

The University of Minnesota

MINNESOTA GEOLOGICAL SURVEY

WILLIAM H. EMMONS, DIRECTOR

IN COÖPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

BULLETIN NO. 13

SURFACE FORMATIONS AND AGRICULTURAL CONDITIONS OF NORTHEASTERN MINNESOTA

BY

FRANK LEVERETT

AND

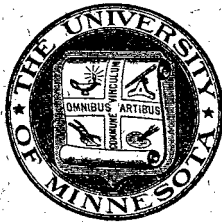
FREDERICK W. SARDESON

WITH A CHAPTER ON

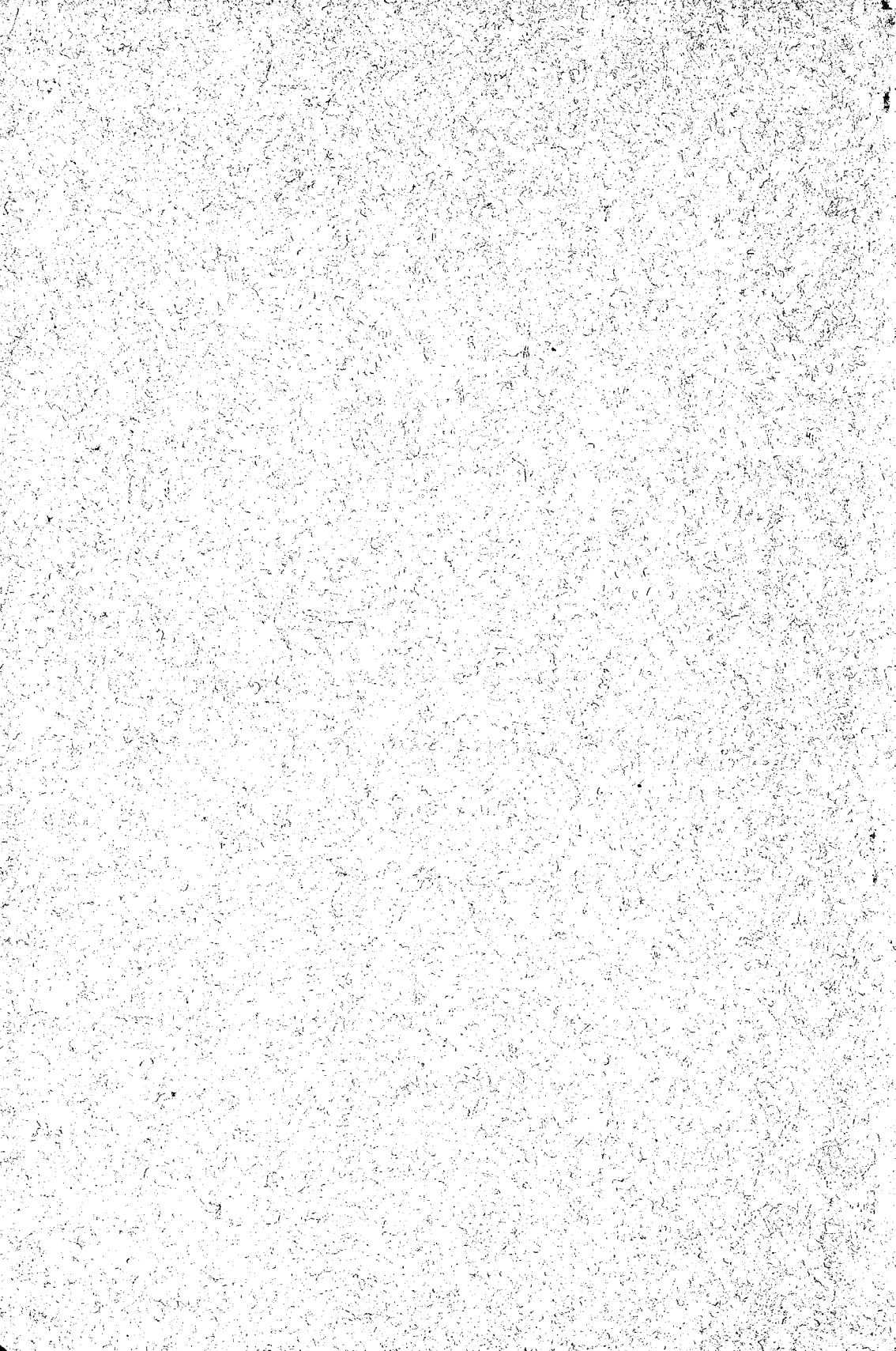
CLIMATIC CONDITIONS OF MINNESOTA

BY

U. G. PURSELL



MINNEAPOLIS
The University of Minnesota
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INTRODUCTION

BY W. H. EMMONS

Soil is the loose unconsolidated material which nearly everywhere covers the surface of the earth and in which plant life may be maintained. It is made up of finely divided rock in which decaying vegetable matter and animal matter are mingled. A soil is generally in a state of change. It is being washed little by little to the creeks and rivers which carry it to the sea, where it often forms delta deposits; if no new soil formed, hard rock would finally be exposed instead of the loose plant-producing soil. But rocks at and near the surface are continually changing and new soil is being formed from the underlying rock or from loose clayey or gravelly material that may constitute the subsoil, or from bowldery material that at many places in Minnesota lies between the hard rock and the soil.

Water and air attack rock matter and break it down. Heat and cold, freezing and thawing, shatter the rocks and give plants an opportunity to send roots into the cracks that are formed, and these, prying the rocks apart, reduce them to particles of still smaller size. Even the hard, solid rocks are ultimately broken down; a building of good solid stone may crumble in a few hundred years, particularly in a moist climate.

Some of the rocky matter is dissolved by the water and carried to the sea in solution. It is such dissolved material that makes water "hard" and that gathers in the bottom of a vessel when water is boiled. But not all of the soluble substances are dissolved and carried away; some remain in the soil and the character of the soil depends largely upon these. Some soils are acid because they have not enough lime. Some are deficient in potash or phosphates, which are necessary if soil is to produce certain crops satisfactorily.

Because it forms the soil, the composition of the underlying material is of great importance. In Minnesota most of the soil is the weathered portion of glacial drift or of lake beds and other features connected with the deposition of the drift. Long ago nearly all of what is now the state of Minnesota was covered over with a great ice sheet hundreds of feet thick that slowly moved down from the Canadian highland carrying with it rocky material which it had gathered in the north. When the ice melted it left large quantities of rock and soil that had mingled with the ice and this material is the loose drift that lies between the hard rock and the surface. At many places where it is not yet disintegrated it appears as large groups of bowlders mixed with clay. Although the

ice sheet moved very slowly, perhaps not more than a few rods a year or even less, it was active for a long period and locally it scoured the country clean of soil and loose material which on melting it piled up somewhere else.

This statement of the origin of the loose material or drift is not speculation, but is substantiated by the most convincing facts. The deposits and all of the features of the country formerly covered with ice are like those that may now be observed in Greenland or Antarctica, where the slowly moving ice fields or glaciers still cover bodies of land of continental proportions. Glacial boulders, boulder clay, scratches on the rocks, morainal hills and kettles, all ordered with respect to definite features of the former ice sheet, may be seen at thousands of places in Minnesota.

In the northern parts of Cook, Lake, and St. Louis counties the ice sheet removed the soil and subsoil, laying bare the underlying hard rock. Before the ice melted in this region it had carried the loose material away. Since that time there has been some weathering of the rock, but at most places not enough to give a good workable soil. Many of these areas are in the Superior National Forest and are well suited for growing forests although they have little or no value for farming. In the southern parts of these counties near the lake there are areas with loose sandy soil well suited to growing garden truck.

The last great ice sheet that covered the area melted very slowly and the southern part was melted long before the northern part. The ice that still remained in the north formed a great dam which held back the drainage of the Red River basin and formed a large lake which is called the glacial Lake Agassiz. This extended from the Red River Valley and plains of Manitoba as far east as the western part of the area herein described, covering nearly all of Koochiching County and the northwestern part of St. Louis County. When the ice retreated and this lake was drained, there were left the old beach ridges which now supply building sites and road material. Extensive beds of lake sediments were left also, and when these are suitably drained they make good soil. Other lakes smaller than Lake Agassiz, but yet extensive, were formed also. When they were drained, their beds likewise became available for plant growth and where properly drained they generally make good soil, especially where the soil contains sufficient clay.

Swamps are very numerous in the northeast quarter of the state. They are portions of the old lake beds and other poorly drained areas and are of little value for agriculture until drained. Since the ice melted a growth of vegetation has been established on them and great thicknesses of partially decayed vegetation have accumulated in them. This forms

the peat which is found in so many of the swamps. Some of it is very thick and will doubtless become a valuable asset in the future when other fuels shall have become more costly.

The great productivity of Minnesota soils is due, not only to their recent origin by reason of which nearly all of them still contain the soluble mineral foods for plants, but also to a favorable climate. The low temperatures which frequently prevail during certain periods in winter make for healthful conditions for animal life and they also benefit plant life. The rainfall, though not excessively great, is sufficient and, since most of it occurs during the growing period, drouths are rare and crop failures almost unknown except in the more sandy soils, which are, however, adapted to quick-growing crops like potatoes. As shown herein, the length of the crop-growing season, that is, the time between late spring frosts and early autumn frosts, is between 100 and 170 days for all except the extreme northeast corner of the state. The long days, high proportion of sunshine, and the moderate humidity are all favorable to plant growth.

This bulletin is a preliminary paper which treats the soils of only the northeast quarter of Minnesota. It will be followed by a report on the entire state, the field work for which already has been completed. The work has been done in accordance with the agreement for coöperation between the United States Geological Survey and the Minnesota Geological Survey, entered into, March, 1912. By this agreement the services of Mr. Frank Leverett were secured for surveying the surface formations and soils. Mr. Leverett has been engaged since 1886, or thirty years, in studying the surface geology of the Great Lakes region and because of his large experience in the greater area he was particularly well prepared to undertake the studies in Minnesota. He has spent, moreover, considerable time in the state studying its physiography in connection with the preparation of a monograph for the United States Geological Survey. Since the reorganization of the State Survey, the salary of Mr. Leverett has been met by the United States Geological Survey, while the greater part of his expenses have been paid by the State Survey. The State Survey has provided also for this work the services and expenses of Professor F. W. Sardeson, who has assisted in this work for the past five seasons. For a short period, also, the State has supplied the services of Dr. Arthur H. Elftman. We wish to acknowledge the generous assistance of the Division of Soils of the Department of Agriculture of the University of Minnesota and of the United States Bureau of Soils. The valuable contributions to the knowledge of the surface formations of Minnesota by the Minnesota Geological and Natural History Survey, under the direction of Professor N. H. Winchell, particu-

larly those of Mr. Warren Upham of that Survey, have aided greatly in the preparation of this report. The section on climatic conditions in Minnesota has been generously contributed without any cost to the Survey by Mr. U. G. Purssell, Director of the Minnesota Section of the United States Weather Bureau. In the preparation of the maps and other data showing dates of killing frosts, lengths of growing season, rainfall, etc., Professor C. J. Posey has rendered efficient service.

The cost of preparation of this report has been met by the Minnesota Geological Survey and the United States Geological Survey. This bulletin is printed by the Minnesota Geological Survey. Arrangements have been made so that land and colonization companies can secure these reports at actual cost of printing, and it is expected that this arrangement will secure a wide distribution. The maps are not intended to be used as a basis for the purchase of land; they do not give an accurate description of each forty-acre tract or each section, but they show the general classification of the land, its climate, and its surroundings.

SURFACE FORMATIONS AND AGRICULTURAL CONDITIONS IN NORTHEASTERN MINNESOTA

BY FRANK LEVERETT AND FREDERICK W. SARDESON

FIELD WORK AND ACKNOWLEDGEMENTS

The field embraced in this report on northeastern Minnesota includes the whole of Cook, Lake, and St. Louis counties, and parts of Koochiching, Itasca, Cass, Crow Wing, Aitkin, and Carlton counties. Its southern limit is the median line of the state, which is near latitude $46^{\circ} 25'$, and its western line is the 94th meridian. It embraces about 17,280 square miles, a little more than 20 per cent of the state.

Following the plan in *Bulletin No. 12*, on Northwestern Minnesota, a brief general description of the surface features and deposits of the entire state is given, and the climate of the entire state also is discussed.

In addition to the field work by the authors, assistance was rendered by Earl R. Preston for two months in studies in Cook, Lake, and St. Louis counties. In the study of these counties assistance was also rendered by Dr. Arthur H. Elftman for a brief period. Dr. Elftman had, some years previously, explored a considerable part of Lake and Cook counties as a member of the Geological Survey under Professor N. H. Winchell, and was thus able to supply valuable data in reference to parts of the county which now are not easily accessible, because of the lack of roads or trails, and which were then studied by working out from camps and by canoe trips through the lakes and connecting streams. In the preparation of this report much aid has been derived from the publications of the Geological and Natural History Survey of Minnesota, prepared under the direction of Professor N. H. Winchell. Much use has been made also of the volume by George A. Ralph, State Drainage Engineer, entitled *Topographical and Drainage Survey of Minnesota for 1906*. Its maps have been especially valuable as a basis for estimating the swamp land areas, and its lines of levels for drawing the contours which appear on Plate I of the present report. Aid has been rendered also by numerous residents of the region in supplying information and in guidance through parts difficult of access, a kind of assistance which is especially valuable in a region so sparsely inhabited and imperfectly opened to travel.

CHAPTER I

PHYSICAL FEATURES OF MINNESOTA

TOPOGRAPHY OF MINNESOTA

GENERAL STATEMENT

The position of Minnesota is near the center of the North American Continent, and the state embraces an area of 84,682 square miles, of which about 93 per cent is land and 7 per cent water. Its extreme length is nearly 400 miles, from latitude $43^{\circ} 30'$, at the Iowa line, to a point about 23 miles north of the 49th parallel, in the projection known as the Northwest Angle, northwest of Lake of the Woods. The greatest width is 367 miles, but the average width is only about 225 miles, or but little more than half of the length.

Minnesota presents more variety in surface features than most of the north central states, yet a great part of its surface is level or only gently undulating. The flattest portion falls largely in the northwest quarter, and was once the bed of the glacial Lake Agassiz, a lake held in on the north, in central Canada, by the great ice sheet. The roughest portion is in the northeastern quarter within the area embraced in this report. This part is composed largely of volcanic formations and iron-bearing rocks which, though glaciated, were not everywhere buried beneath the glacial deposits. In the southeastern part of the state deep erosion valleys along the Mississippi and its tributaries present bold rock bluffs 300 to 600 feet high. The interior and southern parts of the state have features due almost entirely to the work of the great ice sheets, which at successive times, and from different directions, overspread Minnesota. The glacial deposits comprise an intricate system of moraines with undulating to hilly surface, associated with which are level outwash plains of sand and gravel, and gently undulating intermorainic till plains. The moraines were formed along the border of the ice at definite lines where the edge of the ice held its position for a relatively long time. They consist of sharp knolls and inclosed basins and also of more or less parallel ridges which, however, interlock in places. These moraines are distributed in rudely concentric systems which mark successive positions of the border of each ice sheet as it was melting off from this region. The outwash plains lie on the outer border of the moraines, where sandy gravel was spread out by dirt-laden waters escaping from the ice. The till plains lie along the inner or iceward border of the moraines and represent areas over which the ice border melted back somewhat rapidly, forming relatively few knolls and ridges.

