Series 1935, No. 15 Issued March 1941

Soil Survey

Pine County Minnesota

By
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United States Department of Agriculture
and
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University of Minnesota

UNITED STATES DEPARTMENT OF AGRICULTURE
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SOIL SURVEY OF PINE COUNTY, MINNESOTA

By C. S. SIMMONS, in Charge, and A. E. SHEARIN, Soil Survey Division,[1] Bureau of Chemistry and Soils, United States Department of Agriculture, and P. R. McMILLER, SAM HILL, G. D. SHERMAN, I. J. NYGARD, ERIC KNEEN, OLAF SOINE, and SAMUEL LABOVITZ, University of Minnesota

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

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COUNTY SURVEYED

Pine County is in east-central Minnesota along the Minnesota-Wisconsin State line (fig. 1). Pine City, the county seat, is in the southern part and is about 60 miles north of St. Paul, the State capital, and 80 miles southwest of Duluth, the western terminus of navigation on the Great Lakes. Sturgeon Lake, in the northern part, is 45 miles southwest of Duluth. The shape of the county is roughly rectangular, with the southeastern corner cut off by the St. Croix River. The county extends about 48 miles north and south and 36 miles east and west and has a land area of 1,413 square miles, or 904,320 acres.

This part of Minnesota lies within the western lake section of the Central Lowland physiographic province of the United States. The

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

county is part of a plain which slopes toward the southeast and was formed as ground moraine during the middle and late Wisconsin glacial periods. The Patricia ice sheet and the Superior lobe, the former entering from the north and the latter from the northeast, covered the area with red glacial drift. The Patricia sheet deposited loose stony low-lime material over the entire area included in the county, and the Superior lobe deposited clayey high-lime red till in the northern part. Later, the Keewatin ice sheet entered from the southwest and superimposed clayey limy or high-lime gray drift on a small portion of the southern part of the county. The materials deposited in what is now Pine County by the Superior lobe and Keewatin sheet are practically stone free.[2]

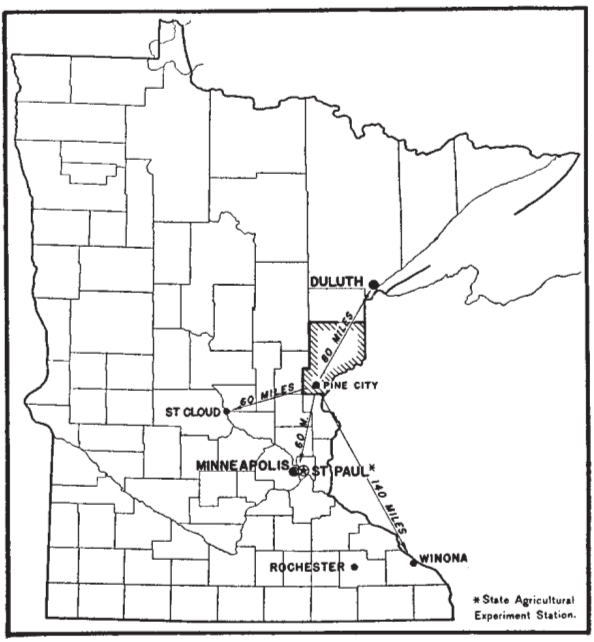

FIGURE 1.—Sketch map showing location of Pine County, Minn.

The relief in most places is undulating or gently rolling, with a few rolling areas in the central part of the county. The smoothest part of the plain is that covered by gray drift, and a few small former lake beds and outwash plains are nearly flat. In the southeastern part, adjacent to the St. Croix River, is a lower plain several miles wide, which is separated from the upland by a distinct steep escarpment.

Sufficient time has not elapsed since the glaciers melted for natural drainage to become complete, and parts of every township are occupied by peat bogs and areas of poorly and imperfectly drained mineral soils. Nearly all of the county lies in the drainage basin of the St. Croix River, which is a tributary of the Mississippi, but about 30 square miles in the extreme northeastern part drain into Lake Superior and form a part of the St. Lawrence drainage basin. In the eastern part short creeks flow directly into the St. Croix River, and the northwestern and southern parts are drained, respectively, by the Kettle and Snake Rivers and their short tributaries. All these streams, except the western part of the Snake River, flow rapidly through steep-sided narrow valleys. From the point where the Snake

[2] LEVERETT, FRANK, with contributions by SARDESON, FREDERICK W. QUATERNARY GEOLOGY OF MINNESOTA AND PARTS OF ADJACENT STATES. U. S. Geo. Survey Prof. Paper 161, 149 pp., illus. 1932.

River enters the county to where it flows into Cross Lake it meanders slowly through a shallow valley that in many places is more than 1 mile wide. Dissection is neither thorough nor complete, and most of the few tributary streams are short and comparatively straight.

Along the Kettle River, rock outcrops are numerous. Most of the rocks are crystalline, but sedimentary formations are found near Sandstone. The only mineral resources utilized at present, other than sand and gravel for road surfacing and concrete work, are building stone quarried near Sandstone and molding sand excavated from open pits in the vicinity of Kerrick.

Where the St. Croix River enters the county near Markville the elevation is about 900 feet above sea level, but it drops to about 800 feet near the point where the river leaves, southeast of Rockcreek.[3] The highest elevation, slightly more than 1,200 feet, is in the northwestern part.[4] The elevation of Cross Lake is 933 feet.[5]

The native vegetation was mixed hardwoods and white pine on the heavier soils, white pine and red (Norway) pine on the loose red drift, and jack pine on the very sandy areas. The original forests were practically free of underbrush. The swamps and wet land supported spruce and tamarack, with some muskeg mosses and mixed hardwoods. The hardwood swamps were in the southern part of the county where the lime content of the surrounding soils was high. Where the forest was cut or burned, reproduction was largely aspen and paper (white) birch with some oaks and a thick undergrowth of briers and hazel.

The first white men to enter what is now Pine County were fur traders and missionaries, who left no permanent settlement; but a Presbyterian mission was established on the eastern shore of Pokegama Lake in 1836.[6] Early settlers came from the New England States, New York, Pennsylvania, and Wisconsin, and in more recent years Norway, Sweden, Denmark, Bohemia, and Poland have furnished many inhabitants. The Scandinavians have settled throughout all parts of the county, Bohemians in the vicinity of Pine City and Beroun, and Poles in the northern part.

Before Minnesota Territory was organized in 1849, the present Pine County was part of St. Croix County, Wis. For 3 years, or until 1852, it was included in Ramsey County, and from then until the organization of Pine County in 1854 it was part of Chisago County. The present boundaries were established in 1858, when parts of the original county were transferred to Kanabec and Carlton Counties.

According to the 1930 Federal census, the population of Pine County was 20,264, all of which was classed as rural—14,603 classed as rural-farm and 5,661 as rural-nonfarm. Of the total population in that year, 3,996 were foreign born and 5,561 of foreign parentage. Pine City, the county seat, with a population of 1,343 in 1930, is in the southern part of the county. Other incorporated villages are: Hinckley, with a population of 682; Sandstone, 1,083; Sturgeon Lake, 210; Willow River, 253; Bruno, 167; Rutledge, 95; Askov, 298;

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[3] St. Croix Falls Wisconsin Improvement Co., St. Croix Falls, Wis. Kettle River Rapids Development, General Map of Reservoir. 1928.

[4] LEVERETT, FRANK, and SARDESON, FREDERICK W. See footnote 2, p. 2.

[5] Stakes set by surveyors of the Works Progress Administration when surveying for a project to raise the level of Cross Lake.

[6] EASTMAN, AUGUSTA B. HISTORY OF THE ST. CROIX VALLEY. 2v. illus. Chicago. 1909.

Brookpark, 159; Finlayson, 241; and Henriette, 128. All these towns have creameries and also serve as concentration centers for other farm products. Other creamery and shopping centers are Beroun, Rockcreek, Denham, Kerrick, Duquette, Cloverton, and Markville, and several creameries are located in the more populous farming communities. The county includes 36 townships, 100 common-school districts, and 10 other school districts.[7]

Main lines of three railroads and five trunk-line highways cross Pine County and furnish adequate transportation facilities to all parts of the county and to outside markets. The Northern Pacific Railway crosses the county from north to south in the western part, the Great Northern Railway in a northeasterly direction from Brookpark, the Minneapolis, St. Paul & Sault Ste. Marie Railway (Soo Line) from north to south in the eastern part, and a branch of the Soo Line serves the extreme northwestern part. These railroads connect with Great Lakes shipping lines at Duluth. State trunk highways, many of which are hard-surfaced, are readily accessible from most sections. Many of the connecting roads are graveled and kept in good condition during both summer and winter, but a few roads in the thinly settled areas are sometimes impassable and others may be temporarily closed by deep snows.

Rural schools are well distributed throughout the county, and several consolidated schools have bus service to transport the pupils. Medical service is inadequate, as there is only 1 doctor for each 118 square miles. The doctors live in the larger towns. The county has no public nursing service and no general hospitals, but a sanatorium for the treatment of tuberculosis is near Pokegama Lake.[8] Telephones are well distributed through the more populous farming districts. Churches are located in all the villages and smaller communities, but many farms are several miles from any religious institution.

Agriculture is the main source of income, and some income is derived from forest products, largely from the sale of firewood. Some wood is trucked to Cloquet, in Carlton County, where it is made into pulpwood, insulating board, toothpicks, and matches. A few small sawmills are in operation. The quarry at Sandstone formerly employed many men, but now (1935) very little stone is being removed. Some income is derived from the resort business along the several lakes. Some of the country along the Snake River east of Pine City and along the Kettle River east of Hinckley has been prospected for copper, but no veins have been found sufficiently valuable to warrant development.

CLIMATE

The climate of Pine County is continental. It is characterized by severe winters and warm summers. Tables 1 and 2, compiled from data recorded by the United States Weather Bureau stations at Grantsburg and Danbury, Wis., are applicable to Pine County. Grantsburg is east of Pine City and Danbury is east of Hinckley.

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[7] JESSNES, OSCAR B., NOWELL, REYNOLDS I., and associates. A PROGRAM FOR LAND USE IN NORTHERN MINNESOTA; A TYPE STUDY IN LAND UTILIZATION. 338 pp., illus. Minneapolis. 1935.

[8] See footnote 7, p. 4.

TABLE 1.—*Normal monthly, seasonal, and annual temperature and precipitation at Grantsburg, Burnett County, Wis.*

[Elevation, 1,095 feet]

Month	Temperature			Precipitation			
	Mean	Absolute maximum	Absolute minimum	Mean	Total amount for the driest year (1910)	Total amount for the wettest year (1903)	Snow, average depth
	°F.	°F.	°F.	Inches	Inches	Inches	Inches
December	16.4	58	−39	0.97	1.50	1.50	9.1
January	10.1	52	−48	.96	1.60	.82	11.2
February	13.1	52	−45	.99	1.10	1.90	8.8
Winter	13.2	58	−48	2.92	4.20	4.22	29.1
March	27.4	80	−29	1.28	.10	2.17	8.6
April	43.6	86	−7	2.04	.75	4.25	5.5
May	55.0	94	18	3.27	.93	6.55	.7
Spring	42.0	94	−29	6.59	1.78	12.97	14.8
June	65.0	101	23	4.67	1.85	1.12	.0
July	69.6	105	38	4.28	4.05	9.37	.0
August	66.4	98	30	3.18	2.81	5.79	.0
Summer	67.0	105	23	12.13	8.71	16.28	.0
September	58.6	97	16	3.70	2.12	10.02	(1)
October	46.8	86	7	2.54	.55	3.14	1.1
November	30.9	75	−32	1.62	.72	.60	6.7
Fall	45.4	97	−32	7.86	3.39	13.76	7.8
Year	41.9	105	−48	29.50	18.08	47.23	51.7

[1] Trace.

TABLE 2.—*Normal monthly, seasonal, and annual temperature and precipitation at Danbury, Burnett County, Wis.*

[Elevation, 908 feet]

Month	Temperature, mean	Precipitation		
		Mean	Total amount for the driest year (1925)	Total amount for the wettest year (1928)
	°F.	Inches	Inches	Inches
December	15.3	1.12	1.04	1.22
January	9.3	1.17	.61	.49
February	16.0	.96	.90	.76
Winter	13.5	3.25	2.55	2.47
March	26.1	1.40	90	1.18
April	42.0	1.84	1.55	3.02
May	54.8	3.26	1.40	2.38
Spring	41.0	6.50	3.85	6.58
June	64.3	4.40	3.21	5.84
July	68.8	4.34	6.33	7.90
August	66.0	3.56	1.43	5.39
Summer	66.4	12.30	10.97	19.13
September	58.6	3.64	2.35	5.80
October	46.6	2.37	.64	3.70
November	30.9	1.56	.50	.42
Fall	45.4	7.57	3.49	9.92
Year	41.6	29.62	20.86	38.10

In the northern part of the county temperatures may be somewhat lower and the average annual rainfall higher than these data show. Short periods of extremely cold weather, with temperatures far below zero, occur during most winters, but thawing seldom takes place during the winter. The ground usually is covered with snow during December, January, and February. Winter cover crops, grains, and alfalfa are grown successfully. The summers are pleasant, with occasional short periods of very hot weather, but during these periods the nights generally are cool. The temperature is most changeable during spring and fall.

The average length of the frost-free season is about 122 days in the southern part of the county and a few days shorter in the northern part, but killing frosts may occur on the peat bogs in all months and elsewhere in any month except July. This short frost-free season is offset somewhat by the fact that at this latitude the days are very long and the skies are comparatively cloudless in the summer, so that plants grow very fast. The climate is favorable to the production of small grains, forage crops, root crops, and potatoes. Corn, except early-maturing varieties, generally is not grown for grain but can be grown successfully as a forage crop. In most seasons plowing can be done from March to November. The precipitation is generally sufficient and evenly distributed for crops common to this section, but short periods of drought are frequent.

Disastrous tornadoes, hailstorms, and cloudbursts, which seriously damage or destroy crops, property, and life, are practically unknown in this section.

AGRICULTURAL HISTORY AND STATISTICS

White men were first attracted to the area that is now Pine County by the extensive pine forests, from which the county derived its name. A farm near the Snake River in Royalton Township was the first on which regular farm crops were grown.[9] Agricultural operations spread slowly to the north and east until much of the timber had been cut, after which settlement was rapid. Agriculture developed very rapidly during the period 1890–1920 but has remained practically stationary since. During this period of development farming of a general type was practiced, but now dairying is the most common agricultural enterprise. In 1930, of the 3,288 farms in the county, 2,186 were classed as dairy farms; 496, general farms; 148, crop-specialty farms; 31, animal-specialty farms; and 30, poultry farms. Although the number of farms has increased rapidly since 1890, the average size has remained practically constant while the acreage of improved land to the farm has almost doubled. Tame hay and wild hay have always been the most important crops and are grown on the largest acreages. In recent years, corn for silage has been grown on a larger acreage than corn for grain, which is an uncertain crop in this climate. Oats have always been the most common grain crop grown. The acreage devoted to wheat has decreased until it is relatively unimportant.

Another very noticeable change accompanying the development of dairying is the increasing acreage devoted to alfalfa. Although the quantity of swamp hay cut always is large, it differs from year to

[9] See footnote 6, p. 3.

year. Many bogs are too wet to be cut over in years of normal rainfall, and in those years sufficient forage is produced on the cropland to make the cutting of marsh grass for hay unnecessary. When a season is drier than normal, crop yields are reduced, and this deficiency is partly made up by hay cut from bogs normally too wet for the use of harvesting machinery. Practically all of the forage and grain produced are used on the farm where grown. Some feed, especially concentrates for both cattle and poultry, are bought outside the county.

