of them are well rounded or biscuitlike, and their surface is very light gray (fig. 44). The lower part of the B horizon is broken by cracks into irregular large sharp-angular clods. The A_1, A_2, and B horizons are typically free from any incrustations of salts and contain no free lime carbonate, but a concentration of carbonates and, in places, of sulphates occurs below the B horizon.

The individual spots of columnar Solonetz are, in very few places, more than a few rods in diameter, but they may be so numerous as to occupy from 25 to 40 percent of the total area. The conspicuous morphological arrangement of the Solonetz profile has been completely demolished by deep cultivation of fields in most places, and such profiles are very rare at the present time.

Because of the origin of their parent material, all typical Fargo soils are entirely free from stones. The stony phase has been developed from different parent material, namely, the lake-washed unassorted till. This phase is included in the Fargo series because of the remarkable similarity of the profile to that of the normal Fargo soil. The stony phase differs from the normal Fargo soil in the

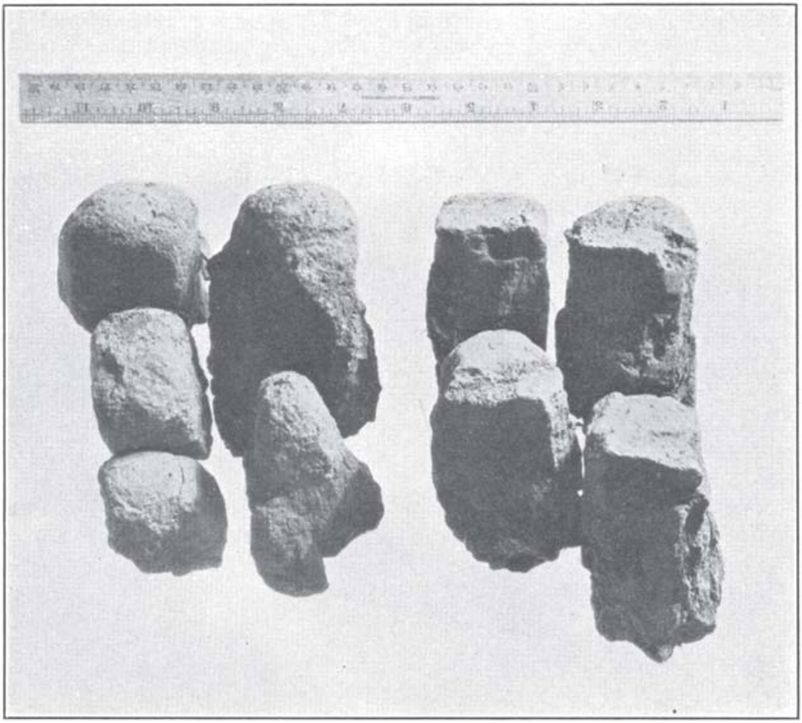

FIGURE 44.—Rounded (left) and flat (right) tops of columns in B horizon of the columnar Solonetz.

presence of a number of boulders scattered on the surface and embedded in the soil mass and also in the less uniform composition of the mineral mass of its parent material. The largest and most conspicuous areas of this soil are in Traverse County, east of Wheaton and farther north. Most of the stones have been removed from the surface.

Because of the small scale of the maps, none of the phases described is indicated separately. These phases occupy no large areas, and their geographical boundaries are very irregular and indistinct; but they occur in many places, and their description will be of help to many readers of this report.

5504—39——7

SUMMARY

The Red River Valley area covered by this survey comprises eight counties in the northwestern part of Minnesota. It consists of two unequal parts, the greater part occupying the bed of the ancient glacial Lake Agassiz, more commonly known as the Red River Valley, and the smaller part occupying the gently rolling or undulating upland surrounding the lake bed.

The boundary separating the forest belt and the open prairie crosses the area and divides it into a woodland and a grassland section. A transitional belt between these two sections forms the third physiographic subdivision. Both the open prairie and the forest extend over the lake bed and the surrounding upland.

The soil and climatic conditions and the surface relief of the open part of Red River Valley are very favorable for large-scale grain production, and this area comprises one of the principal agricultural regions of the United States.