ALTITUDE

The altitude of Minnesota ranges from 602 feet, the level of Lake Superior, up to 2,230 feet, on high rock hills in the northeast part of the state, in western Cook County. The small map, Figure 1, shows that a large part of the state falls between 1,000 and 1,500 feet. The average altitude of the state is not far from 1,200 feet. The portions above 1,500 feet lie chiefly in two areas, one at the northeast and one at the southwest corner of the state, though there is a good sized area around the sources of the Mississippi River in the western part, and several smaller areas in that vicinity; one of these in the southern part of Otter Tail County is known as the Leaf Hills. The altitude of the elevated area in the southwestern part falls short a little of reaching 2,000 feet, but that in the northeastern part includes several small areas, chiefly in Cook County, that rise above 2,000 feet. The portions below 1,000 feet fall in two areas widely separated except for a connecting line along the Minnesota valley, one being on the western edge of the state and the other on the eastern. There is also a narrow strip bordering Lake Superior. The 100-foot contours which appear on the glacial and soil map of northeastern Minnesota (Plate I), show the altitude relations in the district embraced in the present report, while Figure 1 sets forth the conditions for the remainder of the state.

RELIEF

The most conspicuous relief is found in the "Sawtooth Range" and other prominent ridges that closely border Lake Superior and which rise abruptly from 500 to 900 feet above the lake. The rock ranges lying back from the shore, though more elevated than those fronting on the lake, seldom rise more than from 200 to 300 feet above the swamps and lakes among them. In fact several of the lakes of Cook County are above 1,900 feet or within 300 feet of the level of the highest points in the state. The most prominent part of the Mesabi Iron Range in St. Louis County rises from 400 to 450 feet above bordering plains. The Coteau des Prairies rises about 700 feet above the plain northeast of its border, but in Minnesota the rise is usually spread over a space of from 12 to 15 miles or more in width, so that the elevation can scarcely be appreciated by one crossing over it. There is a rather rapid rise of from 300 to 500 feet to the sharp range of hills in Otter Tail and Becker counties from the Red River valley. This rise is of especial interest since it seems to have some influence on the rainfall, the precipitation being greater in these hills where air currents are forced upward and cooled than in the bordering lower lands to the north, west, and south.

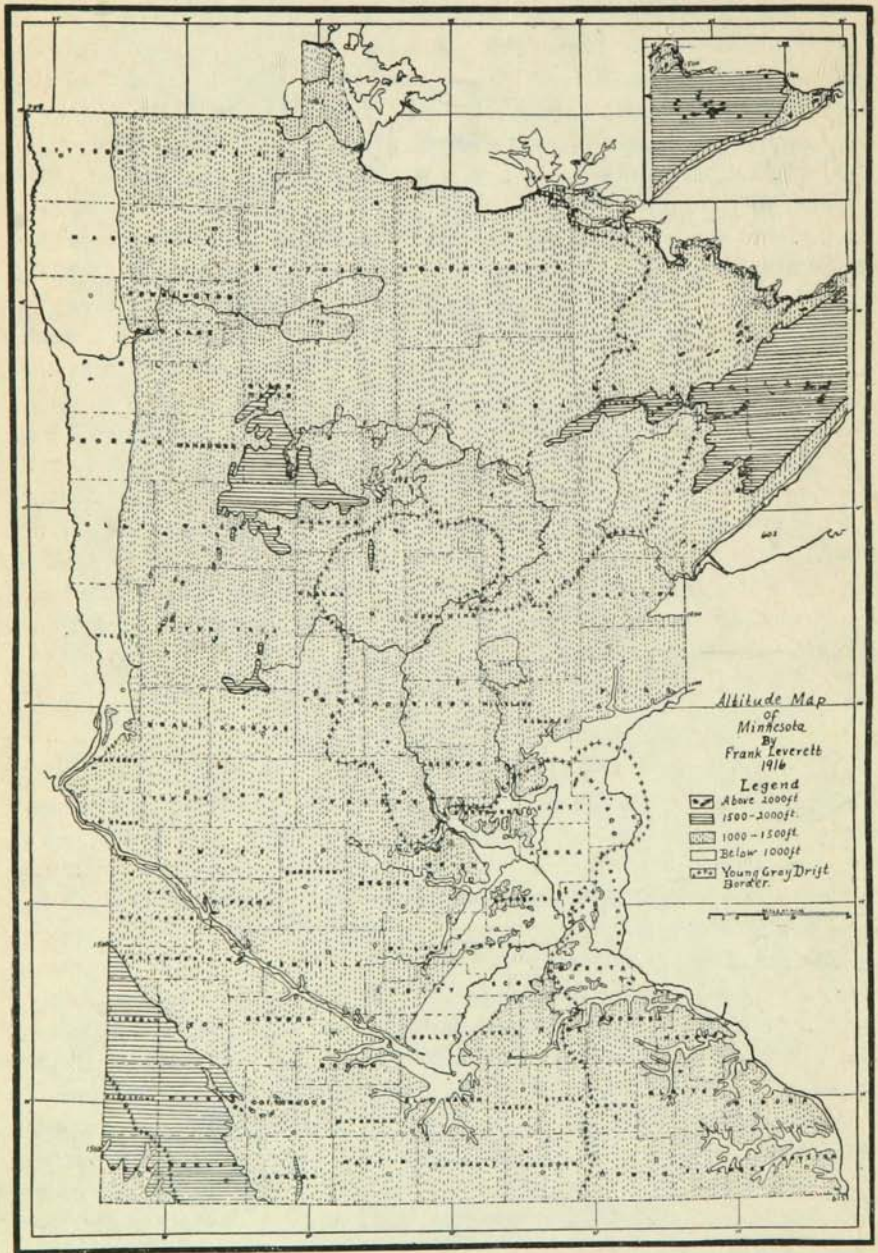


FIGURE I. ALTITUDE MAP OF MINNESOTA

EXPLANATORY NOTE, FIGURE 1

This map shows the great extent of land in Minnesota standing between 1,000 and 1,500 feet above sea level, as well as the distribution of the higher areas and of areas standing below 1,000 feet.

It shows also the effect of low areas in favoring the movement of the latest invasion of ice from the north, that which deposited the young gray Keewatin drift, as well as the effect of the high areas in checking the movement. The great axial movement of the ice was through the low-lying Red River basin, much of which is below 1,000 feet, and thence down the Minnesota valley to the great bend at Mankato over a plain much of which is below 1,100 feet. The thumb-like offshoot of the ice, in a lobe extending from Wright and Hennepin counties north-eastward across Anoka, Isanti, and Chisago counties, into the edge of Wisconsin, was apparently induced by an exceptionally low area, largely below 1,000 feet, over which it passed. In northern Minnesota the ice passed over the relatively low land, 1,200 to 1,300 feet, along and near the Mississippi River in Cass and Itasca counties, into the St. Louis River basin in St. Louis County, and down the Mississippi in Aitkin County; but it was so checked by higher land, 1,500 to 1,750 feet, in Clearwater, Becker, and Hubbard counties, that it could there reach only southeastern Hubbard and neighboring parts of Cass and Wadena counties. The Mesabi Range also held the ice border back nearly to the western edge of St. Louis County while it pushed eastward some distance in St. Louis County, both north and south of the range.

The topography also influenced ice movement in the northeast part of the state. There was a strong movement of ice southwestward through the Superior basin, with its northwest border only a few miles back from the shore on the high land, much of which stands 1,500 feet or more above the sea. This high land was largely covered by a southward ice movement from still higher land in the neighboring part of Canada. The relations of this ice movement to that in the Superior basin, as well as to that which covered western Minnesota is set forth in the discussion of the glacial deposits.

DRAINAGE

The drainage of Minnesota is widely divergent, part of it leading to the Gulf of Mexico, part to the Gulf of St. Lawrence, and part to Hudson Bay. The Gulf of Mexico receives about 57 per cent, the St. Lawrence less than 9 per cent, and Hudson Bay fully 34 per cent of the drainage. There was a time, however, after the glacial ice had melted from Minnesota but was still occupying the northeast part of the Superior basin and neighboring parts of Ontario and Manitoba, when all the drainage was southward to the Gulf of Mexico. The western Superior basin then overflowed into the St. Croix River, while the Red River drainage basin, largely covered by Lake Agassiz, drained southward through Lakes Traverse and Bigstone into the Minnesota valley.

The drainage to the south, or Gulf of Mexico, has generally a gentle descent, and waterfalls are rather rare, though the Mississippi has notable falls at Minneapolis and there are one or more falls or rapids on several of the tributaries. The drainage to Lake Superior is generally rapid and nearly every stream has several cascades. There is, however, a wide area of the upper St. Louis basin in which that stream and its tributaries have relatively gentle descent for many miles. The Hudson Bay drainage has a few rapids and waterfalls in the headwater part of Rainy River and its tributaries, but Red River and its main Minnesota affluent, Red Lake River, have no falls since no outcrops of solid rock occur along them. There is, however, very rapid descent for a few miles along Red Lake River and its tributary Clearwater River in Red Lake County. Red River is subject to great freshets because its lower course often remains frozen after the southern or headwater part has broken up. Thus ice jams are formed which divert the waters from the channel over the bordering plain.

Of the 17,280 square miles of the area embraced in the present report, 5,550 square miles drain to Lake Superior, 8,042 square miles to Rainy River of the Hudson Bay drainage system, and 3,688 square miles to the Mississippi River and tributaries. The streams of these several drainage systems are interwoven in the western part of the area, there being no prominent dividing ridges to separate them. In some cases a swamp may be drained either to the Hudson Bay or to the Gulf of Mexico system, while other swamps may be drained either to the Mississippi system or to Lake Superior. In the northeastern part of the area there is less interweaving of the drainage, though even there easy canoe portages are made between the Hudson Bay drainage and the drainage to Lake Superior.

LAKES

Throughout much of Minnesota, except the northwest, southwest, and southeast corners, small lakes are a common feature. They usually occupy basins among the moraine ridges and knolls and on the outwash plains, but occur to some extent also on the till plains and among rock knobs. The combined area of the lakes within the state is estimated to be about 5,650 square miles, or nearly 7 per cent of the entire area. The largest lake is Red Lake, a very shallow body of water with an area of 440 square miles. Other large lakes are Mille Lacs, also very shallow, Leech, Winnibigoshish, and Minnetonka. Minnetonka and the southern part of Leech Lake extend into a network of deep depressions among morainic ridges, but the other lakes are largely in plains that are slightly below the neighboring districts, partly morainic and partly plain.

SURFACE GEOLOGY

ROCK AREAS

The areas in which rock is so exposed as to render the land untillable are largely in the northeast quarter of the state, or along valleys in the southeast quarter. The northwest quarter is estimated to have less than 10 square miles of bare rock outcrop, and the southwest scarcely 100 square miles. It is doubtful if there is an area of 1,000 square miles in the entire state in which the plow would generally strike into rock ledges. The rock areas thus form a much smaller percentage of the state than the lake areas. The rock areas of the northeast part are chiefly rock bosses standing above the surrounding land, but the beds of the streams that lead directly down to Lake Superior are also usually on rock ledges. Among the rock knobs are some depressions covered only with moss and peaty material, glacial material being scanty, but ordinarily some glacial material is present and nearly all the land has soil enough over the bedrock to support a rich forest growth. Many of the knobs preserve the smooth surface left by the scouring effect of the ice sheet and are nearly destitute of vegetation. But certain others have become disintegrated to a depth of several inches or even to several feet from the surface and are supporting growths of vegetation of considerable density.

The rock areas of the southwest part of the state are largely of Sioux quartzite which in places comes to the surface over areas of several square miles. The rocks have scarcely enough soil over them to support the scanty vegetation. There are a few small areas of granite knobs along the Minnesota Valley from Bigstone Lake down to New Ulm. In the driftless area and part of the drift-covered area in southeastern Minnesota, rock ledges of limestone and sandstone outcrop along the steep

slopes of the valleys, often forming walls of considerable height. Rock is rarely exposed along the stream beds and valley bottoms. The uplands and the higher parts of the slopes of the valleys even in the driftless area usually have several feet of residuary clay and also a coating of loess or wind-deposited silt loam covering the rock formations and rendering the land tillable.

THE EARTHY MANTLE

GENERAL STATEMENT

The variety of earthy, sandy, and gravelly unconsolidated deposits which cover the rocky floor of Minnesota were formed or deposited by different agencies and at different times. They may be grouped as follows:

- First. Residuary material.
- Second. Wind deposits.
- Third. Glacial deposits.
- Fourth. Stream deposits.
- Fifth. Lake deposits.

RESIDUARY MATERIAL

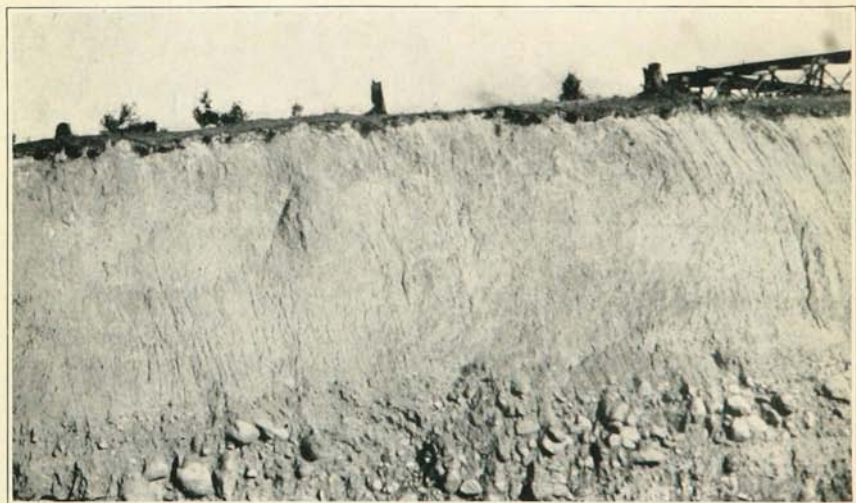
The residuary material, as its name implies, has been left as a residue during the breaking down or decay of the surface rocks through weathering and solution. On limestones it is usually a dark, reddish brown, gummy clay, but on sandstones and crystalline rocks it is usually granular and loose-textured. There is but a small part of Minnesota, chiefly in the southeastern counties, where residuary material is within reach of the plow. It occurs there on the upper part of the slopes of the valleys and on the narrow upland strips between valleys, but it is usually covered by loess.

WIND DEPOSITS

Loess.—The wind-deposited material known as loess is largely a fine silt loam, which forms the surface in an area in the southeast part of the state embracing much of Goodhue, Olmsted, Wabasha, Winona, Fillmore, and Houston counties and parts of Mower, Dodge, Rice, and Dakota counties. It covers a small tract in the southwest part of the state in Rock, southern Pipestone, and western Nobles counties. In the southeastern counties it rests in part on glacial drift deposits and in part on the residuary clay and rock formations of the driftless area. In the southwestern part it covers glacial deposits. In the southeast district its border is very irregular, there being long strips of loess-covered land projecting westward or northwestward into the region free from loess, and



A. SUPERIOR RED DRIFT OVER PATRICIAN RED DRIFT NEAR CLOQUET. THE MAN SITS ON A BOULDER AT THEIR JUNCTION



B. CLAYEY KEEWATIN DRIFT OVER STONY PATRICIAN DRIFT AT BIWABIK

also long strips free from loess extending eastward into the loess-covered tracts. The condition there is such as might result from the presence or absence of vegetation giving different degrees of protective power from the wind; areas with dense vegetation being able to hold dust that settled from the atmosphere while bare ones allowed it to be gathered up and carried on.

Wind-blown sand.—Wind-blown sand is also an important deposit. It embraces a district east of the Mississippi from Minneapolis up to Brainerd. It is narrow above St. Cloud, but below that city extends eastward to the St. Croix River. The sand does not, however, cover the entire surface in this area. Where present it rests upon glacial deposits. It has low ridges seldom 20 feet and usually 10 feet or less in height. There is more or less wind-drifted sand in the sandy parts of the St. Louis River drainage basin, but it is sparingly developed compared to that in the district between the Mississippi and St. Croix rivers. Wind-blown sand occurs also in Aitkin County in the vicinity of McGregor and also in the northeastern part of the county in island-like tracts that are surrounded by marshes. There are numerous small areas of such sand scattered over the state, some of them being along the shores of the glacial Lake Agassiz.