Tables 3, 4, 5, and 6 give selected data from the United States census reports that show the trend of agricultural development for the last 55 years.

TABLE 3.—*Selected farm data for Pine County, Minn.*

Year	Population	Farms				Value of farm property		
		Total	Total area	Average size	Average improved area per farm	Total	Average per farm	Land alone per acre
		Number	*Acres*	*Acres*	*Acres*	*Dollars*	*Dollars*	*Dollars*
1880	1,365	54	6,129	114.0	25.9	76,746	1,421	----------
1890	4,052	261	30,853	118.0	18.3	369,955	1,417	----------
1900	11,546	1,416	148,459	104.8	21.6	2,273,424	1,606	9.70
1910	15,878	2,066	230,689	111.7	31.3	7,453,287	3,608	19.70
1920	21,117	3,088	333,418	108.0	39.5	26,955,346	8,729	49.23
1930	20,264	3,288	361,838	110.0	42.8	24,371,735	7,412	30.87
1935	[1] 15,949	3,814	412,780	108.2	41.7	[2] 11,458,793	[2] 3,004	[2] 27.76

[1] Farm population; total not reported in 1935.
[2] Land and buildings; value of all farm property not reported in 1935.

TABLE 4.—*Acreage of principal crops in Pine County, Minn., in stated years*

Crop	1879	1889	1899	1909	1919	1929	1934
Corn:	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Grain	28	208	1,259	3,037	6,339	1,374	1,582
Silage	----------	----------	----------	----------	----------	7,635	[1] 28,019
Forage	----------	----------	101	403	3,227	3,297	----------
Oats	86	359	2,258	6,567	20,721	21,079	21,349
Wheat	122	107	3,971	3,551	5,756	919	1,139
Rye	----------	28	346	497	4,128	783	459
Barley	----------	21	174	740	3,045	5,947	1,853
Mixed grains threshed	----------	----------	----------	----------	----------	5,481	2,206
All hay	346	2,421	12,066	30,569	54,245	70,218	75,544
Alfalfa	----------	----------	13	10	68	5,645	5,431
Timothy and clover	----------	----------	----------	19,504	35,373	42,230	15,603
Other tame hay	----------	----------	5,185	919	1,519	3,616	7,428
Wild hay	----------	----------	6,868	10,136	17,285	18,727	[2] 47,082
Potatoes	----------	292	1,844	3,005	9,359	7,118	8,073

[1] Includes corn for other purposes. [2] Includes some tame grasses.

TABLE 5.—*Value of agricultural products by classes in Pine County, Minn., in stated years*

Product	1909	1919	1929
	Dollars	*Dollars*	*Dollars*
Cereals	189,951	1,128,099	500,082
Hay and forage	362,443	1,617,296	1,122,480
Vegetables for home use and for sale	158,461	2,105,885	724,507
Other crops	135,281	82,394	44,502
Dairy products sold	248,391	1,256,169	2,155,646
Poultry and eggs produced	89,002	[1] 272,486	582,656
Forest products cut on farms	----------	----------	246,889
Wool	3,453	18,950	13,116

[1] Chickens only.

TABLE 6.—*Number and value of domestic animals on farms in Pine County, Minn., in stated years*

Animals	1920		1930		1935 [1]
	Number	*Value*	*Number*	*Value*	*Number*
Horses	8,731	$846,632	8,471	$750,984	8,201
Cattle	34,649	1,781,355	46,067	2,534,243	43,916
Sheep	7,514	88,162	9,797	79,752	6,858
Swine	8,656	157,985	10,985	146,767	6,558
Chickens	[2] 111,607	[2] 91,004	150,575	118,954	168,739
Bees (hives)	1,810	13,473	888	4,440	----------

[1] Value not reported. [2] All poultry.

Large quantities of stable manure are used on all farms, but commercial fertilizer never has been extensively used. Census data collected prior to 1930 show less than 100 farms reporting its use, and in 1929 only 269 farms reported its use, at a total cost of $158,741, or an average of $59.01. When a complete fertilizer is used it is bought ready mixed. Phosphate and potash often are used on peat land or as a supplement to stable manure for potatoes and rutabagas.

The purchase of feed was reported by 2,410 farms in 1929 at a total cost of $413,193, or an average of $171.45.

Most of the farm labor is performed by the farmer and members of his family, but about one-third of the farmers require additional help. The larger dairy farms employ yearly help, and wages, including room and board, range from $20 to $35 a month. Growers of potatoes and rutabagas employ seasonal help. Most farmers exchange labor during the threshing and silo-filling seasons, and some hire neighbors. In 1929, 1,104 farms reported the hire of labor at a total cost of $80,600, or an average of $73.01.

Until recent years more than 90 percent of the farms were operated by owners, but the 1935 census reports 79.9 percent operated by owners, 19.9 percent by tenants, and 0.2 percent by managers. Some farms are rented for cash, about $150 for 80 acres, but on most farms the share-rental system is prevalent, under which from one-third to two-thirds of the crops are returned to the owner, depending on whether or not he furnishes seed, implements, livestock, and other necessities. Under the most common agreement, each party to the contract receives one-half of the products and the tenant supplies everything. Some fields, hay meadows, and pastures are rented for cash at prices ranging from $2 to $8 an acre. The higher rental is paid for cropland.

Most farms have good buildings and sufficient modern equipment for efficient operation. The houses and barns are large, well built, and kept painted, but on the more recently settled farms temporary shelters are erected until permanent buildings can be built. Horses are the principal source of power, but on some of the larger farms tractors are used, especially when preparing the seedbed. Some farms, especially in the southern part of the county, have access to electric power. In most places good water can be obtained from shallow wells, but many farmers prefer deep-drilled wells. Power to pump water is obtained on many farms from windmills; on others small gasoline engines are used. Threshing is done by privately or cooperatively owned outfits which travel from one farm to another in succession.

Dairying is the principal occupation and source of income on most of the farms. Some milk is retailed in bottles in the larger towns, some is sold to the two cheese factories, but the greater part is sepa-

rated on the farms where produced and the cream sold to a nearby creamery, of which there are 18 in the county, where it is made into butter. The State Department of Agriculture reports that 3,685,936 pounds of butterfat was marketed in this manner in 1934, the value of which was $963,135.89.[10] The most popular breeds of dairy cattle are Holstein-Friesian and Guernsey. Most herds are composed of grade animals, but purebred sires are used almost exclusively. Considerable revenue is also received from the sale of livestock. Swine, excess dairy cattle, and some beef cattle are taken to South St. Paul in trucks, where they are marketed. Most of these animals are raised on the farms classed as general-farming and animal-specialty farms, but some are from the dairy farms.

The production of swine is carried on almost exclusively in the southern part of the county, as most of the farmers in the northern part prefer to buy pork rather than to grow corn to fatten hogs. Some sheep are raised, especially on the more recently cleared farms.

In addition to the 30 poultry farms, every farmer has a flock of chickens. White Leghorn is the most popular breed. Eggs are sold through the local creameries, but most of the fowls are taken by trucks to the nearby cities. The crop-specialty farms depend on potatoes and rutabagas for revenue. The growing of potatoes was once very important, but production has decreased greatly in recent years, owing to the decline in prices. Warehouses in the larger villages market the crop.

In the vicinity of Askov and Sandstone, a large acreage is devoted to the growing of table rutabagas that are trucked to local markets or shipped in carlots to Chicago and other markets. During 1934, 456 carloads were shipped from Askov. Allowing 15 tons to the car and an average price of $7 a ton, this part of the crop yielded an income of nearly $50,000.[11]

SOIL-SURVEY METHODS AND DEFINITIONS

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

The soils are examined systematically in many locations. Test pits are dug, borings are made, and exposures, such as those in road or railroad cuts, are studied. Each excavation exposes a series of distinct soil layers, or horizons, called, collectively, the soil profile. Each horizon of the soil, as well as the parent material beneath the soil, is studied in detail; and the color, structure, porosity, consistence, texture, and content of organic matter, roots, gravel, and stone are noted. The reaction of the soil[12] and its content of lime and salts are determined by simple tests.[13] Drainage, both internal and external, and other external features, such as relief, or lay of the land, are taken into consideration, and the interrelation of soils and vegetation is studied.

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[10] MINNESOTA STATE AGRICULTURAL DAIRY AND FOOD DEPARTMENT. BULLETIN OF INFORMATION ON CREAMERIES, CHEESE FACTORIES, ICE CREAM AND MILK PLANTS. 30 pp., illus. St. Paul. 1935.

[11] Information supplied by A. W. Conaway, managing editor of Askov American, Askov, Minn.

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

[13] The total content of readily soluble salts is determined by the use of the electrolytic bridge. Hydrochloric acid is used to detect the presence of lime carbonate.

The soils are classified according to their characteristics, both internal and external, special emphasis being given to those features influencing the adaptation of the land for the growing of crop plants, grasses, and trees. On the basis of these characteristics soils are grouped into mapping units. The three principal ones are (1) series, (2) type, and (3) phase. Areas of land, such as peat bogs, small or very wet alluvial deposits, and very sandy land, that have no agricultural use, are called (4) miscellaneous land types.

The most important group is the series, which includes soils having the same genetic horizons, similar in their important characteristics and arrangement in the soil profile, and developed from a particular type of parent material. Thus, the series includes soils having essentially the same color, structure, and other important internal characteristics and the same natural drainage conditions and range in relief. The texture of the upper part of the soil, including that commonly plowed, may vary within a series. The soil series are given names of places or geographic features near which they were first found. Thus, Brickton, Bradford, Milaca, and Cloquet are names of important soil series in this county.

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

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

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

In Pine County three systems of survey were used. Where practically all of the land was in farms, a detailed survey was made by working lines one-quarter of a mile apart. Where about half the land was in farms, or about 20 percent of the land was cultivated, a less detailed, or detailed-reconnaissance, survey was made by working lines at one-half mile intervals. A reconnaissance was made in the thinly settled part of the county by working lines 2 miles apart. A sketch

map showing which method was used in the various parts is shown on the map supplementing this report.

SOILS AND CROPS

Pine County embraces an area within which the soils are widely different. The capacity of the soils to produce crops and the adaptation of crops to the various soils also differ greatly.

The type of agriculture practiced and the crops grown in the agricultural section of the county are determined by climate, soil, and economic conditions. The climate and economic conditions combine to favor dairying, as the county is so far removed from the large markets that a nonbulky product must be produced for marketing, and the climate is too cold and the growing season too short for the efficient production of corn and hogs. Even if the growing season were longer, light-colored soils developed under forest, such as the soils in this section, would not be the most desirable for growing corn. The production of one crop, alfalfa, is particularly influenced by soil conditions within the county, as, for best growth, this crop requires a soil that is not strongly acid. Soils comprising a small total area in the southern and northern parts of the county have carbonate of lime near the surface, and most of the alfalfa fields are located on them. Alfalfa produces fair yields on some of the other soils, but, unless the land is limed, it is difficult to obtain a good stand that does not become thin after one or two seasons. Oats and hay, the most extensively grown crops, return good yields on all soils that are not too wet or too sandy. Rutabagas and potatoes thrive best in loose sandy soils, especially the red soils in the central and north-central parts of the county.

In the following pages the various soils are described in detail, and their agricultural relationships are discussed; their location and distribution are shown on the accompanying soil map; and their acreage and proportionate extent are given in table 7.

TABLE 7.—*Acreage and proportionate extent of the soils mapped in Pine County, Minn.*

Soil type	Acres	Percent	Soil type	Acres	Percent
Bradford fine sandy loam	11,520	1.3	Hibbing fine sandy loam	9,600	1.1
Bradford very fine sandy loam	13,632	1.5	Pomroy loamy fine sand	4,416	.5
Brickton silt loam	11,840	1.3	Onamia loamy fine sand	7,424	.8
Brickton fine sandy loam	704	.1	Onamia loamy fine sand, gravel-subsoil phase	1,536	.2
Hibbing very fine sandy loam	22,784	2.5	Omega loamy fine sand	47,744	5.3
Bluffton silty clay loam	18,816	2.1	Omega gravelly loamy fine sand	8,256	.9
Milaca very fine sandy loam	111,424	12.3	Omega gravelly loamy fine sand, rolling phase	4,288	.5
Milaca loam	7,744	.9	Emmert gravelly loamy sand	4,544	.5
Askov fine sandy loam	63,104	7.0	St. Croix fine sandy loam	9,344	1.0
Askov fine sandy loam, stony phase	1,152	.1	St. Croix fine sandy loam, stony phase	6,016	.7
Askov fine sandy loam, rolling phase	832	.1	St. Croix very fine sandy loam	1,408	.2
Pomroy fine sandy loam	2,624	.3	Berrien loamy fine sand	2,240	.2
Knife Lake silt loam	2,816	.3	Bluffton fine sandy loam	1,024	.1
Knife Lake clay loam	2,560	.3	Omega loamy sand	192	(1)
Freer silt loam	16,640	1.8	Adolph silty clay loam	23,168	2.6
Freer fine sandy loam	2,240	.2	Adolph silt loam	7,872	.9
Onamia very fine sandy loam	11,200	1.2	Adolph fine sandy loam	2,688	.3
Onamia fine sandy loam	20,800	2.3	Peat	247,168	27.3
Onamia fine sandy loam, rolling phase	14,784	1.6	Alluvial soils, undifferentiated	21,376	2.4
Warman very fine sandy loam	3,072	.3	Beach sand	832	.1
Warman loamy fine sand	1,664	.2			
Cloquet fine sandy loam	146,752	16.2			
Milaca fine sandy loam	4,480	.5	Total	904,320	

[1] Less than 0.1 percent.

Forty soil types and phases, grouped into 17 series, and 3 classes of miscellaneous material have been classified and mapped. These soils have been grouped for purposes of discussion, so that the relationships between the soils may be clearly understood, into: (1) Soils with calcareous substrata, (2) soils with noncalcareous substrata, and (3) miscellaneous soils and land types.

SOILS WITH CALCAREOUS SUBSTRATA

Included in this group, soils with carbonate of lime at slight depths, are Bradford fine sandy loam, Bradford very fine sandy loam, Brickton silt loam, Brickton fine sandy loam, Hibbing very fine sandy loam, and Bluffton silty clay loam. Except the last-named, these are the most productive and desirable agricultural soils in the county, and, with the exception of the very poorly drained areas of the Bluffton soils, they might also be designated as soils adapted to the production of alfalfa. Although alfalfa can be and is successfully grown on other soils, it produces better yields with less attention on the soils of this group, which were the first to be cleared, as they occupy flat or gently undulating land, contain few stones, and originally supported a stand of mixed hardwood trees. Land in such hardwoods as oak, birch, ash, elm, maple, and other trees is more easily cleared than land covered by pine trees, as the hardwood stumps rot in a few years but pine stumps may remain much longer. Alfalfa, other legumes, grasses, small grains, and corn produce well. Potatoes and rutabagas return large yields when planted on the sandy soils but are not especially successful on the heavier soils. These soils, with the exception of Hibbing very fine sandy loam, are in the southern part of the county, where corn will mature in most years. They have, with the same exception, developed from yellowish-gray calcareous material deposited during the last glacial stage. In the southern part of the county, soils in this group are extensively mapped in Rock Creek, Pine City, and Pokegama Townships and to less extent in Mission Creek and Chengwatana Townships. Hibbing very fine sandy loam covers more than one-fourth of Kerrick, Windemere, and Sturgeon Lake Townships and occurs in smaller areas in Birch Creek and Finlayson Townships in the northern part of the county. The total area of the soils of this group represents 8.8 percent of the area of the county.