The soils of the area are divided into a number of series and types according to their morphologic and genetic characteristics. The most important soils in the area are those included in the Fargo, Bearden, Ulen, Pelan, Barnes, and Nebish series.

Soils of two great zonal groups, Chernozems and Podzols, occur in the area. The Chernozems are represented by the Fargo and the Bearden soils in the lake bed and by the Barnes soils on the upland. The Podzols are represented by the Taylor and the Nebish series in the same regions, respectively. Most of the other soil types are transitional between the Chernozems and the Podzols.

U. S. GOVERNMENT PRINTING OFFICE: 1939

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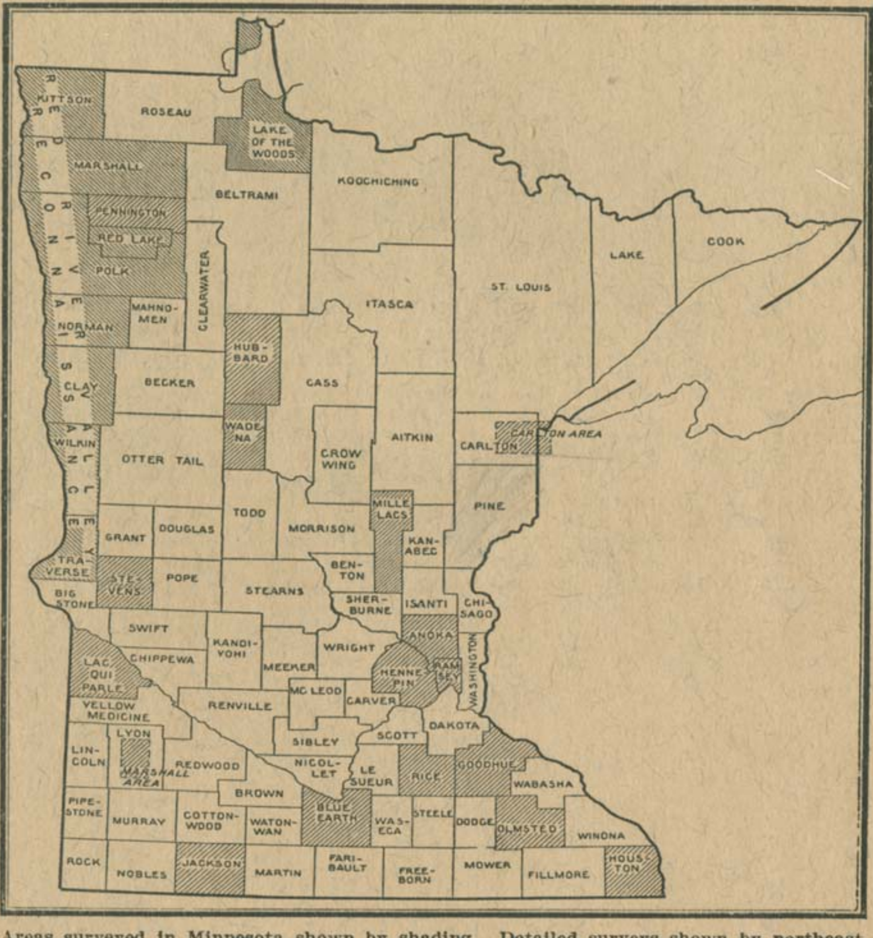
There shall be printed, as soon as the manuscript can be prepared with the necessary maps and illustrations to accompany it, a report on each soil area surveyed by the Bureau of Chemistry and Soils, Department of Agriculture, in the form of advance sheets bound in paper covers, of which not more than 250 copies shall be for the use of each Senator from the State and not more than 1,000 copies for the use of each Representative for the congressional district or districts in which a survey is made, the actual number to be determined on inquiry by the Secretary of Agriculture made to the aforesaid Senators and Representatives, and as many copies for the use of the Department of Agriculture as in the judgment of the Secretary of Agriculture are deemed necessary.



Areas surveyed in Minnesota shown by shading. Detailed surveys shown by northeast-southwest hatching; reconnaissance surveys shown by northwest-southeast hatching.

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