GLACIAL DEPOSITS

The glacial deposits as shown in Figure 2 extend over the entire state except eastern Winona County and the greater part of Houston County, which are in the driftless area of the upper Mississippi. They underlie the wind-deposited sands and much of the loess area. They also underlie stream deposits and lake sediments. The glacial deposits are separable into till or boulder clay in which stones, clay, and sand are closely commingled; and into sand or gravel beds which show some assorting and bedding by water action. The percentage of stony material varies greatly and the matrix also shows variations from compact clay to loose sand. These variations are to be expected in a deposit that had been formed from the dirt and stones included in an ice sheet. Every observing farmer has probably noted and perhaps speculated upon the cause for these variations in the drift deposits which form the basis for so large a part of the Minnesota soil. The assorted sand and gravel beds are largely due to waters escaping from the melting ice and many of them may be traced up to a moraine which marked the position of the ice border at the time they were laid down. They show a decrease in coarseness in passing away from the edge of the moraine, the coarse material having been dropped close to the edge of the ice and only the fine carried to a great distance outside.

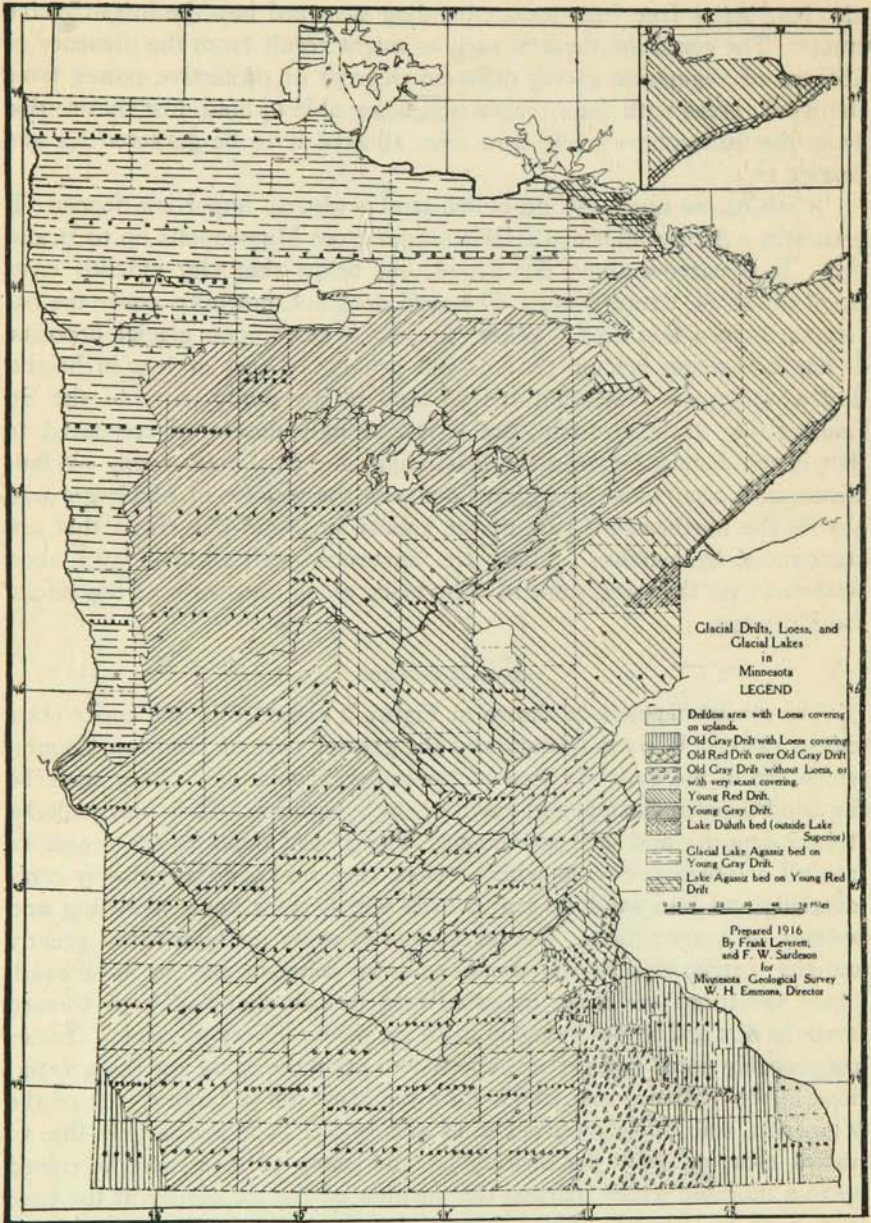


FIGURE 2. MAP OF GLACIAL DRIFTS, LOESS, AND GLACIAL LAKES IN MINNESOTA

The glacial deposits also show some variations that relate to the kind of rock formations over which the ice passed. Thus, the northeastern portion of the state has a rather stony drift from the volcanic and hard crystalline rocks of that region. This stony material was carried as far south as Dakota County and forms the red drift of eastern and northeastern Minnesota. As indicated below, the red drift is the product of more than one ice sheet. The western and southern parts of the state have a large amount of clayey drift material with limestone pebbles imbedded. This material was gathered by this ice as it passed across in its southward course from the shales and limestone of southern Manitoba, that greatly dominate there over the granite and other crystalline rocks. These clayey and limy deposits form what is known as the gray drift of Minnesota, and the ice sheet which formed it, as the Keewatin ice sheet.

STREAM DEPOSITS

The stream deposits, being restricted to the valleys, are of limited area, though in such valleys as the Minnesota and Mississippi they are locally several miles in width and form important agricultural belts. On the Minnesota and the part of the Mississippi below the confluence with the Minnesota the deposits made by the rivers are sand or silt. On the Mississippi above the mouth of the Minnesota the deposits range from sand to coarse cobble and boulders in correspondence with the swiftness of the stream. On nearly all the tributaries of the Mississippi and Minnesota the streams are able to carry coarse as well as fine material. Along the Red River a considerable amount of fine clay and clay loam has been deposited in seasons of flood on the plains outside the immediate river channel. The deposits made by glacial streams or those which had their sources at the edge of the ice and were receiving much of their water from the melting ice, now appear usually as terraces along the valleys above the limits of floods. From the fact that the glacial rivers were of greater volume these deposits are generally composed of sandy and gravelly material somewhat coarser than that carried by the present rivers.

LAKE DEPOSITS

The lake deposits consist of fine sediments washed into the deep parts of the lakes, and sandy and pebbly deposits washed up and formed into beaches along the shores. In parts of the lakes where the glacial deposits which they covered were pebbly and the water was shallow enough for wave action, there was a concentration of stony material by the washing-out of the finer material. By this process considerable areas of the bed of Lake Agassiz were covered by very pebbly beds several inches in depth. They are classed on the soil maps as "lake-washed till." In the

narrow strip along the shore of Lake Superior that was covered by the waters of a glacial lake known as Lake Duluth, there is very little fine sediment; gravelly and cobbly beaches were formed at several successive levels, while fine material was washed down into the deeper parts of the basin covered by the present lake. Fine material also covers the old lake plain in Carlton County and a strip on the south side of Lake Superior.

THE GLACIAL FEATURES AND THEIR HISTORY

It has been found through a study of the deposits in Minnesota and neighboring states that the glacial deposits which form so extensive a mantle in Minnesota are the result of more than one invasion of the ice from the Canadian highlands. At each invasion the ice left a deposit of drift gathered partly from Canada and partly from the deposits over which it passed in Minnesota. The advances were so widely separated in time that the drift deposits of one invasion had large valleys cut in them by the action of streams before the next invasion occurred. The later advances failed to reach the limits of the earlier deposits, so they are still exposed to view, and the degree of erosion of the surface of the older can be compared with that on the surface of the younger deposits. It is found that the older drifts have been so greatly eroded and are so ramified by drainage lines that no lakes or undrained basins remain on them, while the younger drift deposits have numerous lakes and undrained basins and also large, poorly drained areas which the streams have not yet reached. It is because they are not covered by the latest drift that Rock and Pipestone counties in southwestern Minnesota, and Goodhue, Dodge, Wabasha, Olmsted, Winona, Fillmore, and Mower counties in southeastern Minnesota have no lakes and basins such as characterize neighboring counties that were covered by that drift.

The invasions of the ice into Minnesota not only took place at different times, but have come from more than one direction at about the same time. In the earlier invasions the greater part of the state was covered by ice coming from Manitoba as shown by limestone fragments and pebbles derived from rock formations of that country which are imbedded in the lower part of the drift over all of the state except its northeast part. The movements in the closing stage of the glacial epoch were more largely from the northeast, but more than half of the state was invaded from the northwest. The ice sheets were as follows: 1. *The Superior lobe of the Labrador ice sheet*, an extension of ice southwestward from the Superior basin nearly to Mille Lacs Lake; 2. *The Patrician ice sheet*, with southward movement from the highlands north of Lake Superior across eastern Minnesota to points a little beyond St. Paul;



A. A GRAVEL OUTWASH IN LAKE COUNTY



B. GRAVEL IN BEACH OF LAKE AGASSIZ. PHOTOGRAPH BY D. W. JOHNSON

3. *The Keewatin ice sheet*, which moved southward through Manitoba and across western Minnesota. After the melting away of the ice that came from the northern highlands, the Keewatin ice sheet extended over some of the ground that ice had vacated. It crossed the Mesabi Range into the St. Louis basin, and also moved northeastward from near Minneapolis into Wisconsin. This advance over earlier drift deposits is known from the presence of a thin deposit of clayey and limy drift containing rock material brought from Manitoba which covers the drift that was deposited by ice coming from the highlands northwest of Lake Superior. The drift from these highlands together with that from the Lake Superior basin forms the stony red drift of eastern Minnesota, while that from Manitoba forms the clayey and limy gray drift which covers almost all of the remainder of the state.

That the ice mass moved in different directions at different times in certain parts of the state is further shown by striations or ice markings on the surfaces of the rock ledges. In the district east and south of the Lake of the Woods a set of glacial grooves or ice markings bears west of south, while a newer set crosses them in an eastward or southeastward direction. The older set was formed by ice moving into Minnesota from the highlands that lie between Lake Superior and Lake Winnipeg, while the younger set was formed by ice moving into the state from Manitoba. In North Minneapolis there are rock ledges on which the glacial grooves have three courses; first, a southeastward course at the time when the old gray drift which came from the northwest was brought in; second, a southward course at a time when the red drift which came from the north was deposited; third, an eastward course at the time when the ice from the northwest advanced over land that had been vacated by the ice which deposited the red drift.

GLACIAL LAKE FEATURES

Minnesota contains parts of the beds of two large glacial lakes: Lake Duluth, which occupied the western part of the Superior basin, and Lake Agassiz which occupied the Red River basin. Lake Duluth covered a narrow strip along the shore of Lake Superior and extended a few miles beyond the west end of Lake Superior into eastern Carlton County, Minnesota. Its highest stages were 500 to 700 feet above the present surface of Lake Superior, there being an increasing height toward the northeast corner of the state. Lake Agassiz extended as far south as Lake Traverse, and thence it discharged past Brown Valley to the Minnesota. Its border is only from 20 to 30 miles east from the North Dakota-Minnesota line from Lake Traverse northward to Polk County. About 20 miles east-southeast of Crookston it makes an abrupt eastward turn

and continues eastward past the south side of Red Lake and on across Koochiching County into St. Louis County as far as the valley of Little Fork River. It then turns northward and enters Canada from north-eastern St. Louis County. There were several islands in it in northern St. Louis County.

Preceding the development of the large glacial Lake Agassiz there was a temporary ponding of waters in front of the ice in Koochiching, Itasca, and St. Louis counties at a level higher than that of Lake Agassiz, and a discharge of the waters southward across the Mesabi Iron Range into the St. Louis basin along the course of the Embarrass River. With the melting back of the ice border this lake became merged with Lake Agassiz, and its waters then discharged into the Minnesota valley.

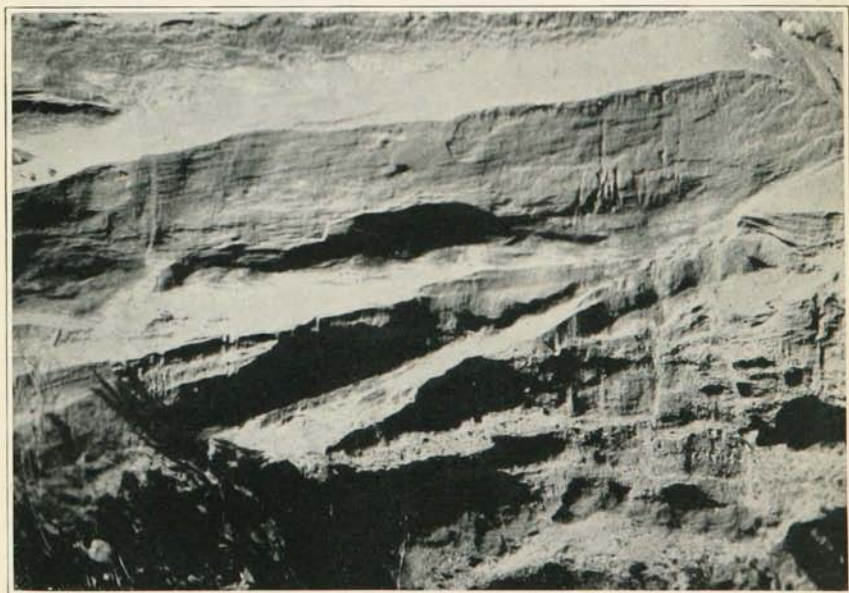
There were also two noteworthy temporary lakes in northeastern Minnesota which were not held up by ice barriers, but instead by land barriers along their outlets. When these were cut away the lakes became drained. One of these, named Lake Aitkin by Upham, occupied the plain bordering the Mississippi in Aitkin County and extended a short distance into eastern Crow Wing County. It was drained by the erosion of the Mississippi valley at its lower end just above Brainerd. The other lake, named Lake Upham by Winchell, occupied a considerable part of the St. Louis basin in western St. Louis County. It was drained by the erosion of the St. Louis valley below Floodwood.

Prominent features of the two great glacial lakes, Lake Agassiz and Lake Duluth, are the beaches or ridges of sand and gravel washed up along their shores. The shores of Lake Agassiz stand high and dry above the flat parts of the lake bed between or below them and form excellent lines for highways. For this reason much of the pioneer settlement and travel was along these ridges. They generally stand from 5 to 10 feet above the bordering plains and occasionally from 15 to 20 feet. On the inner or lakeward side they are generally more prominent than on the outer or landward side. This is due in part to the original slope toward the center of the lake, but there is also a tendency for a lake to eat back into the bordering land and throw its coarser material up on the edge of the plain outside; at the same time the fine material is carried in suspension from the shore into the deeper water.

The levels of these glacial lakes were lowered from time to time, partly by the cutting-down of the outlets and partly by an uplift of this region which caused the water to fall away where the land rose. There was also a change of outlet in Lake Agassiz from the southern end to the northern and in Lake Duluth from the southward outlet into the St. Croix River to an eastward outlet into the Lake Huron basin. As a result shore lines were formed at various levels on the slopes of the



A. ESKER BETWEEN LAKES IN EASTERN LAKE COUNTY. PHOTO BY A. H. ELFTMAN



B. INTERIOR STRUCTURE OF AN ESKER IN LAKE COUNTY. PHOTO BY A. H. ELFTMAN

old lake beds. Because of the gradual lowering of the water level the greater part of the beds of these glacial lakes has at some time been subjected to wave action. This has produced a widespread pebbly coating which is a concentrate from the washing of the surface of the boulder clay and the carrying-away of its finer material. Where the boulder clay was sandy, the sand as well as stones remain, but where it was clayey there is often a clear bed of pebbles a few inches in depth covering the clayey till subsoil. The deep part of Lake Agassiz along the borders of Red River received nearly all the fine sediment which was washed out from the till at higher levels. This forms the bulk of the rich black clay and clay loam of the Red River basin. At its eastern border, fifteen to twenty-five miles from Red River, there is a transition to sand. This is succeeded within two to five miles east by stony sandy deposits which seem to be a glacial material worked over by the lake.