Bradford fine sandy loam.—Where forested, Bradford fine sandy loam has a 1- or 2-inch layer of leaf litter and very dark brown or black decomposed and partly decomposed leaves and twigs. Organic matter from this layer has colored the topmost 1 or 2 inches of the fine sandy loam surface soil dark gray or grayish brown. It is acid in reaction. Beneath this, and continuing to a depth of about 12 inches, is gray or grayish-brown platy fine sandy loam that is very acid. When cultivated, the upper part of this soil, to plow depth, is mixed and becomes gray or grayish-yellow fine sandy loam. Between depths of about 12 and 18 inches the soil is gray silt loam in most places and is acid. Beneath this and continuing to a depth ranging from 25 to 30 inches, the subsoil is grayish-brown or yellowish-brown friable gritty clay loam. From the lower part of this horizon to a depth ranging from 40 to 50 inches is mottled brown, gray,

and grayish-brown stiff clay loam. Between this and the parent material, which nearly everywhere lies from 4½ to 6 feet beneath the surface, is a layer of yellow or grayish-yellow slightly plastic gritty calcareous clay loam.

This soil includes many variations, but they do not alter the agricultural value of the soil to a great extent. One of the most common variations is in places where the surface soil contains sufficient coarser sand to be a sandy loam. This sandy surface layer is, in places, 2 feet thick, and the subsoil layers contain considerable grit. Areas of this included soil are widely scattered, and most of them are small. Near Greeley, in Royalton Township, several small areas have thin streaks of gravel or clay in the subsoil.

Bradford fine sandy loam occupies 11,520 acres in the southern part of the county, and practically all of it is cleared and cultivated. The relief in general is gently undulating, but steep slopes, most of them less than 100 feet long, drop to the streams and some of the larger peat bogs.

This soil has developed from nearly stone-free calcareous gray till deposited by the Keewatin ice sheet. Another desirable feature is that the soil is well but not excessively drained, and water seldom stands on the surface.

The loose character of the surface soil allows easy cultivation with moderate power, under a wide range of moisture conditions, but the soil material has sufficient cohesiveness to prevent serious wind erosion. If not cultivated soon after a rain it becomes very hard. The heavy subsoil retains moisture so well that plants seldom suffer during short periods of dry weather, and, even in times of severe drought, crop failures are few.

This soil is suited to the production of alfalfa. A good seedbed can be prepared easily; the subsoil is friable, thus allowing easy penetration by roots; and the soil material is calcareous at a depth of about 5 feet from the surface. Two cuttings of alfalfa can be made each season, and yields as high as 4 tons an acre are common in favorable years.

Timothy alone and mixed timothy-and-clover hay grow well and yield from 2 to 3 tons an acre. Corn and small grains return excellent yields. Corn, which usually is cut for silage, in favorable seasons yields from 10 to 16 tons,[14] and, where allowed to mature, may yield as much as 50 bushels of grain. Oats yield more than 50 bushels and barley about 40 bushels. Most of the plowing is done in the fall.

Bradford very fine sandy loam.—Where cultivated, the surface soil of Bradford very fine sandy loam, to a depth of about 5 inches, depending on the depth of plowing, is gray or yellowish-gray very fine sandy loam. Between depths of 5 and 10 inches the subsurface layer is yellowish-gray or gray very fine sandy loam or silt loam and is, in many places, faintly mottled with gray. The reaction in both these horizons is acid, and the structure is platy. The upper part of the subsoil, to a depth of about 24 inches, is coffee-brown or grayish-brown gritty clay loam or clay, mottled with gray. The material in this horizon appears brown when very dry but is brownish yellow when crushed. The structure particles are small and angular. A

[14] The yields reported in the text are the result of interviews with farmers.

layer of mottled grayish-brown and reddish-brown gritty clay loam or clay occurs between this and the grayish-yellow sticky limy substratum. In most places the substratum lies at a depth of 4½ or more feet, but in a few places it occurs at a depth of 4 feet.

Included with this soil in mapping are a few scattered areas in which the surface soil is silt loam. The subsoil of such areas is very heavy and in most places plastic.

Bradford very fine sandy loam is associated with the slightly less extensive Bradford fine sandy loam in the southern townships. For the most part the relief is nearly flat, but the slopes to the streams and some of the larger peat bogs are short and steep. This soil has developed from the heavy calcareous practically stone-free till deposited by the Keewatin ice sheet. Both surface and internal drainage are good. Crops do not suffer during short dry periods and seldom fail even during a prolonged drought. The native vegetation was principally oak, ash, elm, maple, and birch.

Practically all of this soil is cleared and cultivated, as it is very productive. Alfalfa, the principal crop, is grown on more than 25 percent of the total area. Yields as high as 4 tons an acre are harvested from two cuttings in favorable seasons, but the average yield is about 3 tons. Timothy and clover hay also is grown extensively and yields from 2 to 3 tons an acre. Corn and small grains return excellent yields. Most of the corn is cut green and in favorable seasons yields about 14 tons of silage an acre. When allowed to mature, it may yield as much as 50 bushels of grain. Oats and barley are less extensively grown and yield 50 and 40 bushels, respectively.

Bradford very fine sandy loam cannot be cultivated under so wide a range of moisture conditions as can Bradford fine sandy loam, and the surface soil becomes hard when not cultivated soon after a rain. Wind erosion is not serious; and, as the surface is nearly flat, sheet and gully erosion are not extensive.

Brickton silt loam.—In a cultivated field, the surface soil of Brickton silt loam, to a depth of about 5 inches, is dark-gray platy silt loam. It is underlain by a 5- to 10-inch layer of gray silt loam or silty clay loam in which a crumb structure is well developed. The subsoil, to a depth of about 36 inches, is very heavy plastic clay that breaks, when slight pressure is applied, into small angular granules about one-eighth inch in diameter. The material is brown, mottled with yellowish brown, near the upper part of the layer and mottled grayish brown and gray near the bottom. The lower part of the subsoil, in most places at a depth of about 3 feet but in some places below a depth of 4 feet, consists of highly calcareous, grayish-brown, brownish-yellow, or olive-gray stratified materials consisting of very fine sand, silt, and clay. In many places calcium carbonate occurs as white streaks, or, at a depth of 4 or 5 feet, as nodules ranging from less than one-fourth inch to more than 3 inches in diameter.

Variations from this soil as described are rare. In a few places in Mission Creek Township the silty upper layers are 20 inches thick and the upper part of the subsoil is reddish brown, and a few areas in this vicinity have a very fine sandy loam surface soil. Included with this soil as mapped are a few acres in Munch Township where both the subsoil and the substratum are dark reddish-brown clay.

Brickton silt loam has a total area of 11,840 acres. It is extensive in Pokegama, Chengwatana, and Mission Creek Townships, and small areas are in nearby townships.

This soil has developed from calcareous gray drift, transported by the Keewatin ice sheet and deposited in still water. Soil material accumulated in this manner is very fine, occupies flat and nearly level surfaces, and is stone free. The silt loam surface soil requires considerable power for cultivation and cannot be worked when very wet, but the flat surface allows the use of all types of farm machinery. The surface soil becomes very hard in dry weather.

Drainage is imperfect, as run-off is very slow and the heavy subsoil retards percolation. Crops do not fail in periods of drought, but yields are lowered when the season is either drier or wetter than normal. The native vegetation was a dense hardwood forest of oak, American linden (basswood), butternut, elm, ironwood, and maple, together with an occasional white pine. Practically all of this soil is cleared, as it has desirable relief, is stone free, is easily cleared, and is very fertile.

Brickton silt loam is well adapted to growing alfalfa, as lime occurs in most places within 3 feet of the surface. Corn and small grains return large yields, but root crops are better adapted to a looser soil. Average yields are similar to those of the Bradford soils and may be higher in very favorable years and lower in years when the rainfall is either above or below normal. Corn for silage yields from 12 to 15 tons an acre, alfalfa from 3 to 4 tons, other tame hay about 3 tons, oats from 50 to 60 bushels, and barley from 40 to 50 bushels.

Plowing usually is done in the fall. Water erosion is not serious, and wind erosion does not appear to be active.

Brickton fine sandy loam.—The surface soil of Brickton fine sandy loam, to a depth of about 5 inches, is grayish-brown fine sandy loam. Beneath this, to a depth ranging from 15 to 20 inches, is a layer of gray or grayish-yellow fine sandy loam or sandy loam. The material in both these horizons is acid in reaction. The subsoil, which continues to a depth of about 50 inches, is plastic gritty clay. It is brown or grayish brown in the upper part and mottled gray, brown, and grayish yellow in the lower part. The lower part of the subsoil, or substratum, which in most places is reached at a depth of 50 inches but in some places lies at a depth of more than 5 feet, is calcareous grayish-brown, brownish-yellow, or olive-gray very fine sandy loam.

In places the surface soil consists of sand to a depth of 3 feet, and the subsoil contains considerable sand. In some places the calcareous substratum is at a depth of 6 to 7 feet.

This is a very inextensive soil. It is associated with Brickton silt loam and has developed on slight elevations that may have been beaches or sand bars in the glacial lake. In places many stones and boulders are on the surface.

The relief is very gently undulating, and both surface and internal drainage are good. Crops suffer during dry periods and may fail during a prolonged drought. The original forest included many white pine trees.

Much of this soil remains in wood lots or is used as pasture. It can be cultivated easily under a wide range of moisture conditions.

Alfalfa grows well. Potatoes are often planted on this soil and return high yields. Small grains return fair yields, but dry periods may reduce the yield. As most areas of this soil are small and scattered, no definite crop yields can be ascribed. Most of the cultivated areas form parts of fields that also include areas of Brickton silt loam. Wind erosion is a serious problem. During heavy rains much soil material may be washed from the surface, but, as the areas are small, gullies are not formed.

Hibbing very fine sandy loam.—The surface soil of Hibbing very fine sandy loam, to a depth of about 5 inches, is grayish-brown platy very fine sandy loam. It is underlain to a depth ranging from 9 to 12 inches by brown platy very fine sandy loam or silt loam that in places is faintly mottled with gray. Below this is a 2- to 6-inch layer of gray or grayish-red vesicular very fine sandy loam or gritty silt loam that is strongly cemented when dry. The thickness of this layer varies within a few inches horizontally, as the contact between it and the layer beneath is very irregular. The next lower layer, which continues to a depth of about 20 inches, is reddish-brown silty clay loam or clay loam slightly mottled with gray. A definite prismatic structure is developed, but the prisms break easily into firm irregular angular granules. Between this and the calcareous substratum is brownish-red clay loam that breaks into irregular angular granules from one-eighth to one-fourth inch in diameter, but the material is plastic and sticky if crushed when wet. In most places the calcareous material occurs at a depth ranging from 50 to 60 inches and is grayish-red gritty clay loam till that breaks into lens-shaped fragments about 2 inches on the horizontal axis and one-fourth inch on the vertical axis. The whole mass of this horizon is calcareous, and pink spots indicate the concentration of carbonates.

The soil as mapped includes minor variations in texture, color, degree of mottling, and thickness of the various horizons. The most common variation contains faint-gray mottlings in any or all layers, especially in the layer overlying the calcareous material. These mottlings are on the faces of the small lumps or aggregates of soil. The depth to carbonate of lime is as much as 8 feet in places. Variations in texture also are common, as the surface soil in places, especially in Kerrick Township, is silt loam. In such places the subsoil may be slightly heavier and the calcareous material may be present at a depth of 45 inches.

Hibbing very fine sandy loam occurs in the northern part of the county where the Superior lobe of the Wisconsin glacial period deposited highly calcareous red drift. It occupies 22,784 acres, or 2.5 percent of the land area of the county and is extensive in Kerrick, Windemere, and Sturgeon Lake Townships. Less extensive areas are in Birch Creek and Finlayson Townships.

This soil occupies undulating or gently rolling relief, with precipitous drops to peat bogs, streams, and lakes. It is nearly stone free and originally supported a growth of mixed hardwoods with some white pine and red pine. The fine-textured surface soil requires considerable power for tillage operations. The soil is well drained, and both surface run-off and internal drainage are rapid.

This is a desirable soil for alfalfa, and probably 10 percent of it is devoted to that crop, which yields from 3 to 4 tons an acre. Other

tame hay yields from 2 to 3 tons. Dent corn may not mature as grain. Corn for silage yields from 10 to 12 tons, oats 45 to 50 bushels, and barley 40 bushels. Potatoes are grown extensively, and yields of 150 or more bushels are common. The more sloping areas are not farmed but are left in permanent pastures or wood lots, as small gullies develop in fields even on gentle slopes, and fall plowing is done only on the flatter areas. Crops on this soil withstand drought well. The surface layer does not bake or harden so rapidly as do the surface soils of members of the Brickton and Bradford series.

Bluffton silty clay loam.—The surface soil of Bluffton silty clay loam, to a depth of about 10 inches, is very dark gray silty clay loam. It is underlain by gray or grayish-yellow plastic clay to a depth ranging from 15 to 20 inches. Beneath this is a layer of mottled gray and rust-brown plastic clay that continues to a depth ranging from 24 to 30 inches, where the material consists of faintly mottled gray and grayish-yellow calcareous silty clay loam. This layer contains some soft white concretions of calcium carbonate.

This soil occupies depressions and swales and borders peat bogs, in association with the Brickton and Bradford soils in the southern part of the county. The total area is 18,816 acres.

This soil as mapped includes many variations. Where the areas occupy small depressions in the Brickton plain, the surface soil may be much lighter gray when dry and the calcareous material may be present at a depth of 4 feet or more beneath the surface. A few areas that once were shallow peat and from which the peat has been burned are included with this soil as mapped, and here the surface soil is gray clay. Where associated with the Bradford soils, the surface soil is dark-gray or dark grayish-brown silty clay loam in places; some grit and a few small rock fragments occur in all layers, and the limy material lies at a great depth, in many places from 6 to 7 feet beneath the surface. In a few small areas in the vicinity of West Rock in Rock Creek Township, the surface soil is silt loam that is gray when dry and dark gray when wet, and the subsoil is brown clay loam similar to that of the Bradford soils.

The surface is flat or nearly so. Stones are present in some places where the soil borders peat bogs, but in other places the land is practically stone free. Owing to the low position occupied by this soil, it receives surface run-off from higher lying soils, and in the spring or after a heavy rain many areas are covered with water and cultivation is hindered. The heavy character of the surface soil requires the use of considerable power for tillage. Both surface and internal drainage are poor. Erosion is not a problem except that, where this soil occurs at the bases of comparatively steep slopes, the material washed from the higher lying soils may be deposited over it. During dry periods the surface soil cracks and crops may be stunted.

The native vegetation was composed of ash, elm, paper birch, and balsam fir, with some spruce and tamarack. Large areas of this soil are utilized for pasture or wood lots, but the small narrow areas within larger bodies of the Bradford and Brickton soils are cleared and farmed with those soils. In the few places where it is not too wet, this is the best soil for corn in the county, as the dark surface soil has a large content of organic matter. Oats and barley frequently lodge, potatoes may fail, and any crop may drown out after

a hard rain. As very few fields consist wholly of this soil, definite yields cannot be given.

SOILS WITH NONCALCAREOUS SUBSTRATA

Pine County, except areas of peat and those soils already discussed, is covered by red material that has no carbonate of lime within a depth of less than 10 feet below the surface, and the soils are acid in all horizons. Some of the soils developed from this red material have fine-textured surface soils and silt loam or silty clay loam subsoils and are fair agricultural soils; others have loose surface soils and subsoils and are less desirable agricultural soils, although a few farms are located on them. The soils with fine-textured surface soils and heavy subsoils are distributed most widely in the western part of the county. These soils are fairly productive, and corn (generally cut for silage), oats, barley, potatoes, rutabagas, and hay are extensively grown on them. Alfalfa is grown but not so successfully as on the soils with calcareous substrata.

The soils with heavy retentive subsoils are Milaca very fine sandy loam; Milaca loam; Askov fine sandy loam; Askov fine sandy loam, stony phase; Askov fine sandy loam, rolling phase; Pomroy fine sandy loam; Knife Lake silt loam; Knife Lake clay loam; Freer silt loam; and Freer fine sandy loam. These soils occupy undulating to gently rolling land and a few areas of nearly flat land. Less than one-half the total area is cleared and in farms, as only the areas with comparatively smooth relief have been settled. Most of the farms are scattered, but in some localities, as near Brookpark and Hinckley, large areas are cleared.

The better soils of this group with loose gravelly subsoils are Onamia very fine sandy loam; Onamia fine sandy loam; Onamia fine sandy loam, rolling phase; Warman very fine sandy loam; and Warman loamy fine sand. These soils occupy flat and nearly level areas, and all have loose open subsoils. They are easily cultivated, and where large areas occur, as east of Hinckley and in Clover, Arlone, and Munch Townships, a large proportion is cleared and in farms.

Soils of a third class within this group, which are sandy with sandy or gravelly substrata, generally are not farmed, but a few areas have been cleared and cultivated in the vicinity of recreational centers or near the larger villages where markets are good, and a few isolated farms are scattered over the section. These soils are Cloquet fine sandy loam; Milaca fine sandy loam; Hibbing fine sandy loam; Pomroy loamy fine sand; Onamia loamy fine sand; Onamia loamy fine sand, gravel-subsoil phase; Omega loamy fine sand; Omega gravelly loamy fine sand; Omega gravelly loamy fine sand, rolling phase; Emmert gravelly loamy sand; St. Croix fine sandy loam; St. Croix fine sandy loam, stony phase; and St. Croix very fine sandy loam. Collectively, these soils occupy 57.3 percent of the land area of the county.

The original vegetation in this section was principally pines, but the forests have been removed by lumbering operations or by fires that swept the area. The present tree growth is largely aspen, paper birch, and gray birch.

Milaca very fine sandy loam.—In a cultivated field the topmost 5-inch layer of Milaca very fine sandy loam is grayish-yellow very fine

sandy loam. When dry it is slightly coherent but can be crushed easily to a fine powder. Between depths of 5 and about 11 inches is mottled grayish-yellow and brownish-yellow very fine sandy loam or silt loam. Beneath this is a 2- or 3-inch layer of mottled gray and reddish-brown silty clay loam that contains some rust-brown spots. When dry this layer is cemented and appears gray, but when moist it is reddish brown. Underlying this and continuing to a depth of about 24 inches, the material is reddish-brown silty clay loam or clayey fine sand, mottled with brownish red and containing some gray and rust-brown streaks. Between depths of about 24 and 32 inches is a layer that has the same colors as the layer above but is slightly sandier and contains some small rock fragments. The substratum, or material from which the soil has been formed, is brick-red unassorted sand, rock fragments, and clay. It is very compact and, when dry, becomes indurated. It is commonly called hardpan.

Included with this soil as mapped are areas where the subsoil is silt loam and some areas where it is clay loam. The substratum in places is loose and in other places contains a large quantity of clay. From a few very small gravelly areas, road gravel is obtained.

Milaca very fine sandy loam covers a total area of 111,424 acres, or 12.3 percent of the land area of the county. It occupies undulating to gently rolling land. All areas have some stones and boulders on the surface and throughout the soil mass. In most places the stones can be removed with little expense, but in many areas they are so numerous that it is impracticable to prepare the land for cultivation. This soil has developed from till deposited as moraines by the Patricia ice sheet. After the stones and stumps are removed the land is easy to cultivate, as the loose surface soil is easily worked and can be cultivated soon after a hard rain.

This is a well-drained soil, as surface run-off is rapid and internal drainage is excellent. Wind erosion is not a serious problem, but sheet erosion and gullying are serious on the more sloping areas. Very few of the sloping areas are cultivated but are either left in wood lots or cleared for pastures. Crops suffer from drought during periods of low rainfall, but when precipitation is normal plants grow rapidly. The original forest growth was principally white pine and red pine, with some oaks and other hardwoods. The second growth is mostly aspen and paper birch, with a thick undergrowth of briers and hazel brush.

Probably more than 20 percent of the total area occupied by this soil is cleared and in crops. Much of the land not cleared has sufficient slope to make it difficult to control erosion or is not easily reached on a good road. Clover-and-timothy hay grows well on this soil and yields from 1 to 2 tons an acre. The soil is well suited to growing cereals; oats yield about 45 bushels an acre and barley from 35 to 40 bushels. Corn is grown for silage and yields from 6 to 8 tons an acre. It is sometimes allowed to mature and yields from 35 to 40 bushels of ear corn. The most common cash crop grown is potatoes, and yields of 150 or more bushels an acre are obtained.

Included with Milaca very fine sandy loam are numerous small areas of somewhat similar soil that are subject to seepage water from adjacent higher land. Over the surface of such areas is a 4- or 5-inch layer of decomposed leaves and twigs. To a depth of 5 or 6 inches

the mineral surface soil is brown platy very fine sandy loam mottled with gray and rust brown. Between depths of 6 and 15 inches the very fine sandy loam is mottled gray, grayish brown, and rust brown, with the rust-brown color predominating in the lower part of the horizon. The next layer, between depths of 15 and 30 inches, is brownish-red sandy loam or sandy clay loam, with some rust-brown mottling. The substratum, below a depth of 30 inches, is like that beneath typical Milaca very fine sandy loam. It is impervious to water, as it is dry even when the overlying soil material is saturated. These seepy areas occur in the vicinity of Denham and in Sturgeon Lake, Birch Creek, and Bremen Townships. Springs are numerous in these areas. Large stones and boulders are numerous on the surface and throughout the soil mass. In many places bedrock lies near the surface, and it outcrops in a few places. The areas are poorly drained internally, but surface run-off is rapid. The original vegetation was ash, oak, birch, and spruce, but the present growth is largely oak, aspen, briers, wild cherry, and hazel brush, with little or no cleared land.

A number of areas included with Milaca very fine sandy loam are distinguished by definitely sandier upper layers and by greater depth to the red till substratum. Most of these areas are along the junction of the red and gray drift, in a belt extending east from Henriette to the northern end of Cross Lake. The relief is choppy; that is, local differences in elevation are slight, but many of the short slopes are steep, and many very small depressions, in which peat or dark-colored soil occur, cannot be shown on a small-scale map. Stones of all sizes are numerous on the surface and through the soil mass. The soil is well drained and can be cultivated easily when used as cropland. Strong winds carry off some soil, and heavy rains may cause serious damage in cultivated fields. During dry periods crops wilt and yields are reduced. The original vegetation was largely white pine and red pine, with some scattered hardwoods. The most common use of this included soil is for pasture land or wood lots, but, where the relief is comparatively smooth and the rocks can be removed easily, it is cleared and cropped.

Milaca loam.—The surface soil of Milaca loam, to a depth of about 5 inches, is grayish-yellow or grayish-brown platy loam. Between depths of about 5 and 15 inches the subsurface soil is gray, grayish-yellow, and grayish-brown mottled platy loam or very fine sandy loam that is strongly cemented when dry. Beneath this and continuing to a depth of about 24 inches is brownish-red stiff clay loam or clay that in many places is mottled with gray and in some places is gritty. Brick-red granular clay or clay loam, in some places slightly mottled with gray and rust brown, extends to a depth of about 40 inches. The substratum, from which this soil is developed, is grayish-red unassorted sandy clay, with a few small angular rock fragments and an occasional large boulder. It breaks into lens-shaped fragments about 2 inches on the horizontal axis and from one-fourth to one-half inch on the vertical axis.

Variations from the profile described are not marked or important. The surface soil in places is very fine sandy loam, and the substratum may be sandy, but the subsoil horizons are definitely much heavier than those of Milaca very fine sandy loam.

Milaca loam occurs in the northwestern part of the county. The largest areas are in Bremen, Kettle River, Pine Lake, Partridge, and Finlayson Townships.

The relief is very gently undulating, and in many places the land is nearly flat. This soil has developed from material deposited as ground moraines by the Patricia ice sheet. This material contains very few boulders, and both the surface soil and the subsoil are practically stone free. Surface drainage is good, but percolation may be slow, because of the heavy character of the subsoil.

This is considered one of the most desirable soils in the section where it occurs, because of its smooth surface and comparative freedom from stones. Most of it is cleared and in crops. Corn for silage is extensively grown and yields from 8 to 10 tons an acre, clover-and-timothy hay yields from 1 to 2 tons, and oats yield from 45 to 50 bushels. This soil generally is plowed in the fall, as erosion is not serious.

Askov fine sandy loam.—The 10-inch surface soil of Askov fine sandy loam is grayish-yellow or brownish-yellow fine sandy loam. Between depths of 10 and 24 inches the subsoil is mottled gray, yellowish-brown, and rust-brown fine sandy loam that is cemented when dry. Between this layer and the sandy substratum, which lies at a depth ranging from 30 to 36 inches, the soil material is slightly mottled or speckled reddish-brown, grayish-brown, and rust-brown clayey fine sand. The substratum is compact reddish-brown sandy till. The only variations in this soil as mapped are that the surface soil in some places is very fine sandy loam and in other places is sandy loam. The subsoil in many places is very slightly mottled. The principal differences between this soil and Milaca very fine sandy loam are that the surface soil is brownish yellow and not mottled and the subsoil is sandier.

Askov fine sandy loam is mapped in the northwestern and west-central parts of the county, where it covers 63,104 acres, or 7 percent of the total land area. It is well developed and extensive near Sandstone and Askov.

The relief ranges from undulating to gently rolling, and erosion is severe on exposed slopes. This soil has developed from till carrying much sandstone material ground up locally and deposited as moraines by the Patricia ice sheet. Rock fragments and boulders are common on the surface and throughout the soil mass. Rock piles, composed of more than 25 percent of sandstone fragments, are numerous where this soil is dominant. Both surface and internal drainage range from good to excessive, and crops suffer during dry periods.

In Partridge and Sandstone Townships many farms are on this soil, but only about 15 percent of the total area of the soil is cleared and cultivated. About 10 percent of the cleared area is devoted to rutabagas, and about 75 percent of the rutabagas grown in the county are produced on this soil. Yields as high as 30 tons an acre are reported on heavily fertilized fields, but the normal yield ranges from 8 to 10 tons. Potatoes are grown commercially and are planted on about the same acreage as rutabagas. The yield may be as high as 300 bushels an acre, but the average is about 150 bushels. Corn for silage yields from 6 to 8 tons, and oats yield about 40 bushels.

Askov fine sandy loam, stony phase.—Associated with typical Askov fine sandy loam are small areas that have so many stones on the surface that clearing for cultivation is practically impossible. Such areas, which occur mainly in Partridge, Finlayson, and Bremen Townships, are mapped as Askov fine sandy loam, stony phase. The profile resembles that of typical Askov fine sandy loam, but all horizons are thicker, slightly more sandy, and contain numerous stone fragments and boulders. Where cleared, the land is used as pasture, but the soil becomes very dry during periods of drought.

Askov fine sandy loam, rolling phase.—A rolling phase of Askov fine sandy loam is recognized where the relief is so rolling that cultivation would be difficult and erosion serious. This soil occupies only a few areas, principally in Partridge and Bremen Townships. The profile is similar to typical Askov fine sandy loam, but the land is choppy or rolling, with low steep-sided ridges extending in a northeasterly direction. Many small areas of wet soil or peat between the ridges cannot be shown on a map of the scale used. Very few areas are cleared, and most of them support a cover of hazel brush, wild cherry brush, and sweetfern.

Pomroy fine sandy loam.—The surface soil of Pomroy fine sandy loam, to a depth of about 5 inches, is brown or grayish-brown fine sandy loam. Beneath this and continuing to a depth of about 10 inches is gray or grayish-brown loamy fine sand, mottled with rust brown, which in many places contains some rounded medium sand grains. Between depths of 10 and about 30 inches the material consists of mottled rust-brown and gray rounded fine sand or sand. In places many rounded stones are in the lower part of this horizon and upper part of the substratum immediately below. The substratum is brownish-red clay loam mottled with rust brown and streaked with gray.

This soil is mapped in small areas, chiefly in Pine Lake and Chengwatana Townships and in isolated areas in nearby townships. The description given above is typical of the soil in Pine Lake Township and vicinity. Here, the surface soil and subsurface soil in many places consist of very fine sand, and the depth to the clayey substratum ranges from 20 to 48 inches. In Chengwatana Township this soil is associated with Brickton silt loam, and here the substratum is heavy gray clay, the depth of which ranges from a few inches to several feet within a distance of 10 yards. In a few places carbonate of lime occurs within 4 feet of the surface. In some places on slight rises the subsoil immediately above the clay is brownish yellow.

Typically Pomroy fine sandy loam occupies nearly flat areas, but in a few places it occupies slight rises. This soil has developed where a layer of sand has been deposited over assorted clay and clayey material. It is practically stone free. Internal drainage is imperfect, and surface run-off is slow. Crops do not suffer during short periods of dry weather, but yields may be reduced during a long drought.

In many places, especially in Pine Lake Township, Pomroy fine sandy loam is associated with loose sandy soils and is cleared and cultivated. Many well-kept farms are located on this soil. Corn for silage yields from 6 to 8 tons an acre, mixed clover-and-timothy hay about 2 tons, oats about 40 bushels, and potatoes 150 bushels. Fall plowing is practiced, because erosion is not serious and the imperfect drainage frequently delays operations in the spring.

Knife Lake silt loam.—The 5-inch surface layer of Knife Lake silt loam is dark-gray or grayish-brown silt loam. The subsurface layer is grayish-brown silt loam or very fine sandy loam, slightly mottled with gray in most places. From a depth of about 11 inches to a depth ranging from 20 to 40 inches is a layer of grayish-brown silty clay loam mottled with gray and brown. Beneath this is red unassorted sand, clay, and rock fragments, or, less commonly, reddish-brown assorted sand and gravel.

The depth to the red material differs from place to place but in few areas is more than 3 feet, and small areas are included in mapping where this material is exposed. Also included in mapping are small areas in the southern part of Pokegama Township and in the northern part of Royalton Township, where the gray drift overburden may have been the kind of material from which the Bradford soils have developed. Another inclusion is an area about 2 miles west of Pine City, on the terrace along the Snake River, with a gray very fine sandy loam surface soil and a dark-brown sticky gritty clay loam subsoil at a depth ranging from 10 to 20 inches. The underlying material is gravel which is being excavated and used for road building.

Knife Lake silt loam occupies rather small areas, in most places adjoining or near Brickton silt loam. A good example of the typical soil is south of Henriette.