GENERAL SOIL CONDITIONS

Soil is composed of materials derived from the subsoil and mixed with organic matter. Subsoil is the weathered and disintegrated top of the underlying geological formation. For its qualities and composition the soil of a given region therefore depends quite closely upon the nature of the geological formations there exposed. In Minnesota the land mantle of glacial and lake deposits affords a well-mixed and rich supply of materials suited for soil-making. This is particularly true where it consists of till or boulder clay in which all classes of material are loosely but thoroughly mixed. This contrasts with soils in which there is too much uniformity and which, when of water-washed sand or gravel, are often deficient in fine material. On the other hand, the loess and the lake silts, though of somewhat uniform texture, make rich soils because of the variety of finely divided minerals which they contain.

The soil and its productiveness depends largely upon the drainage conditions. A soil of clay or clay loam over gravel or loose sand suffers in time of deficient rainfall, while in wet seasons a soil resting upon heavy clay may be drowned out unless surface drainage is perfectly adjusted. For this reason the geologic formation underlying a soil is of great importance. Soil underlain by limestone, by loess, or by a till consisting of a light clay, or a heavy loam will stand great variation in rainfall and still be highly productive. In some parts of the state the surface drainage is naturally well developed, while in other parts it needs to be greatly supplemented by tile draining or surface ditching.

In the Driftless Area the drainage on the uplands is everywhere complete, for nearly every acre slopes toward some drainage line. In the old drift also there are few undrained areas and tiling or surface ditching

is seldom necessary. In the young drift there are many basins, and un-drained depressions and drainage lines are not well distributed over the surface. Except, therefore, where the material is loose enough for the rainfall to be absorbed completely the young drift areas need considerable ditching and tiling. In the bed of Lake Agassiz, although basins and depressions are rare, there are wide areas where the surface is very flat and extensive and systematic tiling or ditching is required to keep the land from being flooded.

VEGETATION

The condition of the soil depends to some degree upon the character of the vegetation which has covered it. In prairie districts there is a more uniform exposure to weathering agencies than in forested districts and consequently a more uniform soil is developed on a given deposit. On the whole, leaching of lime seems to be less rapid on prairies than in forests so that in the newer drift limestones are often present at the surface in prairies, but in the forested areas limestones are usually dissolved out to a depth of some inches and often to some feet from the surface. On the older drift the limestone is generally removed to a depth of several feet both in prairie and forest, but the leaching is perceptibly deeper in the forested areas. The rate of erosion and removal of soil is more uniform in prairie than in forested tracts. It takes more force to dislodge the trees than the grassy vegetation on hillside slopes, and erosion in the forests is likely to become concentrated in occasional gullies, whereas on prairies there are many small channels developed on every hillside which serve to break it down rapidly. On the whole, therefore, erosion is greater but leaching is less in prairie than in forested areas.

The forests occur only on protected slopes in much of southern Minnesota and are absent from such slopes in much of the western part of the state (Figure 3). In the central and northeastern parts they cover plains or uplands as well as valley slopes. The muskegs, which have a scanty forest growth, are developed chiefly in the northern half of the state and chiefly within the forested area.

WEATHERING

There are parts of the newer drift in which fresh material is close to the surface so that they can scarcely be said to have a subsoil different from the drift sheet as a whole. There are also places on valley slopes in the older drift where unweathered material is close to the surface, because erosion keeps pace with the weathering of the drift. At most places, however, the older drift has a mantle of weathered material several feet in thickness, while that of the younger drift is only one or two

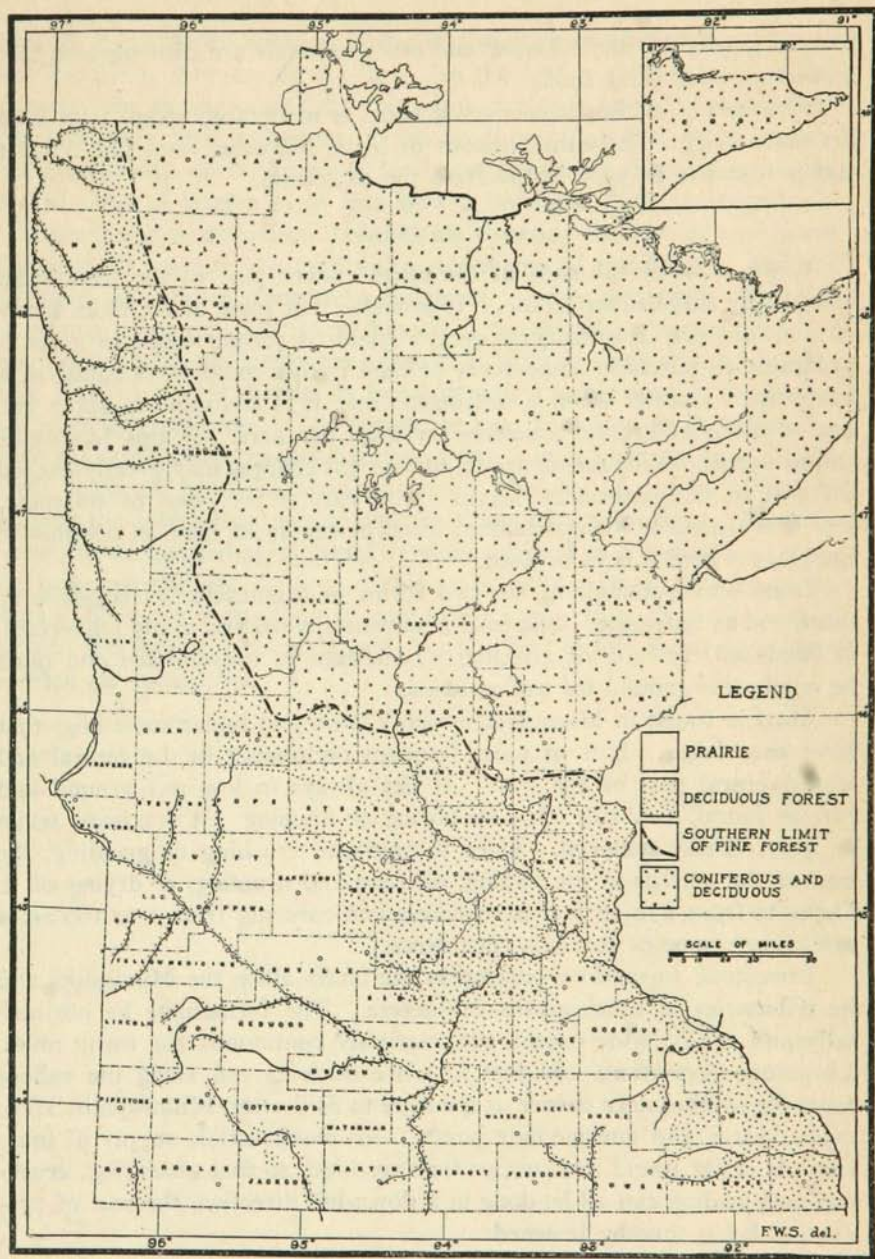


FIGURE 3. MAP OF MINNESOTA SHOWING DISTRIBUTION OF FOREST AND PRAIRIE. (AFTER MAP BY WARREN UPHAM AND BY FREDERIC K. BUTTERS)

feet thick. In this the feldspar and other minerals are disintegrated and made ready for plant food.

Weathering in the loess-covered areas is moderately deep, as it is in the older drift. The entire deposit of loess, however, is of fine texture and is found to be very fertile from top to bottom.

LIME

While most of the soils of the northwestern part of the state seem abundantly supplied with lime, it is probable that some of the more sandy ones would give a sufficiently greater yield of certain crops to make it profitable to purchase some form of lime if this could be obtained at a low price. Usually when a soil needs lime, it is advisable to apply one ton or more of ground limestone or marl per acre. If this has to be shipped any considerable distance, the freight charges may greatly exceed the cost of the material on board of the cars at the point of shipment. For this reason it is important to locate a supply as near as possible to the place where it is to be used.

Lime occurs abundantly in two forms in Minnesota: as bog-lime or marl, and as limestone. The marl is unconsolidated and easily pulverized. It needs no crushing or grinding. Limestone is consolidated and must be crushed or ground for use on fields.

Marl is found in Minnesota in many lakes and under some bogs that have been lakes. It is of most frequent occurrence in the central and north central part of the state. It lies always in low wet ground and can be found, as a rule, only by boring or ditching. It is a soft, white or gray, chalky material. Since it needs no crushing or grinding, the cost of the marl is in the finding, ditching and draining, or drying of it. Deposits from 1 to 10 feet in thickness and covering from 1 to 100 acres are known to be of common occurrence.

Limestone formations outcrop in the bluffs along the Mississippi and its tributaries in southeastern Minnesota. The formations lie horizontally and are of wide extent, or practically continuous for many miles. Limestone formations 100 feet or more thick extend along the valleys from the southeastern corner of the state to Stillwater, Minneapolis, Mankato, Austin, and intermediate points. An inexhaustible supply of limestone is easily found in outcrops that are high, so that quarrying, crushing, and loading can all be done in a down-hill direction, the cost of production being thereby lessened.

EFFECT OF FIRES

There are large areas in Minnesota which have been swept by forest fires, and these fires have destroyed much of the accumulated leaf mold.

In sandy areas the destruction of the leaf mold may have reduced somewhat the productiveness of the land, for the leaf mold acts as a mulch to prevent the drying out of the soil. But in clayey areas there seems to have been very little reduction of the fertility. The leaf mold in such places, however, when turned under has a beneficial effect in loosening the stiff clay. A large area of clay land in the Little Fork drainage basin in St. Louis and southeastern Koochiching counties was burned over some fifty or more years ago, according to statements of the Indians, and the leaf mold was almost completely destroyed. A heavy growth of poplar has sprung up on the drier parts instead of the mixed hardwood that had occupied the land, while the wet areas have a fresh stand of spruce (See Plate XI^{VA}). This district is being rapidly cleared and is producing exceptionally good crops. The forest fire near Hinckley in Pine County, which occurred about twenty-five years ago, swept over an area chiefly of till much of which is loose-textured. This had a similar effect in changing the forest from mixed hardwood and pine to poplar. This area is now one of marked agricultural fertility adapted to a variety of crops. The principal damage by fire in this state, both past and prospective, seems to be in the destruction of peat in the bogs. In such cases there is not only the loss of a valuable fuel, but the land is left in a rough state ill-suited for cultivation.

CHAPTER II

CLIMATIC CONDITIONS OF MINNESOTA

BY U. G. PURSELL

Director of the Minnesota Section of the United States Weather Bureau

INTRODUCTION

The agriculture of any region is controlled by its climate. In some parts of the world temperature is the main factor in determining the limits of growth of certain kinds of crops; in others it is rainfall, and in still others it is the amount of sunshine. All of these factors are important in influencing the crop yield even in districts where the general climatic conditions are satisfactory for the growth of plants. In Minnesota these elements are so favorable that a majority of the crops common to the temperate zone may be successfully grown, and a failure of all the important crops is very rare even over a small portion of the state.

Rainfall is an important factor for most crops in the state, because the proper amount of water in the soil at the critical period of development of the plant is necessary to produce a large crop. The length of the growing season also is important and probably no other factor in the study of climate from the standpoint of the agriculturist should be given more consideration. This is the key to an actual knowledge as to the possibilities of success or failure in the production of crops since in parts of the state crops are menaced by frost at some period of their growth, whereas sunshine and moisture seldom vary in Minnesota beyond safe limits.

The factors which determine the climate of any area are the relative distribution of land and water, the topography of the land surface, and the situation of the area in question with relation to the general movement of the cyclones and anti-cyclones.

The position of Minnesota at the center of North America gives it a climate that is largely continental. In continental climates the temperature extremes are greater and the humidity and rainfall generally less than at places near large bodies of water, such as border on the Atlantic, Pacific, and Gulf coasts of the United States. The effect of winds from great bodies of water is to equalize temperatures of lands near by and to lengthen materially the crop-growing season. This is particularly true of the country in the vicinity of Lake Superior, where the influence of that great inland sea in modifying the cold anti-cyclones

gives to that section a more equable climate than would otherwise obtain in that portion of the state. The summer temperatures are likewise modified and people from long distances inland in steadily increasing numbers are establishing summer homes about the lake, to which they are attracted during the hot summer months. There are more than 7,000 small lakes scattered throughout the state and these have a material local influence in modifying the heat of summer and give comfort to thousands of residents on their shores.

Monthly and annual reports of temperature, rainfall, snowfall, etc., have been published for a large number of regular and coöperative stations in Minnesota since 1895. Recently three special section reports have been issued by the United States Weather Bureau giving monthly and annual precipitation totals for all points in the state with a record of ten years or over, together with average temperatures and other data. In these reports the more important facts from all portions of the state are tabulated and the comparative climatic conditions of the different sections graphically shown.

GENERAL CLIMATIC CONDITIONS

Minnesota is in the path of a large proportion of the low-pressure areas which move across the United States from west to east. These areas move at an average speed of 600 miles in twenty-four hours and are preceded by southerly winds and higher temperature and followed by northerly winds and lower temperature. They are usually accompanied by cloudy weather and precipitation; each storm causing an average of from one to two rainy days as it crosses the state.

As there is an average of almost two of these storms each week with fair weather periods between, it follows that the changes in weather conditions are rather rapid. One or two days of stormy weather preceded by fair weather and followed by clearing and lower temperatures to be repeated in turn, make up the usual routine for the week. However, Minnesota is so far from the coast that damaging ocean storms lose much of their severity before reaching its borders.

The northwestern cold waves pass across the state and send their health-giving winds into all parts, and yet they are frequently not so severe as they are in some of the plains states in the same latitude or even farther south.

Temperature.—The average annual temperature of Minnesota for the period 1895 to 1913 inclusive, is 41.7°, as shown in Table I and graphically by Figure 4. The highest annual mean temperature, 43.9°, occurred in 1900, and the lowest, 39.9°, in 1912. The departure of the average temperature of any year from the normal may readily be deter-

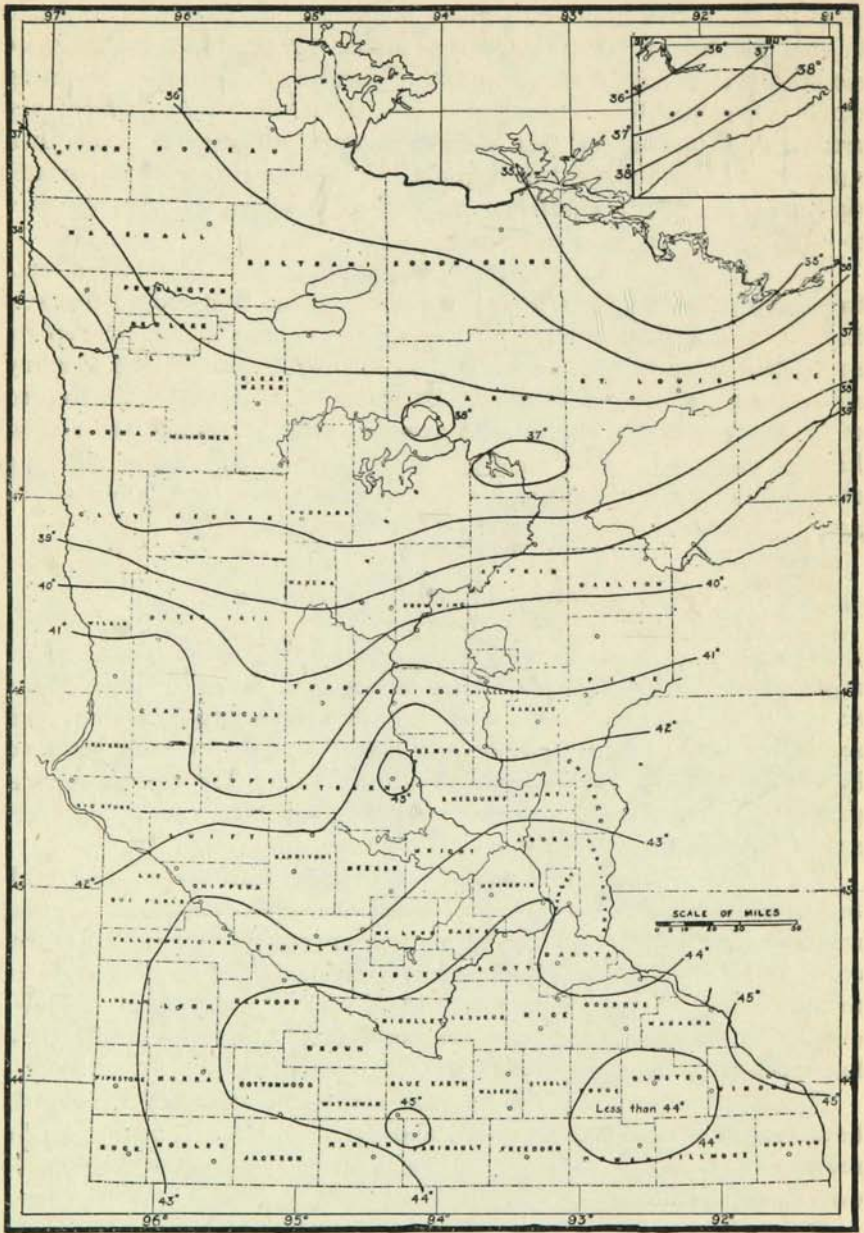


FIGURE 4. MAP SHOWING MEAN ANNUAL TEMPERATURES OF MINNESOTA
(DEGREES FAHRENHEIT)

mined by comparing the yearly average with the mean at the foot of the column.