The relief is very gently undulating. This soil has developed where a thin layer of the fine material from which the Brickton soils developed was deposited over red drift, which may be either till or outwash. In most places many stones and boulders are on the surface. Most of the stone-free areas are cultivated. The silt loam surface soil requires considerable power for cultivation, and tillage operations cannot be performed when the land is wet. Surface drainage is good, as most of the soil occupies slight slopes, but internal drainage is slow. Erosion from wind or water is not serious. During periods of prolonged drought, crops wilt and may die, especially in those areas where the substratum is assorted sand and gravel. The original vegetation was largely mixed hardwoods, together with considerable white pine.

Small grains, corn for silage, and hay are important crops. In normal years oats yield from 45 to 50 bushels an acre, barley 35 to 40 bushels, corn 10 tons of silage, and hay about 2 tons.

Associated with the more typical areas of Knife Lake soils, and occurring also in Pine Lake and Dell Grove Townships, are areas of soil developed from similar fine material but under better drainage. The surface soil, to a depth of about 7 inches, is dark grayish-brown silt loam, and the subsurface soil, to a depth of about 12 inches, is grayish-yellow silt loam containing a few rust-brown spots or streaks. The subsoil, to a depth of about 20 inches, is mottled grayish-yellow, grayish-brown, and rust-brown silt loam or clayey fine sandy loam. Between depths of 20 and 30 inches the material is mottled reddish-brown, grayish-brown, and rust-brown gritty clay loam. The substratum is reddish-brown gritty clay loam streaked with gray and rust brown. These better drained areas occupy slightly undulating areas, low knolls, and slight rises surrounding areas of Knife Lake clay loam. In many places a few cobblestones, 6 or 8 inches in diameter, and some gravel are on the surface and in the

upper horizons. Areas of this soil are cultivated along with Knife Lake clay loam and return similar yields.

Knife Lake clay loam.—The surface soil of Knife Lake clay loam, to a depth of about 5 inches in cultivated areas, is dark-gray clay loam, but in some areas of virgin soil a 3- or 4-inch layer of muck overlies the mineral soil. Beneath this is mottled dark-gray, gray, and rust-brown clay loam. Between depths of 10 and 24 inches the subsoil is mottled or marbled gray, grayish-brown, reddish-brown, and rust-brown gritty clay loam. The substratum is reddish-brown gritty clay loam containing a few gray and rust-brown streaks. The subsoil is, in some places, predominantly gray. In general, both the surface soil and the subsoil are neutral in reaction, but no carbonate of lime occurs in any layer.

This soil covers a small total area in Sturgeon Lake, Birch Creek, and Bremen Townships. The land is nearly flat, and internal drainage and run-off are slow. This soil has developed from fine material deposited in still water, and it is practically stone free. The water table normally is near the surface, and crops seldom suffer from drought.

Most of this land is cleared and cultivated, as the smooth surface, lack of stones, and high average moisture content make it desirable. Acre yields of corn are 6 to 8 tons of silage; of hay, about 2 tons; of oats, about 45 bushels; and of potatoes, 150 bushels. It is customary to plow this land in the fall, as erosion is not active and cultural operations are often delayed by excess moisture in the spring.

Freer silt loam.—The cultivated surface soil of Freer silt loam, to a depth of 6 or 8 inches, is dark grayish-brown silt loam that is gray when dry. Beneath this and continuing to a depth of about 15 inches is highly mottled gray, grayish-brown, and grayish-yellow silt loam that contains some rust-brown spots here and there. The material in these horizons is vesicular and platy. The subsoil, to a depth of about 20 inches, is highly mottled gray, rust-brown, and reddish-brown silty clay loam that has a fine-granular structure and breaks readily into angular fragments about one-eighth of an inch in diameter. The lower part of the subsoil is mottled reddish-brown, rust-brown, and gray clay loam that breaks readily into irregular angular fragments from one-fourth to one-half inch in diameter. The fragments are coated with gray, and this imparts a gray appearance to the freshly broken material. The substratum is brick-red or brownish-red unassorted gritty clayey till.

This soil occupies slight depressions in association with the Milaca and Askov soils, mainly throughout the western and central parts of the county. The individual bodies are small, but the total area is 16,640 acres. Where associated with the Askov soils, the surface soil and the subsoil are slightly sandy in places. In less well drained situations than those just described, the surface soil in places is dark gray, the subsurface soil is gray mottled with grayish yellow and rust brown, and the subsoil layers are more predominantly gray.

The surface is nearly flat or slightly saucerlike. The soil has developed from red till deposited by the Patricia ice sheet and in places is stony, some areas so stony that clearing is impractical. Both surface and internal drainage are slow, and during very wet periods

water may stand on the surface. Crops seldom suffer during dry periods.

Because most of this soil occurs in small bodies within areas of other soils, agricultural practices are governed by the surrounding soils except where imperfect drainage hinders cultivation. Corn and hay grow better on this soil than on the surrounding Milaca and Askov soils, but small grains frequently lodge and potatoes may be drowned out. In some places, where this soil is drained by open ditches, it is a valuable addition to the field.

Freer fine sandy loam.—The colors of the surface and subsoil layers of Freer fine sandy loam are similar to the corresponding layers of Freer silt loam, but all layers are sandier. To a depth of about 8 inches, the surface soil is dark-gray or grayish-brown fine sandy loam, and below this, to a depth of about 12 inches, it is gray fine sandy loam mottled with rust brown and grayish yellow. Beneath this and continuing to a depth of about 36 inches is the mottled gray and grayish-yellow silt loam subsoil spotted with rust brown. The substratum is composed of unassorted sand, silt, clay, and stone fragments.

This soil occurs in depressions, generally associated with the Askov soils and the red sandy soils in the central and western parts of the county, but in a few places it is associated with Milaca very fine sandy loam. It is of small total extent.

The areas are nearly flat or depressed. The soil has developed from loose red till deposited by the Patricia ice sheet, and in many places it is stony on the surface and in all horizons. Drainage is imperfect, run-off is slow, and water frequently stands on the surface.

Very little of this soil is farmed, as it occurs most extensively in nonagricultural sections, but, where cleared and cultivated as part of a field of some better drained soil, corn and hay grow well.

Onamia very fine sandy loam.—The surface soil of Onamia very fine sandy loam, to a depth of about 6 inches, is grayish-brown very fine sandy loam containing a few faint-gray mottlings. The soil material breaks into plates ranging from about one-sixteenth to one-eighth inch thickness. Beneath this and continuing to a depth of about 12 inches is light grayish-brown very fine sandy loam with a few brown stains. The material in this layer breaks into thin plates about one-eighth inch thick but shows evidence of vertical cleavage planes on which the brown stains appear. Between depths of 12 and 18 inches the material consists of mottled grayish-brown and brown silt loam or silty clay loam. This material breaks readily into small angular fragments ranging from one-eighth to one-fourth inch in diameter, and the grayish-brown color is on the faces of the fragments. When crushed the mass is yellowish brown. Between this layer and the substratum, which in most places lies at a depth of about 30 inches, is a layer of reddish-brown clay loam that breaks into angular fragments about one-fourth inch in diameter. The substratum consists of loose brownish-red or brownish-yellow assorted sand and gravel, which are excavated and used for road building and concrete work.

East of Hinckley and in the extreme southwestern corner of the county the subsoil is silty clay loam, and the gravel lies at a depth

below 50 inches. In several places gravel occurs at a depth of 24 inches, and in a few locations the substratum is sand.

Onamia very fine sandy loam covers 11,200 acres, mostly in the townships east of Hinckley. Small isolated areas are along streams in several other townships in the section where noncalcareous soils occur. The land is nearly flat, as the soil has developed from material deposited as an outwash plain when the Patricia ice sheet melted, or as a terrace along a stream. Few of the stones in the surface soil or subsoil are more than 3 inches in diameter. Drainage is excellent, and, even though run-off is slow, water never stands on areas of this soil. Crops suffer and sometimes fail in dry seasons.

This is a very desirable soil, as it is not only stone free and easily cultivated but is very productive. Corn for silage yields from 8 to 10 tons an acre in years of normal rainfall, hay yields about 2 tons, oats yield from 45 to 50 bushels, and potatoes yield about 150 bushels. Wind erosion is sometimes serious, but soil washing does not occur. Fall plowing is a common practice.

Onamia fine sandy loam.—The 5-inch surface layer of Onamia fine sandy loam is gray fine sandy loam. It is underlain to a depth of about 11 inches by faintly mottled yellowish-brown and grayish-yellow fine sandy loam. Beneath this and continuing to a depth of about 24 inches is the subsoil of yellowish-brown sandy clay loam. The substratum is brownish-yellow assorted sand and gravel. This soil as mapped includes many variations, as the surface soil in some places is sandy loam and in many places the subsoil is very sandy but slightly cemented and grayish brown rather than yellowish brown. In a few places streaks of clay are in the subsoil and substratum.

This is a fairly extensive soil, mapped in nearly all except the northern two tiers of townships, but it is most extensive in the townships east and southeast of Hinckley.

In most places the surface is nearly flat, but in some places it is undulating. The soil has developed from outwash materials deposited by water from the melting of the Patricia ice sheet or by streams. In some places large rounded stones are numerous both on the surface and throughout the soil. Drainage ranges from good to excessive, and crops suffer during dry periods.

Onamia fine sandy loam is not extensively farmed, except east of Hinckley along the State highway and in Munch Township. It is easily cleared and cultivated, but yields are not high, and the likelihood of failure due to drought is serious. Corn for silage yields about 6 tons an acre, hay about 1½ tons, oats 35 bushels, and potatoes 150 bushels. Much of the cultivated land is plowed in the fall. Considerable surface soil may blow away, but damage caused by water erosion occurs in very few places.

Onamia fine sandy loam, rolling phase.—In Sturgeon Lake, Kettle River, Pine Lake, Dell Grove, Ogema, and Clover Townships, and to a small extent in several other townships, areas of Onamia fine sandy loam with a choppy to rolling relief are separated as Onamia fine sandy loam, rolling phase. In many places many rounded stones and boulders are on the surface, and the land is not farmed, except in Dell Grove Township, where the material overlying the gravel is similar to the upper part of Askov fine sandy loam and the relief is gently rolling. Much of this rolling land is used as pasture.

Small areas of dark-colored soil and peat, too small to map separately, are included with this soil.

Warman very fine sandy loam.—The 9-inch surface soil of Warman very fine sandy loam is dark-gray very fine sandy loam containing a few rust-brown spots. The subsoil is mottled gray, grayish-brown, and rust-brown silt loam or silty clay loam to a depth of 21 inches. The gray mottling is predominant in the upper part of the horizon, and the rust-brown mottling is predominant in the lower part. Beneath this and continuing to a depth of about 30 inches the material is mottled reddish-brown, grayish-brown, and rust-brown silty clay loam. The substratum is brownish-red sand and gravel.

A few areas in which the surface soil is silt loam are included with this soil in mapping. In some places the subsoil is clay loam, and in other places it is sandy clay loam. Narrow streaks of sand are numerous in the subsoil. The depth to sand and gravel ranges from 24 to 48 inches but in most places is about 30 inches.

Warman very fine sandy loam is associated with Onamia very fine sandy loam and Onamia fine sandy loam. It occupies nearly flat areas, and drainage ranges from imperfect to poor. This soil has developed from outwash sand and gravel similar to that underlying the Onamia soils. It generally occurs in small areas surrounded by the Onamia soils, with which it is farmed. It is well adapted to the production of corn and hay, but small grains are apt to lodge. In early spring or during a period of high rainfall, water may stand on this soil and hinder cultural operations or drown crops.

Warman loamy fine sand.—The surface soil of Warman loamy fine sand, to a depth of about 8 inches, is dark-gray loamy fine sand. Between depths of 8 and about 20 inches the material is mottled gray, rust-brown, and grayish-brown fine sandy loam. Beneath this and continuing to a depth of about 30 inches the material is streaked rust-brown, grayish-brown, and gray fine sand or fine sandy loam. In most places the substratum is grayish-brown sand, but in some places it is sand and gravel.

Included with this soil in mapping are a few areas in which the texture of the surface soil is loamy sand and also some areas in which the subsoil horizons are sandy, with very little fine material. The color of the subsoil in some places is coffee brown. Only a small total area of this soil is mapped, although it is widely distributed. It is associated with the sandier Onamia soils and with members of the Omega and Emmert series. Most of the bodies are small.

This soil occupies flat or nearly flat areas and is practically stone free. It has developed from sandy outwash material. Drainage ranges from imperfect to poor, and water frequently stands on the surface.

Very little of Warman loamy fine sand is farmed, except in conjunction with an adjoining cultivable soil. It produces high yields of corn and hay, but small grains may lodge.

Cloquet fine sandy loam.—In uncultivated areas the 2-inch surface layer of Cloquet fine sandy loam is gray or grayish-brown loamy fine sand. Below this is a 2-inch layer of light-gray fine sand, which is underlain by yellowish-brown fine sandy loam or very fine sandy loam. Between depths of about 15 and 24 inches is grayish-brown fine sandy loam or very fine sandy loam that is slightly cemented when dry

and faintly mottled with light gray. Below this and continuing to a depth of about 36 or more inches the material consists of cemented reddish-brown loamy fine sand containing spots of gray and reddish brown. The substratum, lying at a depth of about 3 feet, is reddish-brown or brownish-red loose glacial till consisting of a mixture of sand, small stone fragments, and many large boulders.

Variations in this soil are not pronounced or numerous. In places the surface soil is very fine sandy loam, loamy very fine sand, or loamy sand. The subsoil horizons in some places are loose and incoherent, and the depth to the substratum ranges from 2 to 5 feet.

This is the most extensive mineral soil in the county. It occurs in the northern half and occupies 146,752 acres, or 16.2 percent of the total land area of the county.

The relief is rolling, and stones and boulders are numerous on the surface and through the soil mass. Both the surface soil and the subsoil are acid in reaction. This soil has developed from till deposited by the Patricia ice sheet. Drainage ranges from good to excessive, and crops wilt readily during a dry period. The original native vegetation was dominated by white pine and red pine; the second growth is chiefly aspen and birch, with some oak and cherry, and, in places, young white pine and red pine.

A very small proportion of the land is farmed, and the farms are in the less rugged sections. Corn yields from 4 to 5 tons of silage an acre, oats yield about 30 bushels, potatoes about 150 bushels, and rutabagas from 8 to 10 tons. Little fall plowing is practiced, because sheet and gully erosion are serious and much surface soil may blow away.

Included on the map with typical Cloquet fine sandy loam are scattered areas in the northeastern part of the county, especially in the vicinity of Nickerson, in which the relief ranges from rolling to choppy and steep slopes are numerous. In a few places the elevations differ 100 feet within 100 yards, but local differences of 50 feet are common. The profile characteristics of the included soil are practically the same as those of the typical soil, except that cementation of the material in the lower part of the subsoil is absent. Large stones and boulders are numerous on the surface and throughout the surface soil and the subsoil. Drainage ranges from good to excessive. The native vegetation was principally red pine and white pine, but the second growth consists of some pine with much aspen, paper birch, and some oak and cherry. There are very few farms on this included soil, as yields are low and crop failures are frequent in periods of dry weather.

Milaca fine sandy loam.—In uncultivated areas the surface soil of Milaca fine sandy loam, to a depth of about 3 inches, is gray or grayish-yellow sandy loam. It is underlain, to a depth of about 10 inches, by mottled gray and grayish-yellow sandy loam spotted in many places with rust brown. Between depths of about 10 and 24 inches the material is brownish-red sandy clay loam. The substratum is loose gravelly brownish-red till.

Variations from this description are numerous, as this soil is essentially a complex of soils in the section occupied mainly by Milaca soils where the till and the soil developed from it are loose, incoherent, and variable in texture. The surface soil in places is loamy sand, and the

subsoil in many places is very loose and in others slightly cemented. The main difference between this soil and Emmert gravelly loamy sand is that the Emmert soil contains little or no fine material and is everywhere incoherent and uncemented. Near the place where the Snake River leaves Cross Lake, an area in which bedrock lies within 3 feet of the surface is included with this soil in mapping. In another inclusion, along the eastern side of Pokegama Township just north of the Snake River, the deep substratum is stratified and contains lenses of sand, clay, and gravel, but the soil and the upper part of the substratum are developed from till.

Milaca fine sandy loam is associated with Milaca very fine sandy loam mainly in the western part of the county. The relief ranges from choppy to gently rolling, and stones and boulders are numerous in both the surface soil and the subsoil. This soil has developed from till deposited as terminal moraines by the Patricia ice sheet. Drainage is good to excessive. The land is seldom cultivated but most commonly is used as pasture, as crops suffer from lack of moisture during periods of low rainfall.

Hibbing fine sandy loam.—The 8-inch surface layer of Hibbing fine sandy loam is brownish-yellow fine sandy loam. It is underlain by a subsurface layer of yellowish-brown fine sandy loam, which continues to a depth of 24 inches, and beneath this the material consists of brick-red clayey noncalcareous till.

This soil is developed in places where a thin layer of sandy material overlies heavy red till similar to that beneath Hibbing very fine sandy loam. In places the overlying material is stony and resembles the material in the upper horizons of the Cloquet soils; in other places it is loamy fine sand similar to that in the upper part of the Omega soils. The depth to the heavy till ranges from a few inches to 6 feet. The reaction is acid throughout.

This soil occurs principally in the north-central part of the county, in association with the Cloquet and Omega soils. It is most extensive in Norman Township.

In places where the upper horizons are similar to the corresponding layers of the Cloquet soils, the relief ranges from choppy to rolling, and many stones are on the surface and in the upper part of the soil; but in places where they are similar to those of the Omega soils, the relief is undulating or nearly flat, and the surface and upper part of the soil are stone free. Drainage is good, and water never stands on this soil.

The native vegetation was largely white pine and red pine, and the second growth is aspen, birch, and cherry.

A few farms are on areas of this soil where the heavy substratum is near the surface and the relief is undulating. Yields are variable, depending on the character of the soil, but, as a whole, this soil is more productive than either the Cloquet or Omega soils.

Pomroy loamy fine sand.—The surface soil of Pomroy loamy fine sand, to a depth of about 3 inches, is dark-gray loamy fine sand. Beneath this and continuing to a depth of about 15 inches is brown loamy fine sand. This is underlain by yellowish-brown loamy fine sand that extends to a depth of about 30 inches. The substratum is reddish-brown fine sand or sand with a complex lithological composition. At a depth ranging from 3 to 10 or more feet the material

consists of clay or silty clay. The material in all horizons is slightly acid in reaction.

This soil is associated with Pomroy fine sandy loam in the northwestern part of the county. It is most extensive in Bremen and Pine Lake Townships, and a few areas are in Mission Creek Township.

The relief is gently rolling. This soil is developed from sand, probably deposited as a bar or a beach in a glacial lake when the Patricia ice sheet melted. It is stone free in most places. Surface and internal drainage are excellent. In most places this soil is surrounded by peat or a moist soil, and crops seldom suffer from lack of moisture. The native vegetation was mostly white pine and red pine.

Probably because most areas of this soil are surrounded by poorly drained soils, a large part of the land is cleared and cultivated. Alfalfa can be grown successfully and yields about 2 tons an acre. Yields of corn, oats, and hay differ with the season and are determined largely by the depth to the water table.

Onamia loamy fine sand.—The 4-inch surface soil of Onamia loamy fine sand is dark-brown loamy fine sand. It is underlain by brown or reddish-brown loamy fine sand, which continues to a depth of 18 or 20 inches. The substratum is grayish-brown, yellow, or reddish-yellow fine sand and medium sand. In a cultivated field the surface soil is grayish brown or yellowish brown. The brown subsoil in many places is 2 feet thick. In Chengwatana Township, associated with Pomroy fine sandy loam, is an area where both surface soil and subsoil are grayish yellow. This included soil retains moisture better than typical Onamia loamy fine sand but contains no clay within 6 feet of the surface.

Onamia loamy fine sand is widely distributed over the southern and western parts of the county and is fairly extensive along the Snake River. The land is undulating or nearly flat, but south of Pokegama Lake a few areas have a choppy relief. The soil has developed from sandy outwash and is stone free or nearly so. Drainage is excessive, and crops die during prolonged dry periods.

Onamia loamy fine sand in general is not farmed, but a few areas in the vicinity of Pine City are used for growing garden crops. Good yields are obtained when the moisture supply is sufficient and manure and commercial fertilizer are used.

Onamia loamy fine sand, gravel-subsoil phase.—Associated with typical Onamia loamy fine sand are a few small bodies in which the substratum is gravelly. These have been correlated as Onamia loamy fine sand, gravel-subsoil phase. Most of this soil occurs in Chengwatana Township.

The 4-inch surface soil is dark-brown or dark grayish-brown loamy fine sand, and the subsoil, which extends to a depth ranging from about 15 to 20 inches, is brown loamy fine sand or fine sandy loam. The substratum is reddish-brown sand and gravel. In other respects this soil is similar to typical Onamia loamy fine sand. Areas in which the subsoil is fine sandy loam produce fair yields of corn, small grains, and potatoes in favorable years.

Omega loamy fine sand.—The 4-inch surface soil of Omega loamy fine sand is brown incoherent loamy fine sand; the subsoil, which continues to a depth of about 25 inches, is brown or yellowish-brown

incoherent loamy fine sand; and the substratum is reddish-brown incoherent fine sand. The sand in most places is nearly pure quartz, but in a few places the mineral composition is complex and the subsoil approaches a fine sandy loam.

Omega loamy fine sand is most extensive in the northwestern part of the county along the Kettle and Willow Rivers and in the southeastern part along the St. Croix River. The total area is 47,744 acres, or 5.3 percent of the land area of the county. The reaction of the material in all horizons is acid. The surface is nearly flat or gently undulating. This soil has developed from sandy outwash and is free of stones and gravel. Drainage is excessive, and crops soon wilt in dry weather.

The native vegetation was jack pine, and the second growth is similar. This soil is not extensively farmed, except in the vicinity of the village of Willow River.

Omega gravelly loamy fine sand.—The surface soil of Omega gravelly loamy fine sand consists of a 4-inch layer of brown loamy fine sand containing some gravel; the subsoil, which continues to a depth ranging from 25 to 30 inches, is brown loamy fine sand or fine sandy loam containing some gravel; and the substratum is reddish-brown mixed sand and gravel. This soil differs from Omega loamy fine sand in that some gravel and a few rounded stones or boulders, about 10 inches in diameter, are on the surface and throughout the soil. The mineral composition also is more complex than it is in Omega loamy fine sand, and this feature is responsible for the heavier subsoil. The reaction is acid throughout.

This soil is associated with Omega loamy fine sand. It is developed most extensively in Kerrick Township. Most of the areas are undulating. The soil has developed from loose outwash and has excellent drainage. The native vegetation was jack pine, but much aspen, birch, and cherry are mixed in the second growth. This soil is seldom farmed, as it occurs in inaccessible positions, but it is probably more productive than Omega loamy fine sand.

Omega gravelly loamy fine sand, rolling phase.—In places where Omega gravelly loamy fine sand has a rolling to choppy relief, the soil is correlated as a rolling phase. It is associated with the other Omega soils, mainly in Nickerson and Ogema Townships. Many stones and boulders are on the surface and throughout the soil mass, but in other characteristics this soil is similar to Omega gravelly loamy fine sand. Included with this soil as mapped are several areas in the vicinity of Sturgeon Lake, where no gravel or boulders are present, and the soil resembles Omega loamy fine sand.

This soil is not extensive, and very little of it is cleared and cultivated.

Emmert gravelly loamy sand.—The 3- or 4-inch surface soil of Emmert gravelly loamy sand is dark-brown loamy sand. Beneath this, to a depth of about 10 inches, the subsoil is brown loamy sand and gravel, and between depths of 10 and about 30 inches it is reddish-brown sand and gravel. The substratum is grayish-brown sand and gravel. Large stones and boulders are numerous on the surface and throughout the soil; in places they constitute 50 percent of the soil mass.

This soil is well distributed over the county in association with the red soils, but the largest bodies are in Wilma and Ogema Townships. The relief ranges from rolling to hilly and includes many steep slopes.

The material from which this soil developed was deposited as kames or eskers by glacial streams of the Patricia ice sheet. Drainage is excessive, and, where the land is cleared, erosion is active. This soil is not cultivated, but a few areas are used for pasture. The gravel substratum is an important source of gravel for road surfacing and in some places is used in making concrete.

As mapped, Emmert gravelly loamy sand includes one small area of Kroschel loamy sand, containing less than 10 acres, in the southwestern part of Royalton Township, and another in the southwestern part of Pokegama Township, where the soil material was deposited as an esker during the Keewatin glaciation. The total area of the Kroschel soil is too small to warrant separation on the map. The surface soil, which extends to a depth of about 6 inches, is grayish-brown loamy sand, and the subsoil, to a depth of about 24 inches, is gray or grayish-brown loamy sand that is slightly cemented when dry. The substratum in some places is poorly stratified calcareous sand and gravel and in other places sand, or layers of sand, gravel, and some clay. This substratum differs within short distances; on one side of a road it may be calcareous sand and gravel and on the other deep sand. The included Kroschel soil is used as pasture land.

St. Croix fine sandy loam.—The topmost 1-inch layer of St. Croix fine sandy loam is dark-gray or nearly black fine sandy loam. Beneath this and continuing to a depth of about 10 inches is brown loose fine sandy loam or sandy loam that in many places contains some gravel. Between depths of 10 and about 20 inches the material is brown fine sandy loam, and the substratum is grayish-brown loamy sand streaked with rust brown. The dark surface layer in many places is 3 inches thick, and the subsoil is silt loam in some areas. In some places mottling occurs in all horizons. This soil is underlain by indurated red till similar to that under the Milaca soils. The depth to the till ranges from 2 to more than 6 feet. Where the till occurs at a slight depth the substratum described above is absent and the subsoil rests directly on the compact till. The soil is acid throughout all layers.

This soil occupies terrace positions along the St. Croix River in the southeastern part of the county. The relief is undulating or gently rolling. The soil has developed from material deposited by the glacial St. Croix River, and rounded stones and boulders are on the surface, throughout the soil, and in the substratum. Drainage ranges from good to imperfect, and crops suffer during dry weather.

Where the stones are comparatively few and the surface is nearly flat, some of the land is farmed, but less than 10 percent of the total area is cleared. Fair yields are obtained in seasons when rainfall is normal and well distributed.

St. Croix fine sandy loam, stony phase.—Many areas of St. Croix fine sandy loam that are so very stony as to make clearing for cultivation impossible are classified as a stony phase. This soil has more rolling relief than typical St. Croix fine sandy loam. None of the land is cultivated, but a few areas are used for pasture.

St. Croix very fine sandy loam.—The 4-inch surface soil of St. Croix very fine sandy loam is dark-brown very fine sandy loam. Beneath this and continuing to a depth of about 20 inches is the subsoil of brown or brownish-red very fine sandy loam, and the substratum is reddish-brown sand or gravel. The soil material is faintly acid in all horizons. In a few areas clay occurs at a depth of 3 feet.

Included with this soil as mapped is an area adjoining the escarpment in Pine City Township where the surface soil, which is 8 inches thick, is dark-gray fine sandy loam; between depths of 8 and 22 inches the subsoil is gray or grayish-brown loamy fine sand; and the substratum is assorted grayish-brown sandy clay loam that contains streaks of loamy sand and silty clay loam.

This soil is associated with St. Croix fine sandy loam. The relief is nearly flat or very gently undulating. This soil has developed from fine material deposited by the St. Croix River during glacial times and is practically stone free throughout. Drainage is good, and short dry periods do not reduce yields.

Most areas of this soil situated near a road are cultivated. Yields of corn are about 6 tons of silage an acre; of hay, about 1½ tons; and of oats, 40 bushels.

MISCELLANEOUS SOILS AND LAND TYPES

Discussed under this heading are several soils and classes of material that do not fall under the previously described groups or that occur in very small areas. Most of them are nonagricultural, although a few types are desirable agricultural soils but occupy very small total areas.

Berrien loamy fine sand.—The 6-inch surface soil of Berrien loamy fine sand is gray or grayish-brown loamy fine sand; and the subsoil, which extends to a depth of about 36 inches, is yellowish-brown loamy sand that in most places is mottled with gray and streaked with rust brown or coffee brown below a depth of about 24 inches. The substratum is reddish-brown or grayish-yellow gritty clayey till. The surface soil in some places is loamy fine sand and in other places is sandy loam. Included with this soil in mapping are several areas where the heavy substratum lies at a depth ranging from 8 to 10 feet, as in a body north of Greeley in Royalton Township.

Berrien loamy fine sand is not extensive. It is associated with the Bradford soils and is developed where a layer of sand or fine sand was deposited on the till. The material in the surface soil and subsoil is faintly acid. This soil occupies areas of undulating relief and is practically stone free.

It is farmed in the same manner as the associated Bradford soils but is slightly less productive, and care must be taken to prevent the surface soil from being blown off in the spring, when strong winds are common. The land is well drained and can be cultivated with moderate power over a wide range of moisture conditions. Corn can be matured in many seasons and yields 45 bushels an acre, or, when cut for silage, from 8 to 10 tons; mixed clover and timothy hay yields about 1½ tons; oats yield 40 bushels when moisture is adequate; and potatoes yield about 125 bushels. Alfalfa is not grown extensively,

but where the substratum is close to the surface, yields of 2 tons an acre are obtained.

Bluffton fine sandy loam.—The surface soil of Bluffton fine sandy loam is dark-gray or black fine sandy loam, 8 or 10 inches thick. It is underlain by gray loamy fine sand or fine sandy loam to a depth of about 24 inches, in many places mottled with rust brown. Between depths of about 24 and 36 inches the material is mottled gray and rust-brown loamy fine sand or fine sandy loam. The underlying material is mottled gray and rust-brown gritty clayey till. In some places the surface soil and subsoil are sandy loam or loamy sand, and the depth to the heavy substratum ranges from 2 to 4 feet.

This soil is inextensive. It is associated with Berrien loamy fine sand and the Bradford soils. The reaction is nearly neutral in all horizons. The soil has developed under imperfect drainage, where a thin layer of sand or fine sand was deposited on gray till. It is stone free and occupies flat or nearly level areas. Crops withstand short periods of drought without serious damage.

This soil is well adapted to the production of corn and small grains. Corn yields about 10 tons of silage an acre, and oats yield about 45 bushels.

Omega loamy sand.—A few small areas of Omega loamy sand are mapped in Dell Grove and Partridge Townships on what appears to be the beach of a former glacial lake. The relief is undulating. The surface soil is composed of yellowish-brown loose sand, and the subsoil and substratum consist of brownish-yellow loose sand. This soil is very inextensive, and it is not cultivated.