Table I. Monthly and Annual Mean Temperature for Minnesota (Degrees Fahrenheit)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1895	.....	.....	.....	49.9	56.9	54.6	67.8	67.4	61.5	41.4	27.8	18.3	.....
1896	12.3	17.9	21.4	44.5	60.9	66.5	69.9	67.9	54.3	42.4	18.0	20.3	41.6
1897	7.2	15.3	20.7	43.7	55.2	62.5	71.6	64.2	65.3	50.0	26.6	12.3	41.2
1898	18.3	16.4	30.3	43.5	55.6	67.0	69.8	66.9	66.6	42.9	26.6	11.9	42.2
1899	9.9	4.5	14.7	44.0	55.1	65.4	70.2	69.1	56.4	49.0	39.6	17.9	41.2
1900	18.4	5.2	23.4	49.5	59.0	66.8	68.8	74.3	58.2	55.1	25.4	18.6	43.9
1901	13.2	10.0	27.3	45.7	58.2	65.5	74.7	69.8	57.3	49.2	28.8	13.0	42.8
1902	15.9	15.5	34.0	42.6	57.0	61.3	69.7	65.2	55.2	47.1	33.3	12.6	42.6
1903	11.3	10.6	29.6	43.3	55.7	62.3	67.2	63.6	55.5	46.1	27.3	9.8	40.3
1904	4.5	2.3	24.8	38.8	55.4	63.2	66.0	64.9	57.4	47.4	36.7	16.7	40.1
1905	5.6	8.9	33.7	42.0	52.6	63.0	67.3	68.9	61.9	43.5	33.1	20.6	41.5
1906	17.0	13.8	20.6	47.9	53.7	63.7	68.3	68.7	63.3	45.7	30.7	15.9	42.0
1907	3.8	14.8	28.7	34.7	45.5	63.3	68.2	66.1	55.9	45.4	31.7	21.3	40.1
1908	16.4	17.9	26.4	45.2	53.9	62.5	69.4	65.5	64.2	47.0	33.8	17.5	43.4
1909	10.5	13.7	26.1	35.8	53.2	65.0	69.2	70.9	58.7	44.7	33.8	10.0	41.0
1910	11.8	7.6	41.7	48.0	51.6	67.8	70.6	65.8	58.4	50.8	25.3	14.7	42.8
1911	5.4	16.6	32.7	42.7	59.8	69.7	68.2	64.0	56.7	43.4	20.2	19.4	41.6
1912	-6.7	10.6	19.8	45.5	55.9	62.5	68.5	63.9	57.2	47.5	33.9	20.0	39.9
1913	7.2	8.6	20.4	46.4	52.7	67.4	67.3	69.2	58.6	42.7	36.9	26.1	42.0
1914	16.9	2.8	26.6	41.2	57.6	64.6	72.4	66.1	60.0	52.6	33.0	.....	.....
Mean	10.5	11.2	26.5	43.8	55.3	64.7	69.3	67.1	58.8	46.5	30.1	16.7	41.7

The coldest month is January, which has a mean temperature of 10.5° , although the average for February is only 0.7° higher. In a great many instances February has averaged colder than the preceding January. This condition occurred in the seven successive years from 1898 to 1904 inclusive. Average January temperatures are plotted on Figure 5.

July is the warmest month, with an average temperature of 69.3° , although in a few years the mean temperature for June or for August is higher than for July of the same year. Average July temperatures are plotted on Figure 6.

The highest summer mean, 70.0° , occurred in 1900 and 1901 (Table II). The coldest summer was that of 1903, with an average of 64.4° .

The warmest crop-growing season (April to September inclusive) of the eighteen years under discussion was in 1900, when the average was 62.9° , and the coldest was in 1907, with an average of 55.6° .

The warmest winter (December to February inclusive) was in 1907-8, when the mean temperature was 18.5° . The coldest was in 1903-4, with a mean temperature of 5.5° . Table II shows also the warmest and coldest spring and autumn.

In Figures 7 and 8 are shown the highest and lowest temperatures ever recorded in the various counties where records have been kept. From these figures it can readily be seen that the extreme range of temperature is from 107° at Grand Meadow and Milan, to -59° at Lech Lake Dam and Pokegama Falls. Temperatures above 100° have been recorded in all counties except those about the headwaters of the Missis-

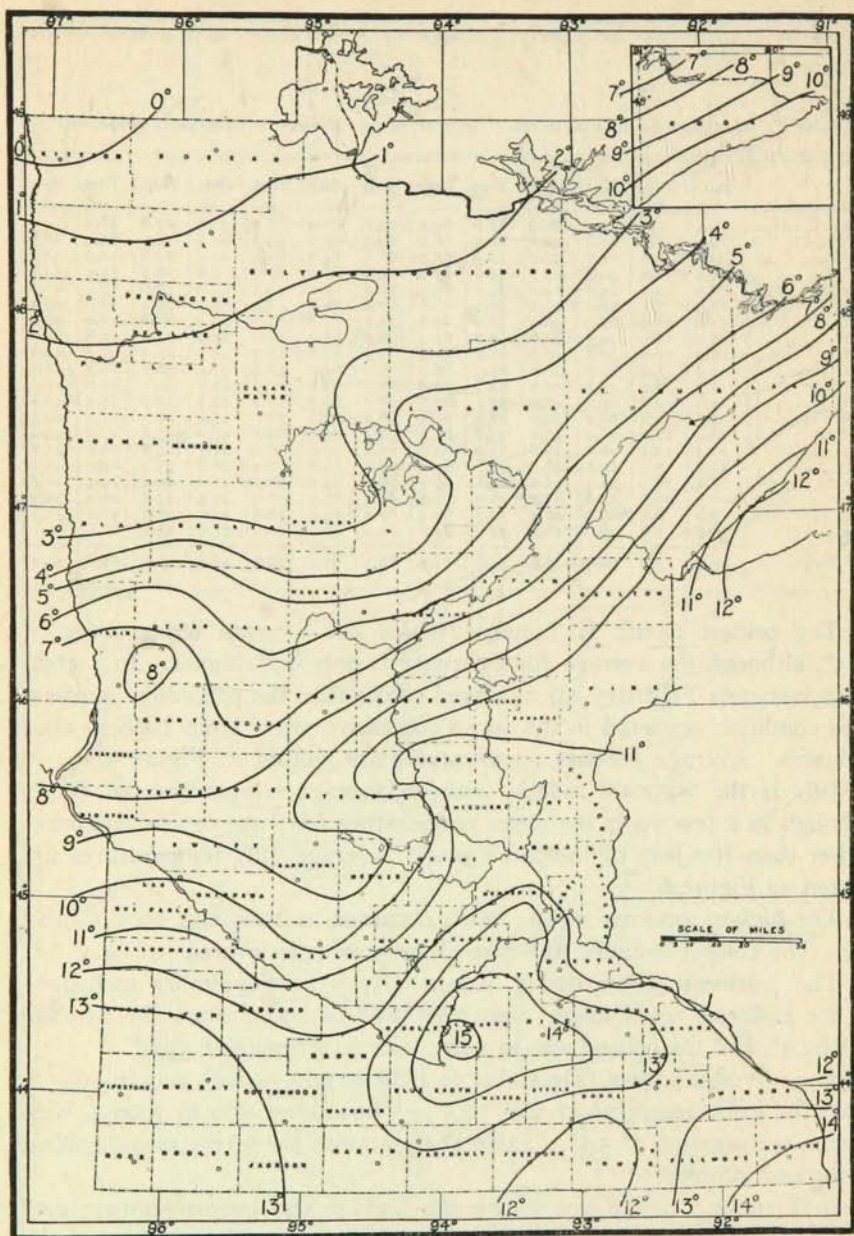


FIGURE 5. MAP SHOWING MEAN TEMPERATURES OF MINNESOTA FOR JANUARY (DEGREES FAHRENHEIT)

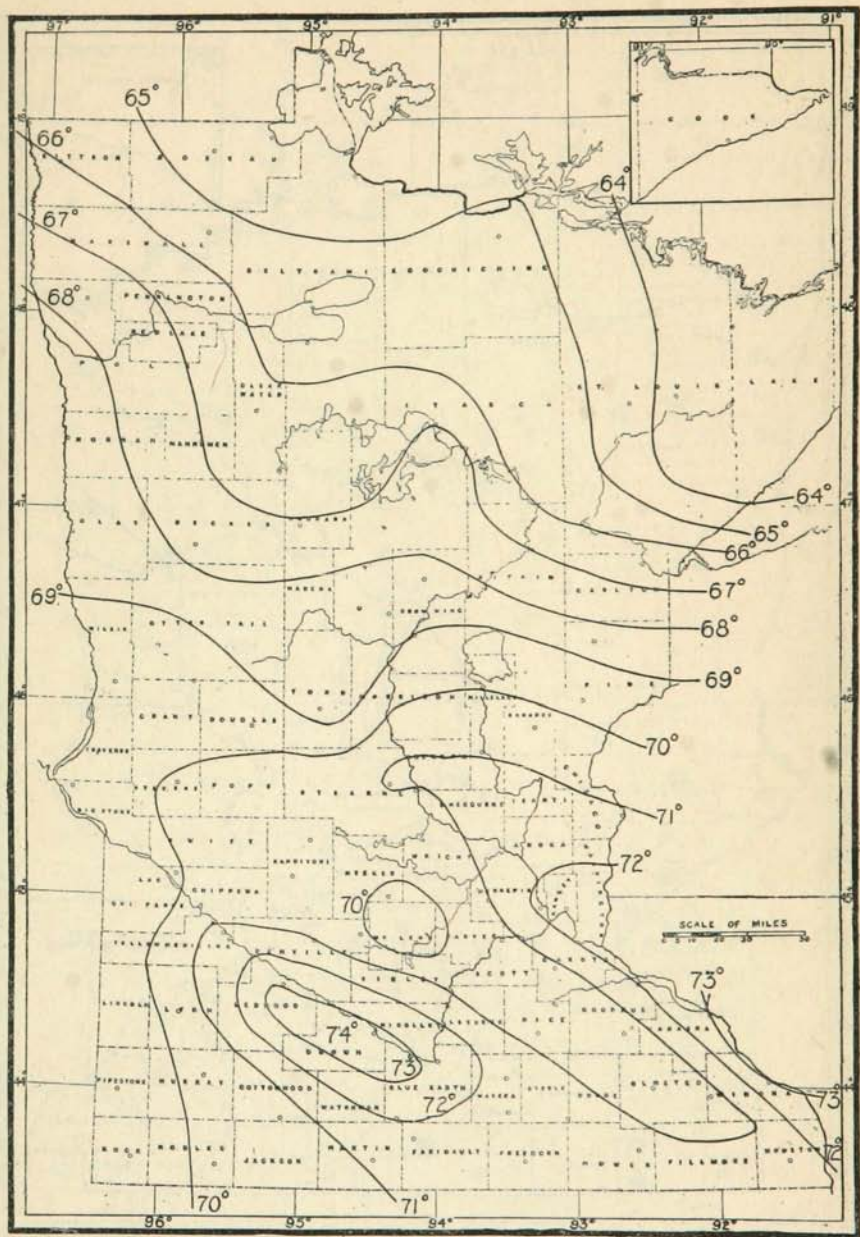


FIGURE 6. MAP SHOWING MEAN TEMPERATURES OF MINNESOTA FOR JULY
(DEGREES FAHRENHEIT)

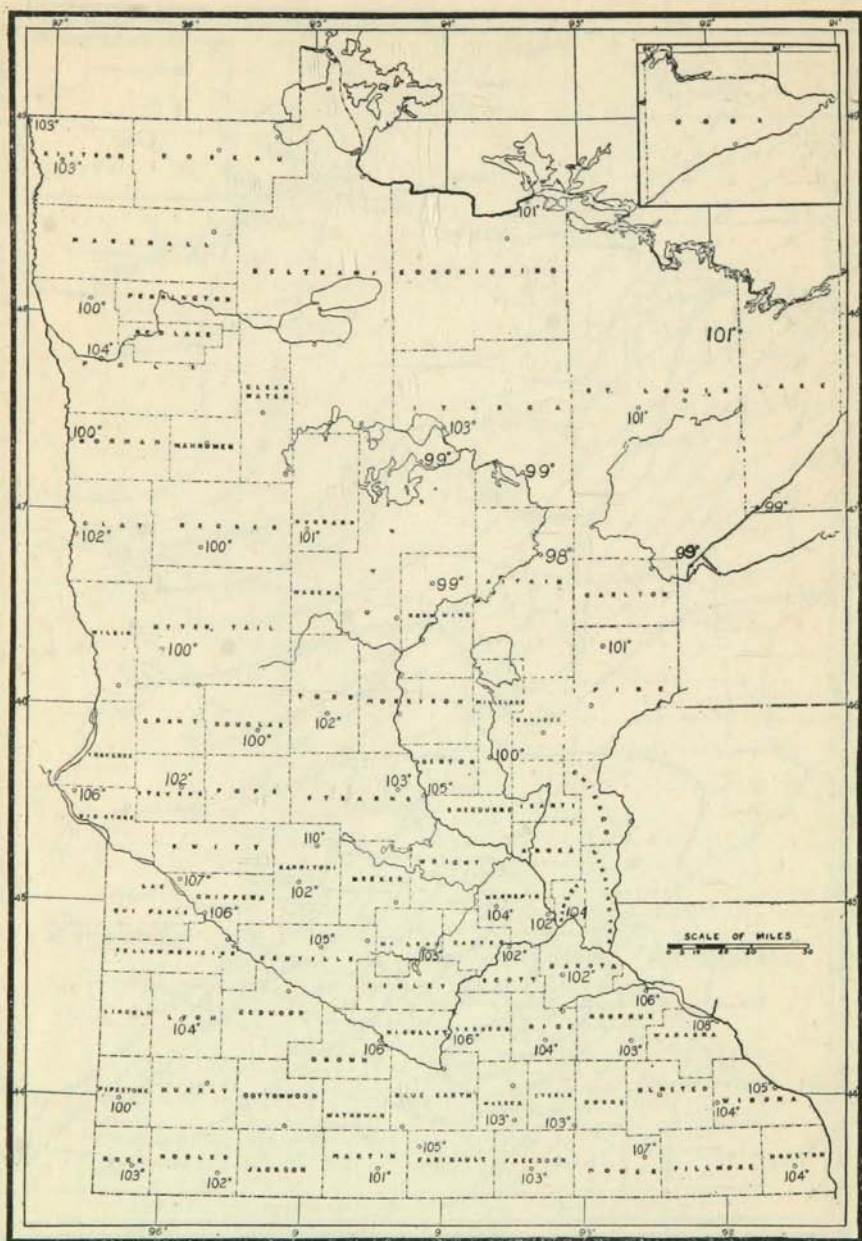


FIGURE 7. MAP SHOWING HIGHEST KNOWN TEMPERATURES IN MINNESOTA (DEGREES FAHRENHEIT)