Adolph silty clay loam.—The surface soil of Adolph silty clay loam, to a depth of 8 or 10 inches, is dark-gray or black silty clay loam, and in many places a layer of peat or muck, a few inches thick, overlies the mineral soil. Beneath the surface layer of mineral soil the material is gray silty clay loam mottled with rust brown. Between depths of about 18 and 30 inches is mottled gray, rust-brown, and reddish-brown clay loam. The substratum is grayish-red till or gravel. The surface soil and subsoil horizons in some places are silt loam and in others are clay loam.

This soil is widely distributed in the central and northern parts of the county, associated with the red upland soils. It occupies 23,168 acres, or 2.6 percent of the land area of the county, and most of it occurs in small areas. The surface is nearly flat or depressed. Drainage is poor, run-off is slow, and water stands on areas of this soil for long periods after rains. It has developed on both the till and outwash plains, but much of the surface material probably has washed in from surrounding soils.

Adolph silty clay loam is cultivated only where it occurs as a small area in a field with better drained soils, and it often delays cultural practices. It is a desirable soil for pasture, as the grass cover continues to grow even during long periods of dry weather.

Adolph silt loam.—The 7-inch surface soil of Adolph silt loam is dark-gray silt loam; the subsoil, which extends to a depth ranging from 15 to 20 inches, is gray gravelly sandy loam mottled with rust brown; and the substratum is mottled brownish-red, rust-brown, and gray sand, gravel, and clay. The texture of the surface soil and sub-

soil in some places is sandy loam or fine sandy loam, and the substratum in a few places is clay or silty clay loam. Some areas have a layer of muck or peat, a few inches thick, on the surface.

This soil is not very extensive. It is mapped mainly in association with the St. Croix soils and occupies flat areas which are often submerged during wet weather. It is nearly stone free in places, but in some areas the stones are numerous on the surface and through the soil mass. The land is not cultivated, and little of it is used as pasture. Some swamp hay is cut from the wetter spots.

Adolph fine sandy loam.—The 12-inch surface soil of Adolph fine sandy loam is dark-gray or black fine sandy loam that in places is covered with a layer of peat a few inches thick. Beneath the surface layer of mineral soil and continuing to a depth of about 36 inches, the material is mottled gray, grayish-brown, and rust-brown fine sandy loam. The substratum is red sandy till or outwash. The surface soil and the subsoil in some places consist of loamy sand or sandy loam, and the subsoil in places is of a solid gray color. In some areas the sandy surface soil is thick, and the substratum lies below a depth ranging from 6 to 8 feet.

Areas of this soil are widely scattered over the county, but their total extent is small. They occupy small, flat or depressed positions. Drainage is poor, and water often stands on the surface for long periods. The land is seldom cultivated, but it supports good pastures, as it remains moist throughout periods of drought.

Peat.—Peat is formed, in wet situations, from the remains of plants that grew and died on the spot. Most of the bogs in Pine County were once lakes or ponds, and the accumulation is deep, ranging from 1 to more than 20 feet in thickness. No large areas occur in which the deposit is less than 2 feet thick. In general the surface layer, to a depth ranging from 1 to 2 feet, is very dark brown or black, and the underlying material is brown. In some places the entire mass is very dark, and in others it is brown. Partly decayed plant remains can be seen in most areas.

This is the most extensive land type in the county. It has a total area of 247,168 acres, or 27.3 percent of the land area of the county, and occurs in every township. Many of the areas are very large, some including more than 1,000 acres. The surface is level. In the northern part of the county the original vegetation in most places was spruce and tamarack, but in the southern part many bogs supported such hardwoods as ash, elm, and basswood. Some bogs in the northeastern part of the county supported a growth of sphagnum moss and heath shrubs.

About 3 percent of the area of peat is cleared and cultivated. The fields are distributed widely, but several large fields are in the southern part of the county. The most common crop grown is potatoes, of which the quality is good and the yield high if the land is properly fertilized and the crop escapes injury from frost. Corn and vegetables are grown on some areas, and reed canary grass is recommended for wet areas. Crops grown on peat land are subject to damage from frost, which may occur any month during the year, and, where drainage ditches are not adequate, heavy rains may cause flooding. Wild sedges, suitable for hay, seed naturally in cleared

areas, and almost 10 percent of the peat land is used in the production of wild hay. Yields as high as 4 tons an acre are reported, but the average is about 1 ton.

The first essential for the cultivation of peat land is drainage, which in most places is accomplished with open ditches. The peat material generally is high in nitrogen, but potash, phosphorus, and, in many places, lime must be added before good yields can be obtained.[15]

Included with peat as mapped are a few small areas of muck, an organic soil in which the plant material has decomposed to the extent that all evidence of plant-cell structure is eradicated and the mass is black. A few areas are in the northwestern part of the county, and others are north of Beroun. About 100 acres north of Beroun are cultivated. Here the depth of the organic material ranges from 18 to 24 inches, but the average depth throughout the county is about 4 feet. Good yields of corn, rye, and potatoes are obtained.

Alluvial soils, undifferentiated.—Alluvial soils, undifferentiated, include the sediments, regardless of texture, that have been deposited recently by streams during periods of overflow. The texture ranges from loamy sand to silty clay loam, and most areas are poorly drained.

This class of material occurs in almost every township and has a total area of 21,376 acres, or 2.4 percent of the land area of the county. A few small bodies along the larger streams are cultivated occasionally, and many areas are included in pastures.

Beach sand.—The margins of some of the lakes are separated as beach sand. For the most part they are bare of vegetation. In places where the surrounding soils are clayey, as near Pokegama, Cross, and Oak Lakes, and the northern part of Sturgeon Lake, the beach material is partly clay in places, and in other places it is stony. Much of the beach surrounding Grindstone Lake is stony.

LAND USES AND AGRICULTURAL METHODS

The economical production of forage is important in any community where dairying is practiced, and this is accomplished in Pine County with pasture, wild hay, tame hay, alfalfa, and silage. Roots for forage are not grown to a great extent. Pastures are generally maintained on uncleared or partly cleared land and receive little attention. Alsike and Dutch white clover grow naturally and are seeded broadcast on pasture land by some farmers, but few farmers maintain cultivated pastures. Cattle can graze from May until October, but, in seasons of low rainfall, additional coarse feed must be given. Wild hay receives no attention.

Other crops, with the exception of alfalfa, are grown in rotation. The most common crop rotation consists of corn, potatoes or rutabagas, oats or barley, and hay for two seasons. Most farmers recognize the crop adaptability of the different soils, and few try to cultivate the wet or the sandy areas.

Timothy and mixed timothy and clover are the most common hay crops other than alfalfa. They are seeded with oats or barley and

[15] More detailed information regarding the management of peat soils may be obtained from the Division of Soils, University of Minnesota, University Farm, St. Paul, Minn.

receive no fertilization. Reed canary grass is grown successfully but not extensively on peat land.

Alfalfa is popular and grows well on the heavier soils with limy subsoils in the northern and southern parts of the county. It is not extensively grown on the sandier soils, but fair yields can be obtained. Alfalfa fields are maintained for several years, but many are plowed after the fourth year. On some farms, when the stand of alfalfa becomes thin, the field is disked and reseeded without rotation. Some farmers scatter manure on alfalfa fields once during the life of the stand or when reseeding.

The production of potatoes, both for home use and for sale, is important in all parts of the county. Green Mountain, Rural New Yorker, and Russet Rural are the most popular varieties. They are planted between June 1 and June 15 on sod land to which manure is added. They are harvested in September, and yields of 150 bushels an acre are obtained. Much of the cultivated peat land is planted to potatoes. This soil is easily worked and when properly fertilized produces high yields of clean, high-quality potatoes if the crop escapes injury from frost. Some certified seed is grown and shipped to southern markets.

A considerable acreage is devoted to growing rutabagas. Magnum Bonum, Up-to-Date, and Acquisition are the most popular varieties, and yields of 25 tons an acre are reported. This crop usually is planted early in May and harvested in October. Considerable hand labor is required in cultivation and harvesting.

Dent corn is grown mainly for silage, as it cannot always be ripened in this climate. In the southern part of the county the maturing of corn for grain is more certain, but only flint corn is grown in the northern part. Commercial fertilizer is not commonly used.

Oats are the most extensively grown grain crop. Generally they are the second crop in the rotation and receive no fertilization. Planting is usually done about May 1 and harvesting during the last half of July. The crop is threshed directly from the field. Similar cultural methods are followed with barley, except that it is harvested earlier.

PRODUCTIVITY RATINGS

In table 8 the soils of Pine County are rated according to their capacity to produce the more important crops of eastern Minnesota, and they are listed in the approximate order of their general productivity under current farming practices.

The rating compares the productivity of each soil for each crop to a standard, namely, 100. This standard index represents the approximate average yield obtained without amendments on the more extensive and better soil types of the sections in which the crop is most widely grown. An index of 50 indicates that the soil is about half as productive for the specified crop as are those with the standard index. Soils given amendments, such as lime, commercial fertilizers, and irrigation, and unusually productive soils of comparatively small extent may have productivity indexes of more than 100 for some crops.

TABLE 8.—*Productivity ratings of soils in Pine County, Minn.*

Soil [1]	Crop productivity index [2] for—								General productivity grade [4]	Land classification [5]
	Corn silage	Oats	Barley	Timothy and clover hay	Alfalfa	Potatoes	Wild hay	Pasture [3]		
Bradford fine sandy loam	90	100	100	100	80	80	----	100	1	Excellent cropland.
Bradford very fine sandy loam	90	100	100	100	80	80	----	100		
Brickton silt loam	90	100	100	100	80	70	----	100		
Hibbing very fine sandy loam	80	90	90	90	70	70	----	100	2	Good cropland.
Knife Lake silt loam	80	90	90	90	60	50	----	100		
Bluffton silty clay loam	70	70	70	100	60	50	----	100	3	
Warman very fine sandy loam	70	70	70	100	----	70	----	100		
Onamia very fine sandy loam	70	80	80	80	----	80	----	80		
Milaca loam	70	80	80	80	60	70	----	90		
Brickton fine sandy loam	70	70	70	70	80	80	----	80		
Milaca very fine sandy loam	60	80	80	70	60	80	----	80		
Bluffton fine sandy loam	60	70	70	70	----	80	----	90		
Warman loamy fine sand	60	70	70	70	----	70	----	90		
Freer silt loam	70	60	60	80	----	60	----	90		
Askov fine sandy loam	60	70	70	70	50	80	----	80		
Knife Lake clay loam	50	70	70	80	----	60	----	90	4	Fair cropland.
Pomroy fine sandy loam	50	70	70	70	----	70	----	90		
Freer fine sandy loam	50	60	60	70	----	60	----	80		
Onamia fine sandy loam	50	60	60	60	----	80	----	70	5	
Berrien loamy fine sand	50	60	60	50	40	40	----	50		
St. Croix very fine sandy loam	50	60	60	50	----	70	----	50		
Peat, drained	[6] 100	----	----	------	----	[6] 100	50	[7] 100	6	Generally best suited for grass or timber production.
Adolph silty clay loam	50	50	50	80	----	------	80	100		
Adolph fine sandy loam	50	50	50	80	----	------	80	90		
Pomroy loamy fine sand	40	50	50	40	40	60	----	60	7	
Hibbing fine sandy loam	40	40	40	40	----	50	----	60		
Milaca fine sandy loam	30	30	30	30	----	50	----	60		
St. Croix fine sandy loam	30	30	20	30	----	60	----	50		
Cloquet fine sandy loam	20	40	30	30	----	60	----	60		
Onamia loamy fine sand	20	40	30	20	----	40	----	40		
Adolph silt loam	------	----	----	------	----	------	80	80		
Onamia loamy fine sand, gravel-subsoil phase	10	20	10	10	----	40	----	50	8	
Omega loamy fine sand	10	20	10	10	----	50	----	30		
Omega gravelly loamy fine sand	10	20	10	10	----	50	----	30		
Alluvial soils, undifferentiated	------	----	----	------	----	------	----	80		
Askov fine sandy loam, stony phase	------	----	----	------	----	------	----	50	9	
Askov five sandy loam, rolling phase	------	----	----	------	----	------	----	50		
St. Croix fine sandy loam, stony phase	------	----	----	------	----	------	----	50		
Onamia fine sandy loam, rolling phase	------	----	----	------	----	------	----	50		
Peat, undrained	------	----	----	------	----	------	50	10	10	
Emmert gravelly loamy sand	------	----	----	------	----	------	----	20		
Omega gravelly loamy fine sand, rolling phase	------	----	----	------	----	------	----	20		
Omega loamy sand	------	----	----	------	----	------	----	20		
Beach sand	------	----	----	------	----	------	----	------		

[1] Soils are listed in the approximate order of their general productivity under the average current practices, the most productive first.

[2] The soils are given indexes that indicate the approximate average production of each crop in percent of the standard of reference. The standard represents the approximate average yield obtained without the use of amendments on the more extensive and better soil types of the sections in which the crop is most widely grown. The indexes are largely estimates, as data on yields are yet too fragmental to be adequate. Those reported in the text are a result of interviews with farmers. Undoubtedly, the reported yields are slightly higher than the actual yields averaged over a period of years, because the farmer is influenced by the yields in favorable years and under better practices. This table is largely an estimation and evaluation of the reported yields.

[3] Because of insufficient data, the indexes for pasture are only comparative within the county and have not been related to the national standard used for pasture ratings.

[4] This classification indicates the comparative general productivity of the soils under dominant current practices. Refer to text for further explanation.

[5] This is a general classification to indicate the physical suitability of the soils for farm crops or grazing and forest uses. In the actual delineation of land classes on a map, other considerations, such as pattern of distribution of soil types, are important.

[6] These indexes refer to production with the use of commercial fertilizers in those favorable seasons that are free from damaging frosts. As a result they probably apply to less than one-half of the growing seasons.

[7] This index for pasture refers to the production obtained with adequate fertilization and drainage.

NOTE.—Leaders indicate that the crop is not commonly grown.

The following tabulation sets forth some of the acre yields that have been set up as standards of 100. They represent long-time average yields of crops of satisfactory quality on the better soils without the use of amendments.

Crop:		
Oats	bushels	50
Barley	do	40
Potatoes	do	200
Corn silage	tons	12
Clover and timothy hay	do	2
Alfalfa	do	4
Wild hay	do	1

Although extensive areas of land with imperfect and poor drainage exist in Pine County, artificial drainage is not commonly practiced on mineral soils, but, as peat areas cannot be cultivated unless artificially drained, indexes for cultivated crops have been given for peat only in the drained condition.

The productivity indexes in table 8 are based on reported yields obtained under the current practices of the better farmers. Except on peat, commercial fertilizers are not generally used. Stable manure is added to all the mineral soils.

The principal factors determining the productivity of land are generally stated to be climate, soil (this includes a long list of physical, chemical, and biological characteristics), slope, drainage, and management. Actually, no one of these factors operates distinctly from the others, although some one may dominate. The soil type itself is conceived by the modern soil scientist to represent "the combined expression of all those forces and factors that, working together, produce the medium in which the plant grows." Crop yields over a long period of years furnish the best available summation of these associated factors, and, therefore, are used where available. In this rating of the soils of Pine County, many of the indexes are based on inductive estimates rather than on actual reported yields. This is necessary because of lack of definite information.