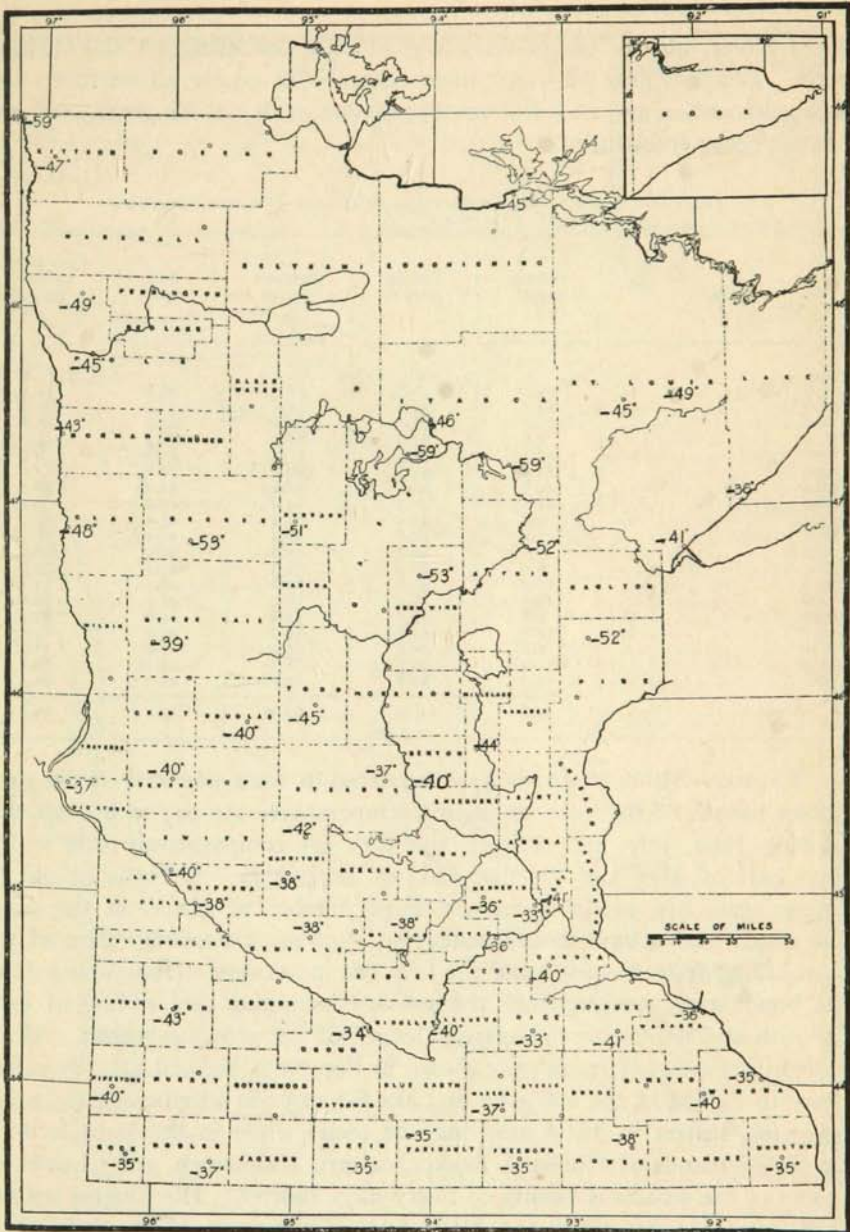


FIGURE 8. MAP SHOWING LOWEST KNOWN TEMPERATURES IN MINNESOTA (DEGREES FAHRENHEIT)

issippi River, and in the country immediately bordering on Lake Superior. Temperatures of -40° have occurred in nearly all northern and central counties and in a few southern counties, but these great extremes do not occur frequently.

Table II. Seasonal Temperatures for Minnesota (Degrees Fahrenheit)

Year	Winter mean	Spring mean	Summer mean	Fall mean	April to Sept. inclusive (crop-growing season)
1895					61.4
1896	16.2	42.3	68.1	38.2	60.7
1897	14.3	39.9	66.1	47.3	60.4
1898	15.7	43.1	67.9	43.4	60.6
1899	8.8	37.9	68.2	48.3	60.0
1900	13.8	44.3	70.0	46.2	62.9
1901	13.9	44.1	70.0	45.1	62.0
1902	14.8	44.5	65.4	45.2	58.5
1903	11.5	42.9	64.4	43.0	57.9
1904	5.5	40.0	64.7	47.2	57.6
1905	10.4	42.8	66.4	46.2	59.3
1906	17.1	40.7	66.9	46.6	60.9
1907	11.5	36.3	65.9	44.3	55.6
1908	18.5	41.8	65.8	48.3	60.1
1909	13.9	38.4	68.4	45.7	58.8
1910	9.8	47.1	68.1	44.8	60.4
1911	12.2	45.1	67.3	40.1	60.2
1912	7.8	40.4	65.0	46.2	58.9
1913	11.9	39.8	68.0	46.1	60.3
1914	15.3	41.8	67.7	48.5	60.3
Mean	12.8	41.7	67.0	45.3	59.8

Frosts.—Although frosts have occurred in some portions of the state every month of the year, damaging temperatures are not to be expected during June, July, and August, and they are comparatively rare in the last half of May and the first half of September. Records of ten or more years are available from a large number of places in the state, of which charts have been constructed showing the average date of the last killing frost in spring and the first one in autumn. Using these dates as boundaries, we can mark the average beginning and ending of crop growth and determine the average length of the growing season. All of this information is graphically shown in Figures 9, 10, and 11. By reference to Figure 11 the influence of Lake Superior in lengthening the crop-growing season in its vicinity may be seen; while in the same latitude in the highlands of Hubbard, Becker, eastern Mahnomon, and Clearwater counties the season is twenty to thirty days shorter. The longest season, 160 days, obtains along the Mississippi River from Hennepin County to the southeastern corner of the state, and the shortest, 100 days or less, is in the region of the Mesabi and Vermilion Iron ranges.

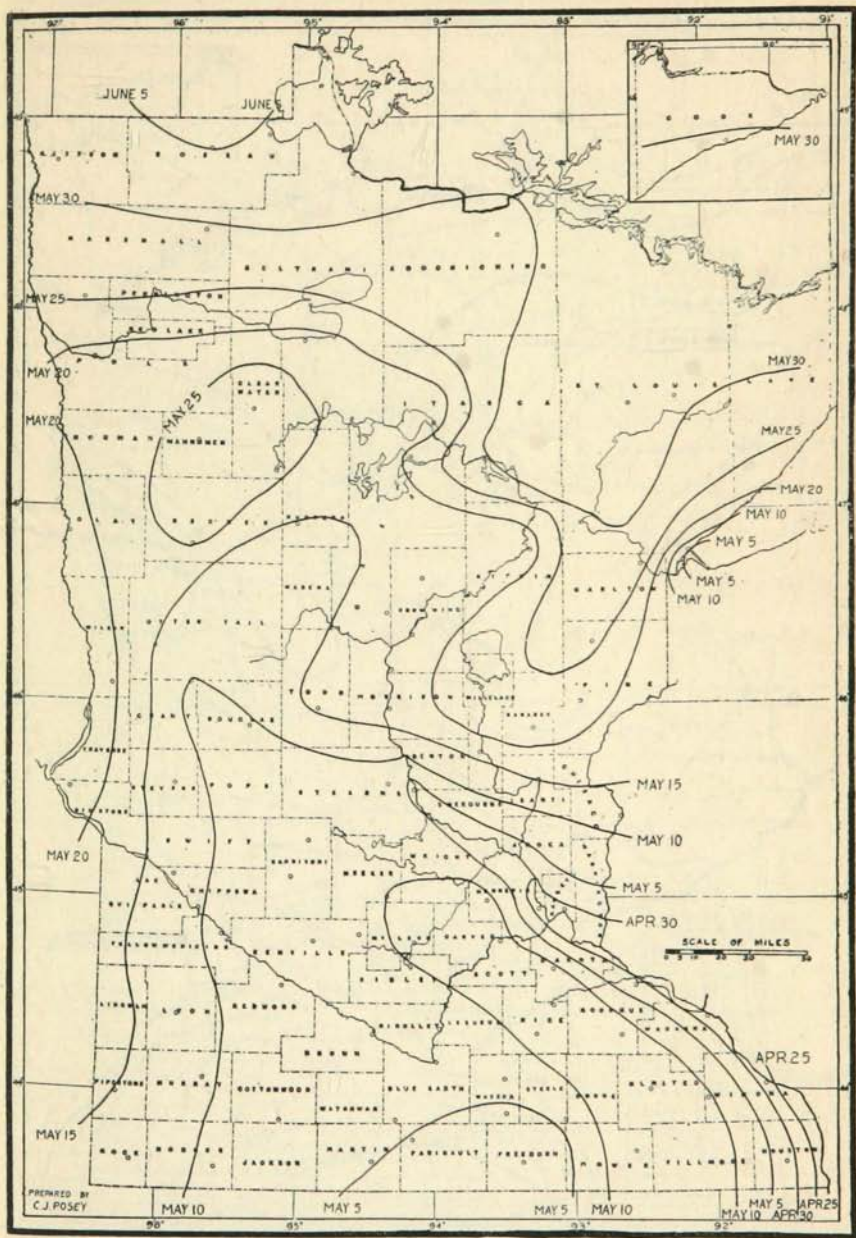


FIGURE 9. MAP SHOWING AVERAGE DATE OF THE LAST KILLING FROST IN SPRING IN MINNESOTA

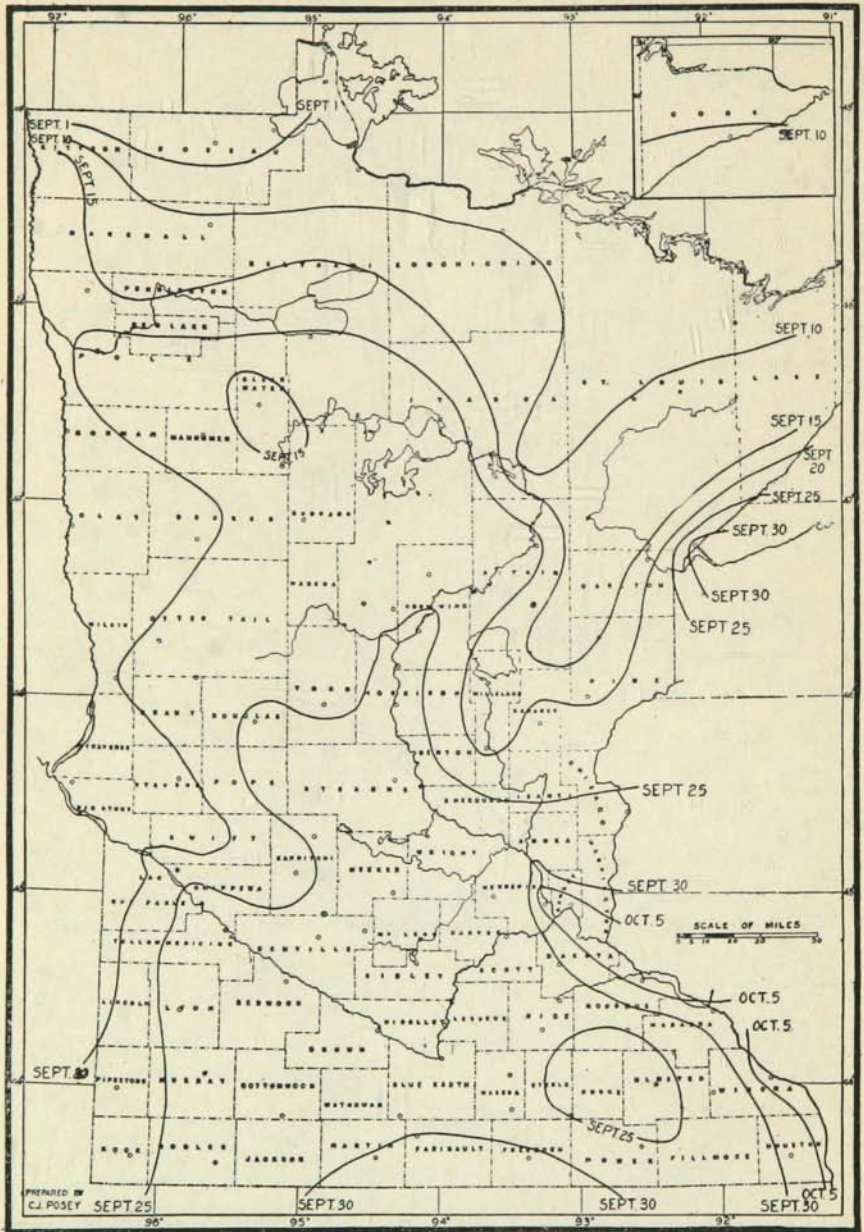


FIGURE 10. MAP SHOWING AVERAGE DATE OF FIRST KILLING FROST IN AUTUMN IN MINNESOTA

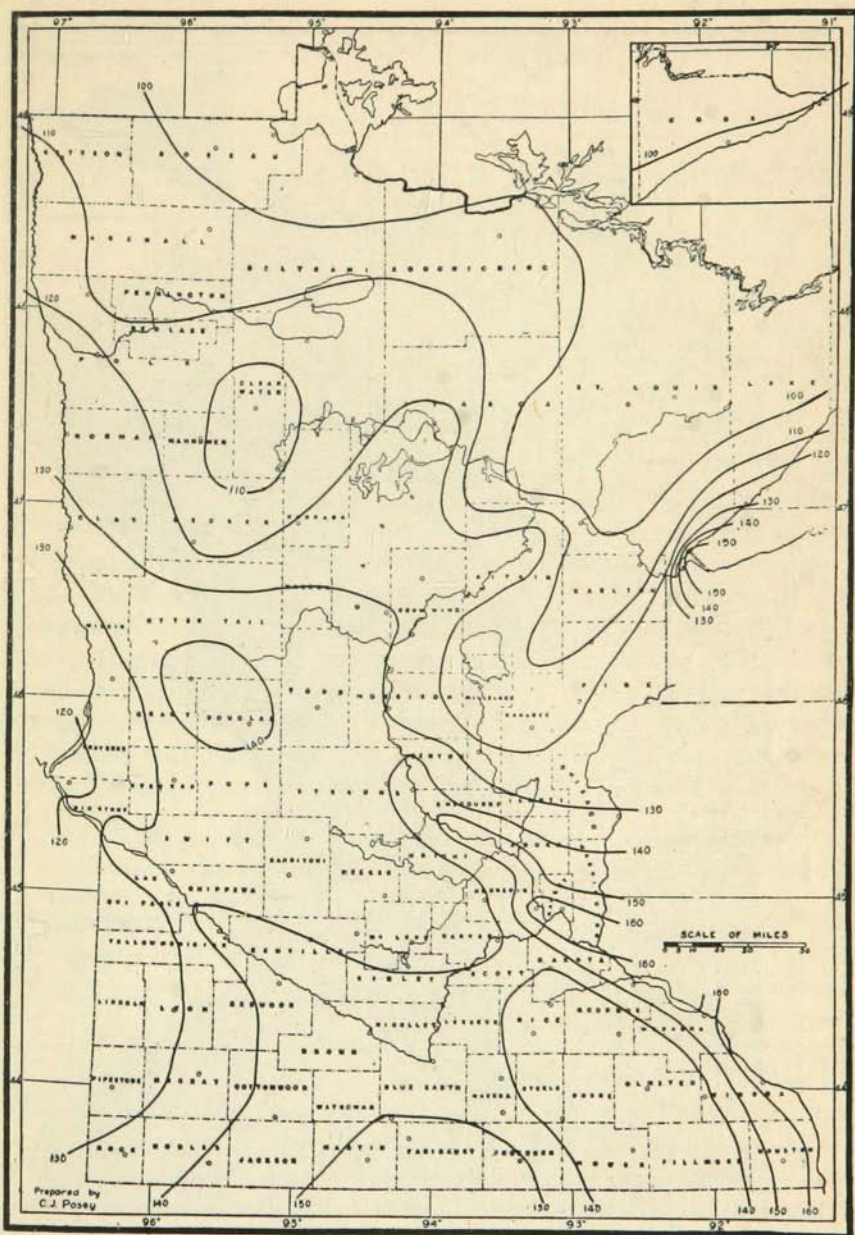


FIGURE II. MAP SHOWING NUMBER OF DAYS OF THE AVERAGE CROP-GROWING SEASON IN MINNESOTA

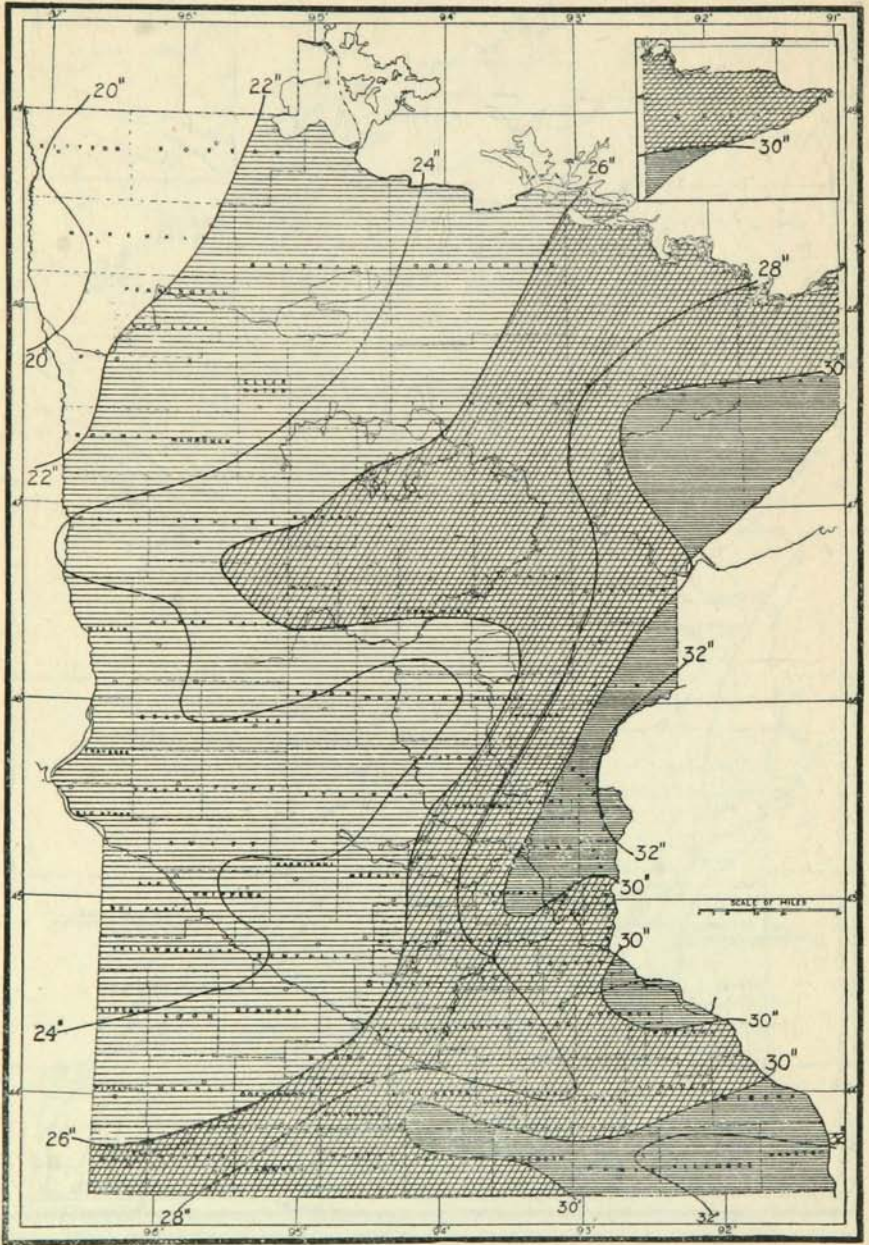


FIGURE 12. MAP SHOWING THE AVERAGE ANNUAL PRECIPITATION FOR MINNESOTA

Table III. Average Monthly and Annual Precipitation for Minnesota (in Inches)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Total April to Sept. incl.
1895	.....	.....	.....	1.68	3.30	4.37	3.25	2.27	3.93	0.25	1.22	0.28	.....	18.80
1896	0.76	0.39	1.97	5.91	5.02	4.07	1.88	2.28	2.49	2.95	2.69	0.61	32.04	21.65
1897	1.77	1.21	2.07	1.55	1.38	5.40	6.62	2.54	1.89	1.55	0.53	0.38	27.23	19.38
1898	0.16	1.02	1.21	1.04	3.26	3.93	2.94	3.22	1.52	3.83	1.02	0.18	24.21	16.51
1899	0.60	0.78	1.58	1.49	4.46	6.36	2.84	5.35	1.47	3.22	0.63	0.95	30.14	21.97
1900	0.48	0.56	1.3c	1.47	0.90	1.71	5.48	6.44	6.55	3.85	0.62	0.51	29.79	22.55
1901	0.38	0.40	1.68	1.73	1.41	5.81	3.33	2.21	4.34	1.86	0.78	0.57	24.26	18.83
1902	0.44	0.67	0.92	1.67	5.10	3.32	4.76	4.35	2.23	1.93	1.57	1.79	29.46	21.43
1903	0.45	0.59	1.75	2.82	5.37	1.96	5.11	4.65	5.03	3.13	0.35	0.84	32.85	25.54
1904	0.39	0.62	1.51	1.72	2.43	4.26	3.96	2.77	3.14	3.50	0.14	0.82	29.65	18.28
1905	0.65	0.55	1.21	1.46	5.54	6.41	4.12	4.36	3.45	2.53	2.64	0.15	33.10	25.34
1906	1.15	0.27	1.20	1.72	5.58	4.55	2.93	4.66	3.73	2.28	1.82	0.91	31.66	23.17
1907	1.17	0.58	0.94	1.01	2.14	4.31	3.57	4.11	3.48	1.31	0.57	0.57	24.03	18.62
1908	0.31	1.11	1.47	2.55	6.31	6.35	3.21	2.07	2.41	1.91	1.18	0.79	29.49	22.90
1909	1.32	1.31	0.54	1.89	3.36	3.53	3.84	5.54	3.16	1.56	2.68	1.54	29.27	20.32
1910	0.83	0.45	0.27	1.54	1.58	1.39	1.94	2.35	2.45	0.97	0.52	0.44	14.73	11.25
1911	0.81	0.88	0.63	1.88	3.48	3.79	3.61	4.27	3.35	3.93	1.12	1.35	29.10	20.38
1912	0.40	0.21	0.45	2.04	4.13	1.66	4.30	3.97	3.03	0.97	0.36	0.93	22.45	19.13
1913	0.33	0.44	1.27	1.87	3.53	3.08	5.56	2.79	3.33	2.58	0.66	0.05	25.49	20.16
1914	0.81	0.44	1.12	2.41	2.89	8.34	2.48	3.97	3.08	2.00	3.38	.....	.....	23.77
Mean	0.70	0.66	1.22	2.00	3.55	4.18	3.79	3.66	3.23	2.31	1.07	0.71	27.72	20.33

Precipitation.—The annual average precipitation of the state as a whole for a period of eighteen years, 1896 to 1914 inclusive, is 27.72 inches, and for the crop season, April to September inclusive, for twenty years, 1895 to 1913, is 20.33 inches. The monthly, seasonal, and annual averages for this period are shown in Table III. The year with the greatest annual rainfall was 1905, when the total was 33.10 inches. The driest year was 1910 with 14.73 inches. In that year the rainfall during the crop-growing season was 11.25 inches.

Table IV. Average Monthly and Annual Precipitation by Drainage Districts

Watersheds	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Lake Superior	0.88	0.88	1.41	2.05	3.50	4.19	4.21	3.73	4.18	2.80	1.45	1.13	30.40
Rainy River	0.94	0.94	1.42	1.96	3.10	4.04	3.76	3.32	2.98	2.08	1.46	0.98	26.98
Red River	0.55	0.56	0.98	1.84	2.85	3.83	3.34	3.12	2.32	1.55	0.72	0.56	22.22
Mississippi (above St. Croix)	0.73	0.70	1.23	2.16	3.42	4.13	3.61	3.57	3.00	2.29	1.05	0.73	26.63
St. Croix and Mississippi (below St. Croix)	0.92	0.95	1.49	2.37	4.01	4.46	3.72	3.69	3.72	2.73	1.36	1.13	30.57
Minnesota River	0.79	0.73	1.19	2.30	3.52	4.18	3.34	3.44	2.63	2.11	1.02	0.79	26.04
Big Sioux and Des Moines Rivers	0.50	0.54	1.13	2.09	4.00	4.39	3.49	3.58	2.79	2.07	0.94	0.63	26.15
State	0.76	0.75	1.25	2.18	3.53	4.19	3.55	3.50	3.02	2.24	1.09	0.84	26.90

June is the wettest month with an average rainfall of 4.18 inches, and July is next with 3.79 inches. The lowest monthly rainfall is that of February with an average of 0.66 inch. The greatest rainfall in one month for the state as a whole was 8.34 inches in June, 1914. The lowest rainfall for any month was .05 inch in December, 1913.

The geographic distribution of annual and monthly precipitation is

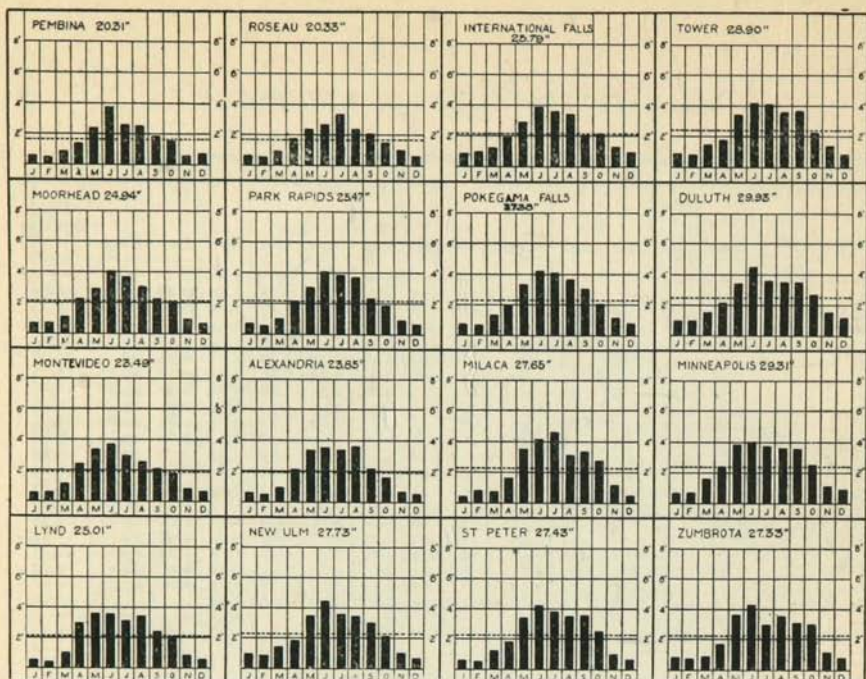


FIGURE 13. DIAGRAM SHOWING COMPARATIVE MONTHLY DISTRIBUTION OF PRECIPITATION IN MINNESOTA. LETTERS INDICATE MONTHS, BLACK COLUMNS INDICATE INCHES OF RAINFALL IN EACH MONTH AT STATION NAMED

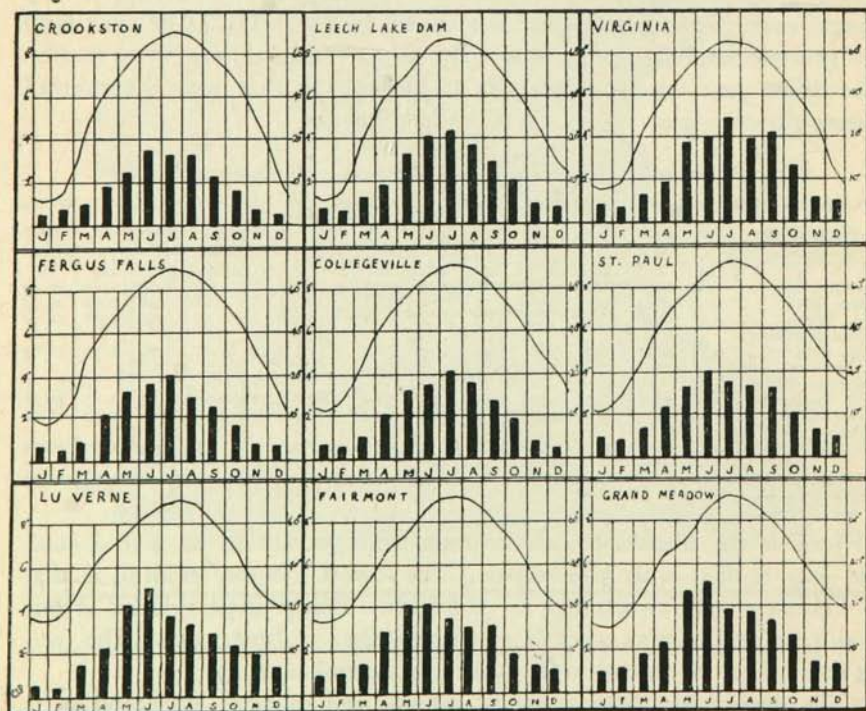
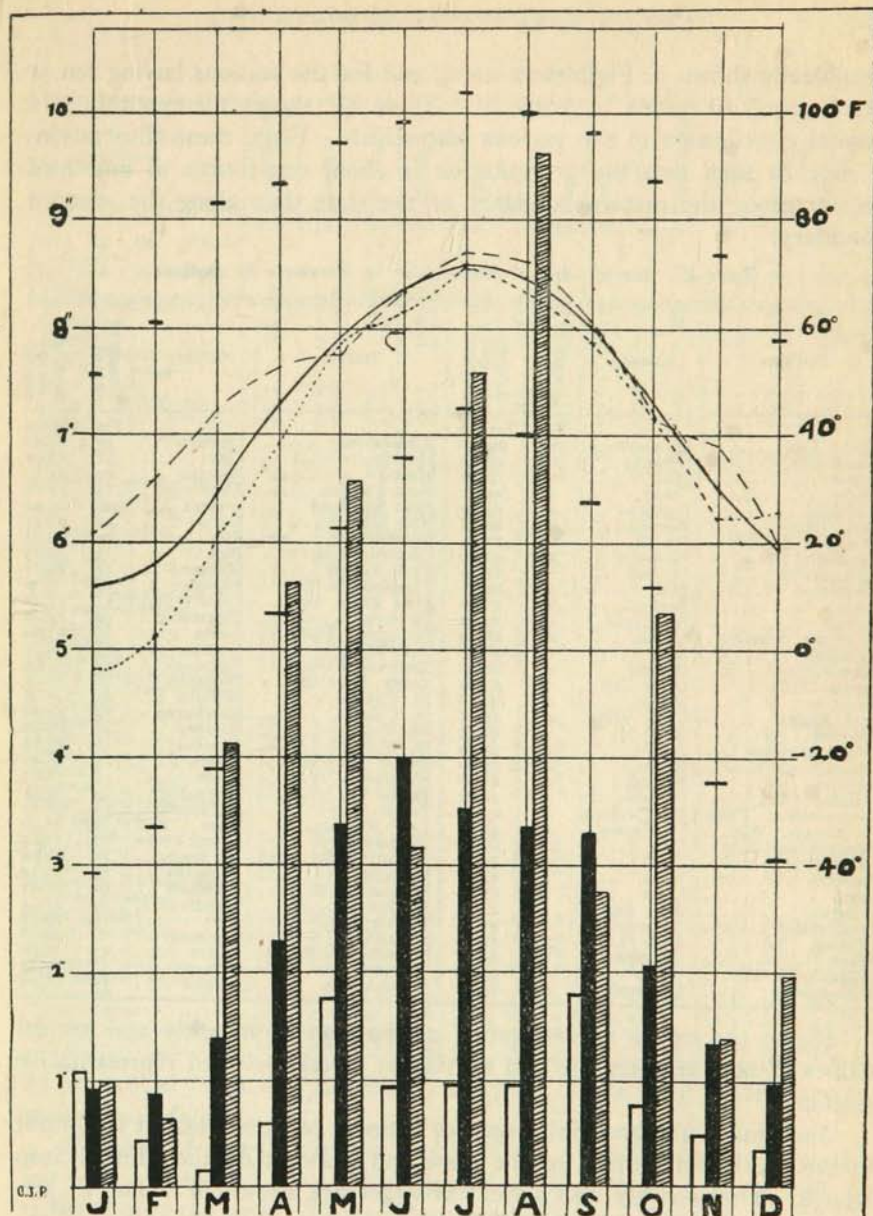


FIGURE 14. DIAGRAM SHOWING MEAN MONTHLY RAINFALL AND MEAN MONTHLY TEMPERATURE AT SEVERAL STATIONS IN MINNESOTA. MONTHS ARE INDICATED BY THEIR FIRST LETTERS. THE GREATEST RAINFALL IS IN THE GROWING SEASON.