The soils are listed in the order of their general productivity, under dominant current practices, and productivity grade numbers are assigned in the column "General productivity grade." The general productivity grade is based on a weighted average [16] of the indexes for the various crops, using the approximate areal extent and value of the various crops in the county as bases. If the weighted average

[16] Because of differences in the suitabilities and uses of soils in Pine County, the following weights in percentage were given each crop index for the four general conditions that were set up, in order to arrive at the general productivity grade:

Crop	Soils with calcareous substrata	Soils with noncalcareous substrata	Poorly drained soils	Soils having indexes only for pasture
Corn	25	25	20	
Oats	25	25		
Barley	5	5		
Timothy and clover	20	25	20	
Alfalfa	10	5		
Potatoes	10	10		
Wild hay			10	
Pasture	5	5	20	25

falls between 90 and 100, the soil type is assigned a grade of 1; if it falls between 80 and 90, a grade of 2 is given, and so on. Since it is difficult to measure mathematically either the exact significance of a crop in local agriculture or the importance and suitability of certain soils for particular crops, the weightings set up were used only as guides. Certain modifications dictated by personal judgment have been allowed in the general rating of the soils.

The column headed "Land classification" summarizes in a simple way the productivity and use capabilities of the various soils by placing them in a few groups on the basis of their relative suitability for crops, grass, and timber.

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

Economic considerations have played no part in determining the productivity indexes, so they cannot be interpreted into land values except in a very general way. Distance to market, relative prices of farm products, and other factors influence the value of land.

MORPHOLOGY AND GENESIS OF SOILS

Pine County lies within the region of Podzol soils[17] in northern United States. These soils have developed under forest in a cold humid climate. Solution and leaching are the dominant soil-forming processes, and the chemical reaction between percolating water and soil particles is less important. The typical, true Podzol profile developed under these conditions is: A_{00}, leafmold and comparatively fresh organic debris; A_0, organic matter in various stages of decomposition; A_1, comparatively thin dark-grey surface mineral layer containing considerable organic matter; A_2, light-gray or white material (bleicherde); B, brown to coffee-brown slightly coherent material (orterde) or indurated and cemented material (orstein); and C, the parent material.

The moderate permeability and siliceous composition of much of the parent material of the soils of this county have favored the development of the Podzol profile, and in such material this profile is readily apparent, except where it has been destroyed by cultivation or disturbed by lumbering operations and severe burning. In certain areas, heavy soil materials, poor drainage, or both have retarded the development of the regional soil profile.

Askov fine sandy loam illustrates true Podzol development as it occurs in this county. This soil is extensive. It is developed in the vicinity of Sandstone and Askov from glacial till that contains many fragments of sandstone, which probably were broken off locally, as indicated by the numerous outcrops in the vicinity and the slight depth to bedrock.

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[17] MARBUT, C. F. SOILS OF THE UNITED STATES. U. S. Dept. Agr., Atlas of American Agriculture, pt. 3 (Advance Sheets No. 8), 98 pp., illus. 1935.

Following is the description of a profile of Askov fine sandy loam, as observed in a brushy wood lot along United States Highway No. 61, one-half mile north of Sandstone. The area from which the sample was taken probably was burned over recently, as there is very little humus and many charred logs. It supports a thick growth of aspen and paper birch brush with an occasional large white pine. Ground pine and wintergreen (teaberry) are prominent in the ground cover.

1 (A_{00} and A_0). A 1-inch layer of dark-gray or nearly black fluffy organic matter. The duff was sampled in one layer, as it was thin and impossible to separate. The upper part of the layer consists of dry leaves of the current year's crop, and the lower part is black sticky humus. The pH value is 6.0.[18]

2 (A_2). 0 to 1 inch, gray loamy fine sand or loamy very fine sand (bleicherde). The sample was not clean, as numerous roots of mosses and wintergreen made sampling difficult. The pH value is 4.8.

3 (B). 1 to 11 inches, brownish-yellow fine sandy loam, with some very fine sandy loam (orterde). At the upper limit of this horizon is a ½-inch layer of coffee-brown material that was not sampled. The pH value is 4.8.

4. 11 to 18 inches, mottled gray, yellowish-brown, and rust-brown fine sandy loam, with a granular structure, in which the irregular angular granules are about ⅛ inch in diameter. The granules are very weak and crush readily. The gray fraction of the coloring is on the surface of the structure granules and gives a freshly broken surface a gray cast, but a scraped surface or the crushed mass is yellowish brown. The pH value is 5.2.

5. 18 to 23 inches, highly mottled gray, grayish-brown, and rust-brown cemented fine sandy loam containing an occasional spot of partly modified reddish-brown till. The structure is coarse granular and vesicular. The granules are about ¼ inch in diameter and weakly developed. The gray fraction of the mottling occurs on the surface of the structure granules and in streaks that may be old root channels. The pH value is 4.8.

6. 23 to 30 inches, slightly mottled or speckled reddish-brown, grayish-brown, and rust-brown clayey fine sand. This horizon contains many spots of partly modified reddish-brown till. The structure is coarse granular or nut, and the irregular angular granules are about ½ inch in diameter. They are crushed readily to a reddish-brown mass, and many are coated with gray. The pH value is 5.2.

7 (C). 32 to 40 inches, reddish-brown or brownish-red gritty till, with a weakly developed disklike structure. The granules crush readily to a reddish-brown mass. The material in this horizon is sandier than that in the horizon above. The pH value is 6.0.

Other soils showing this definite Podzol profile are the Omega, Pomroy, and Onamia loamy fine sands, and Cloquet and Hibbing fine sandy loams.

In places where the drainage is less thorough and the upper horizons may be saturated for short periods, the ash-gray A and brownish-yellow B horizons are not well developed. This condition is illustrated by Milaca very fine sandy loam, which has mottled A and B horizons. The following description of a profile of Milaca very fine sandy loam, observed in a wood lot 3 miles north of Beroun on the highway, is typical of the Milaca soils as mapped in this county, although the A horizon may have more silt than is typical. Also, the B horizon is not everywhere developed as in this profile. The original forest growth (judging from the remaining stumps) was pine,

[18] The pH values were determined in the field, colorimetrically.

but the present growth consists of aspen, paper birch, and some small oaks. A few boulders and many irregular rock fragments are scattered over the surface and through the soil mass.

A 1-inch layer of undecomposed leaves.

1 (A_0 and A_{00}). A 2-inch layer of humus, composed of dark-gray or black fluffy decomposed leaves and twigs, which contains many small roots. The pH value is 5.5.

2 (A_2). 0 to 4 inches, gray very fine sandy loam or silt loam, mottled with brownish yellow and streaked with rust brown along former root channels. The upper limits of the horizon are stained with organic matter. The soil material has a weakly laminated structure. The pH value is 5.0.

3 (A_3). 4 to 9 inches, mottled grayish-yellow and brownish-yellow very fine sandy loam or silt loam. The vesicular structure is well developed. Some of the small round holes are 1/16 of an inch in diameter, but the average size of the vesicles is about 1/32 of an inch. The pH value is 5.0.

4 (B_1). 9 to 12 inches, mottled gray and reddish-brown silty clay loam containing some rust-brown spots. The crushed mass is yellowish brown. The material has a granular structure. The granules are irregular, angular, and range in diameter from 1/16 to 1/4 inch, although most of them are about 1/8 inch. The gray fraction of the mottling occurs on the surface of the structure granules. The pH value is 4.8. (Note: This horizon is not everywhere present.)

5 (B_2). 12 to 24 inches, reddish-brown clayey fine sand mottled with brownish red, with a few gray and rust-brown streaks along old root channels. The structure is weakly granular, and the granules are about 1/8 inch in diameter. The pH value is 5.8.

6 (B_3). 24 to 32 inches, reddish-brown clayey fine sand or fine sandy loam, mottled with brownish red, with some root channels mottled with gray and rust brown. The structure is weakly coarse granular, and the granules range from 1/8 to 1/4 inch in diameter. The pH value is 6.4.

7 (C) 32 to 40 inches, brick-red or brownish-red sticky gritty till, which is compact or cemented and has a disklike structure. The plates are about 2 inches long on the horizontal axis by 1/4 inch on the vertical axis. The pH value is 6.8.

This stage of the cycle in podzolization is shown also in the Bradford, Brickton, Knife Lake, and St. Croix soils and in Hibbing very fine sandy loam, Pomroy fine sandy loam, Onamia very fine sandy loam, and Onamia fine sandy loam. The Bradford and Brickton soils show the development to less degree than the other soils, as the subsoils are heavy, but in places an incipient bleicherde and orterde are developed in each soil.

Under imperfect drainage, as illustrated by Freer silt loam, the normal B horizons are not developed. This soil represents the imperfectly but not poorly drained soil developed on red till. The following description of a profile of this soil represents the more nearly well drained areas. The more poorly drained areas mapped have a 4- to 6-inch dark-gray silt loam surface layer and a gray subsurface layer. The present forest growth is largely aspen, with some paper birch. Hazel and ferns comprise the undergrowth. A few boulders and many smaller stone fragments are on the surface and through the soil mass. Many areas of this soil are too stony to prepare for cultivation. The profile of Freer silt loam examined is in a wood lot on a very slight elevation 1½ miles southeast of Brookpark.

1 (A_0 and A_{00}). A 2-inch layer of dark-gray or black fluffy organic matter. The loose leaves on the surface were not sampled. The pH value is 6.5. (Note: A very thin layer of dark-gray or black plastic clay loam with a

crumb structure lies between this and the following horizon. It was not sampled.)

2 (A_1). 0 to 6 inches, grayish-brown silt loam having a laminated and vesicular structure. In the less well drained areas the material in this horizon is dark gray. The pH value is 6.2.

3 (A_2). 6 to 15 inches, mottled gray, grayish-brown, and grayish-yellow silt loam, in which the vesicular and laminated structure is well developed. The vesicles are small, generally about 1/32 of an inch or less in diameter, although some are larger, about 1/16 of an inch. The pH value is 4.8.

4 (B_1). 15 to 19 inches, highly mottled gray, rust-brown, and reddish-brown silty clay loam containing some grit. The structure is fine granular, and the irregular angular granules are about 1/8 inch in diameter. The gray fraction in the mottling is largely on the faces of the structure granules. The pH value is 4.5.

5 (B_2). 19 to 36 inches, mottled reddish-brown, rust-brown, and gray clay loam, with a nut structure. The fragments range from about 1/4 to 1/2 inch in diameter. A very thin coat of gray is on the faces of the fragments, and in places this gives an exposure a somewhat pink cast. The pH value is 4.8.

6 (C). 36 to 42 inches, brick-red or brownish-red gritty clayey till, with a disklike structure. The plates range from 2 to 3 inches on the horizontal axis and are about 1/4 inch thick. The pH value is 6.2.

Where drainage conditions are poor or where the soils were developed under submerged conditions, Half-Bog or Bog soils occur. The Half-Bog soils are represented by the Adolph and Bluffton soils, which have dark surface soils and gray subsoils, and the Bog soils by peat and muck.

SUMMARY

Pine County is in the east-central part of Minnesota. It has an area of 1,413 square miles, or 904,320 acres. Pine City, the county seat, is about 60 miles north of St. Paul and 80 miles southwest of Duluth. The county is sparsely settled except in the southern part, and large areas are better suited to forestry and recreational purposes than to agriculture. Railroad and highway transportation facilities are adequate for present needs in all sections.

The climate is favorable to the production of small grains, forage crops, root crops, and potatoes. Tornadoes, hailstorms, and cloudbursts are practically unknown. Dairying is the most common agricultural pursuit, and practically all crops are fed on the farm where produced. Some potatoes and rutabagas, however, are shipped out.

The soils have been classified on the basis of soil characteristics and land use. They are grouped into 17 soil series including 40 soil types and phases, in addition to 3 classes of miscellaneous soil material. Peat, Cloquet fine sandy loam, and Milaca very fine sandy loam are by far the most extensive soils and occupy 55.8 percent of the total land area of the county. Peat, which is partly decomposed plant remains and alone occupies 27.3 percent of the land area, is not cultivated extensively. Light-colored soils predominate in the rest of the county. In the central part, Askov, Milaca, Onamia, Omega, and several soils of small extent have developed gray or grayish-yellow surface soils and reddish-brown subsoils from sandy glacial drift. A few townships in the northern part and several in the southern part were covered with calcareous drift, and the most productive soils have developed from this material.

Hibbing very fine sandy loam, occurring in the northern part, has a brown surface soil and subsoil developed on brownish-red clayey calcareous till. In the southern part the Bradford and Brickton soils have developed gray surface soils and grayish-brown subsoils on gray or grayish-yellow calcareous drift.

The Freer and Adolph soils are mapped in imperfectly and poorly drained situations, associated with the sandy red soils; and Bluffton silty clay loam is associated with the Bradford and Brickton soils. These soils have gray or dark-gray surface soils and mottled gray, grayish-yellow, and rust-brown subsoils.

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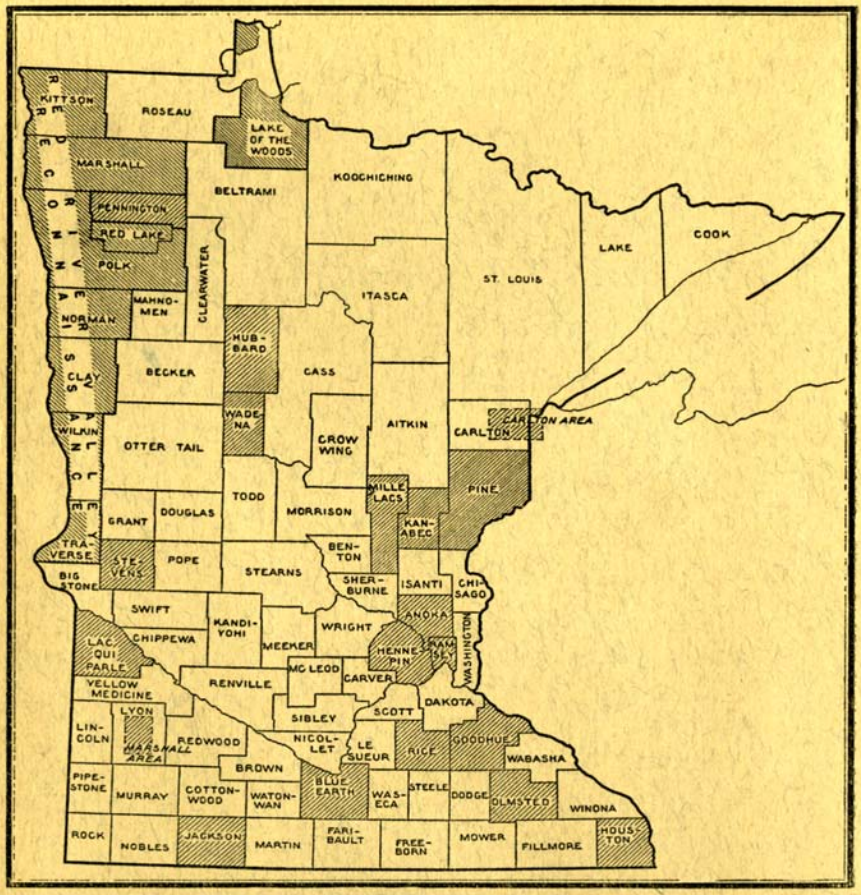

Areas surveyed in Minnesota shown by shading. Detailed surveys shown by northeast-southwest hatching; reconnaissance surveys shown by northwest-southeast hatching.

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