■ = mean monthly rainfall, 1873-1913.
 ▨ = monthly rainfall of year of greatest rainfall recorded, 1849.
 □ = monthly rainfall of year of least rainfall recorded, 1910.
 Solid curve = mean monthly temperature, 1871-1913.
 Dotted curve = mean monthly temperature for year of lowest annual temperature recorded, 1875.
 Dashed curve = mean monthly temperature for year of highest annual temperature recorded, 1878.
 Horizontal dashes show absolute maximum and minimum temperatures recorded.

FIGURE 15. DIAGRAM SHOWING RAINFALL AND TEMPERATURES (DEGREES FAHRENHEIT)
 AT ST. PAUL, MINNESOTA FROM 1837-1913. MONTHS ARE
 INDICATED BY THEIR FIRST LETTERS

graphically shown in Figures 12 to 14, and for the stations having ten or more years of record in Table V. Table IV shows the monthly and annual distribution in the various watersheds. From these illustrations it may be seen that the precipitation is about one-fourth to one-third greater along the eastern boundary of the state than along the western boundary.

Table V. Average Annual Precipitation in Minnesota by Stations

Stations	County	Length of record	Average annual precip.		Station	County	Length of record	Average annual precip.	
			Yrs.	Inches				Yrs.	Inches
Albert Lea	Freeborn	21	29.90	Montevideo	Chippewa	22	23.50		
Alexandria	Douglas	25	23.74	Moorhead	Clay	31	24.92		
Angus	Polk	10	19.00	Morris	Stevens	27	23.23		
Ashby	Grant	14	24.47	New London	Kandiyohi.	18	23.62		
Beardsley	Bigstone	16	23.79	New Richland	Waseca	10	29.91		
Bird Island	Renville	22	24.23	New Ulm	Brown	32	27.74		
Blooming Prairie	Steele	13	27.45	Northfield	Rice	12	29.92		
Caledonia	Houston	19	33.70	Osceola, Wis.	Polk	21	32.13		
Collegeville	Stearns	19	22.76	Park Rapids	Hubbard	22	25.71		
Crookston	Polk	22	22.41	Pembina, N. D.	Pembina	14	19.79		
Detroit	Becker	16	25.96	Pine River Dam	Crow Wing	25	27.52		
Duluth	St. Louis	41	29.93	Pipestone	Pipestone	12	24.18		
Fairmont (near)	Martin	25	28.20	Pokegama Falls	Itasca	25	27.62		
Faribault	Rice	14	28.00	Red Wing	Goodhue	16	31.71		
Farmington	Dakota	24	29.29	Redwood Falls	Redwood	13	24.65		
Fergus Falls	Otter Tail	24	23.24	Reeds Landing	Wabasha	16	29.31		
Flandreau, S. D.	Mocody	22	24.57	St. Charles	Winona	21	30.68		
Fort Ripley	Crow Wing	43	25.25	St. Cloud	Sherburne	19	27.68		
Glencoe	McLeod	15	26.64	St. Paul	Ramsey	41	28.68		
Grand Meadow	Mower	24	32.59	St. Peter	Nicollet	18	27.89		
Grantsburg, Wis.	Burnett	21	33.06	Sandy Lake Dam	Aitkin	19	26.47		
Hallock	Kittson	13	21.37	Shakopee	Scott	15	28.85		
Halstad (Ada)	Norman	16	21.27	Tonka	Hennepin	13	30.54		
International Falls	Koochiching	10	25.75	Tower (Ely)	St. Louis	10	28.17		
La Crosse, Wis.	La Crosse	40	31.17	Two Harbors	Lake	18	30.56		
Leech Lake Dam	Cass	24	27.00	University, N. D.	Grand Forks	20	20.47		
Long Prairie	Todd	20	25.17	Virginia (Mt. Iron)	St. Louis	18	30.74		
Luverne	Rock	15	27.60	Wabasha	Wabasha	17	30.54		
Lynd	Lyon	19	25.43	Wahpeton, N. D.	Richland	20	23.07		
Mankato	Blue Earth	14	27.50	Willmar	Kandiyohi.	10	25.54		
Mapleplain	Hennepin	17	31.11	Willow River	Pine	10	29.98		
Milaca	Mille Lacs	13	27.27	Winnebago	Faribault	14	30.58		
Milan	Chippewa	18	24.49	Winnibigoshish	Itasca	25	25.66		
Milbank, S. D.	Grant	21	22.69	Winona	Winona	16	29.63		
Minneapolis	Hennepin	21	29.31	Worthington	Nobles	17	28.24		

Figure 14 makes an interesting comparison of monthly and annual values of both temperature and rainfall at certain selected representative stations.

Snowfall.—The snowfall averages from 24 to 54 inches. It is lightest in the southwest portion of the state and heaviest on the Mesabi Iron Range. The monthly and annual averages are shown in Table VI, arranged according to sections and drainage districts.

Winds.—The prevailing winds are from the northwest over most of the state. The monthly and annual prevailing directions are shown for a large group of stations in Table VII. The average hourly wind velocity is shown for six regular Weather Bureau stations and three special stations in Table VIII.

Relative humidity.—The average annual humidity for the state is

Table VI. Average Snowfall

Stations	Length of record, yrs.	January	February	March	April	May	June	July	August	September	October	November	December	Annual
		Yrs.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
<i>Lake of the Woods Group—</i>														
<i>Rca River Valley Group—</i>							0	0	0	0.2	0.4	8.4	8.2	50.5
Tower	9	9.0	8.6	10.9	4.2	0.6								
St. Vincent-Pembina ..	14	8.4	5.1	6.9	5.2	0.7	0	0	0	0.1	0.7	5.7	6.4	39.2
Crookston	14	6.3	6.7	8.8	3.2	2.0	0	0	0	T.	0.4	4.5	5.7	35.8
Moorhead	17	7.6	6.7	8.9	4.9	0.3	0	0	0	0.1	1.0	6.9	6.8	43.7
<i>Upper Mississippi River Valley Group—</i>														
Park Rapids	14	9.0	6.5	9.1	5.4	0.9	0	0	0	0.2	1.4	7.4	6.3	46.2
Lake Winnibigosish ..	14	8.6	6.5	9.9	3.3	0.8	0	0	0	T.	1.0	7.8	7.8	45.7
Sandy Lake Dam.....	14	9.0	9.5	10.6	3.6	0.7	0	0	0	0.2	1.1	7.4	7.4	49.4
<i>Lake Superior Group—</i>														
Mt. Iron	13	9.9	7.8	11.2	3.9	1.1	0	0	0	0.1	0.8	8.1	11.6	54.4
Duluth	25	10.3	9.1	11.1	4.0	1.0	0	0	0	0.1	0.3	8.2	8.7	52.8
<i>Lower Mississippi River Valley Group—</i>														
La Crosse, Wis.....	15	8.4	8.7	6.6	1.4	T.	0	0	0	T.	0.1	3.9	8.9	37.1
Grand Meadow	14	8.0	9.8	9.9	3.1	0.4	0	0	0	T.	0.3	5.3	9.3	46.1
St. Charles	9	7.7	9.4	9.5	2.4	0.2	0	0	0	0	0.1	4.3	9.3	42.9
Red Wing	8	8.0	5.6	4.4	1.8	0.2	0	0	0	T.	0.3	1.5	7.1	28.9
St. Paul	24	7.7	6.2	8.8	3.6	0.2	0	0	0	T.	0.2	4.7	5.7	37.1
<i>Lower Minnesota River Valley Group—</i>														
Shakopee	14	7.7	8.1	7.8	1.9	T.	0	0	0	T.	0.4	3.0	4.6	33.5
St. Peter	13	5.5	6.1	7.1	0.7	T.	0	0	0	0	0.4	1.4	4.0	25.2
Winnebago	10	6.5	7.5	6.3	1.0	T.	0	0	0	T.	0.3	2.3	6.5	30.4
<i>Middle Mississippi River and St. Croix Valleys Group—</i>														
Minneapolis	18	8.3	8.6	9.5	4.0	0.2	0	0	0	T.	0.3	4.5	6.4	42.4
Collegeville	14	6.7	5.6	8.5	1.8	0.4	0	0	0	T.	0.3	3.5	5.0	31.8
Pine River Dam.....	14	9.1	8.4	9.5	2.8	2.8	0	0	0	0.1	0.6	5.9	6.8	44.0
Osceola, Wis.....	11	9.1	8.4	11.7	2.8	T.	0	0	0	T.	0.1	5.5	6.8	44.4
Grantsburg, Wis.	11	9.2	9.0	12.2	4.2	0.1	0	0	0	0	0.1	8.5	8.9	52.2
<i>Upper Minnesota River Valley Group—</i>														
New Ulm	14	8.9	7.5	9.5	1.7	0.2	0	0	0	T.	0.3	3.5	4.4	36.0
Bird Island	14	4.7	5.8	6.0	1.5	0.4	0	0	0	T.	0.5	3.5	3.4	25.8
Milan	14	7.5	8.1	11.2	1.6	0.5	0	0	0	T.	0.6	4.1	6.1	39.7
<i>Minnesota River Watershed Group—</i>														
New London	14	4.6	4.2	7.0	1.7	0.1	0	0	0	0	0.3	2.7	3.4	24.0
Long Prairie	14	5.7	5.5	7.4	2.4	0.4	0	0	0	T.	0.2	3.3	4.4	29.3
Morris	14	5.2	5.4	7.8	2.1	0.5	0	0	0	0	0.6	3.2	4.4	29.2
Fergus Falls	13	6.2	5.7	7.6	2.8	0.4	0	0	0	T.	1.0	5.7	5.8	35.2
<i>Southwestern Group—</i>														
Fairmont	13	5.0	10.0	8.8	1.9	0.1	0	0	0	T.	0.2	3.9	5.3	35.2
Worthington	13	4.1	7.2	7.6	1.2	T.	0	0	0	0	0.3	2.7	3.6	26.7
Lynd	14	6.3	5.1	7.4	2.8	0.5	0	0	0	T.	1.2	2.8	5.3	31.4
Gary, S. D.....	11	4.4	6.6	12.4	4.5	0.2	0	0	0	T.	1.2	4.2	4.1	37.6

83 per cent at 7 a.m. and 72 per cent at 7 p.m. Table IX gives the monthly and annual data.

Number of rainy days.—In Table X the number of rainy days during each month and the year is given for thirty-three stations well distributed over the state. The smallest number is 64 at Lynd, Lyon County, and the largest 132 days at Duluth.

Sunshine.—The sunshine is abundant, averaging from 43 to 53 per cent of the highest amount possible. The daylight hours are materially longer during the crop-growing season in the northern portion of the state than in the southern. The greatest percentage of sunshine is in the southwestern portion and the least in the northeastern part.

Table VII. Prevailing Wind Direction

Stations	Length of record, yrs.	January	February	March	April	May	June	July	August	September	October	November	December	Year
<i>Lake of the Woods Group—</i>														
Tower	9	nw.	w.	nw.	w.	w.	w.	w.	w.	w.	w.	w.	nw.	w.
<i>Red River Valley Group—</i>														
St. Vincent-Pembina ..	23	nw.	nw.	nw.	nw.	nw.	se.	s.	se.	nw.	nw.	nw.	nw.	nw.
Crookston	14	s.	nw.	s.	n.	nw.	s.	sw.	se.	nw.	s.	s.	nw.	s.
Moorhead	28	nw.	nw.	nw.	n.	n.	se.	s.	se.	se.	se.	nw.	nw.	n.
<i>Upper Mississippi River Valley Group—</i>														
Park Rapids	16	nw.	nw.	nw.	nw.	s.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.
Lake Winnibigoshish..	16	nw.	nw.	w.	nw.	nw.	w.	w.	w.	w.	nw.	nw.	nw.	nw.
Sandy Lake Dam.....	14	nw.	nw.	nw.	se.	e.	e.	nw.	nw.	s.	nw.	nw.	nw.	nw.
<i>Lake Superior Group—</i>														
Mt. Iton	14	nw.	n.	n.	n.	n.	s.	s.	n.	s.	s.	nw.	nw.	n.
Duluth	38	sw.	nw.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	sw.	sw.	ne.
<i>Lower Mississippi River Valley Group—</i>														
La Crosse, Wis.	36	s.	s.	n.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
Grand Meadow	15	nw.	nw.	nw.	nw.	nw.	se.	s.	s.	s.	sw.	nw.	nw.	nw.
St. Charles	13	nw.	nw.	nw.	se.	se.	nw.	se.	nw.	s.	se.	nw.	nw.	nw.
Red Wing	12	nw.	nw.	nw.	se.	e.	se.	sw.	w.	e.	w.	nw.	nw.	nw.
St. Paul	38	nw.	nw.	nw.	nw.	se.	se.	se.	se.	se.	se.	nw.	nw.	se.
<i>Lower Minnesota River Valley Group—</i>														
Shakopee	14	nw.	nw.	nw.	se.	se.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.
St. Peter	13	nw.	nw.	nw.	nw.	nw.	nw.	se.	nw.	se.	nw.	nw.	nw.	nw.
Winnabago	9	nw.	nw.	nw.	nw.	se.	se.	se.	se.	se.	se.	nw.	nw.	nw.
<i>Middle Mississippi River and St. Croix Valleys Group—</i>														
Minneapolis	18	nw.	nw.	nw.	nw.	ne.	s.	s.	s.	s.	s.	nw.	nw.	nw.
Collegeville	14	nw.	nw.	nw.	s.	nw.	sw.	s.	nw.	s.	nw.	nw.	nw.	nw.
Pine River Dam.....	16	nw.	nw.	nw.	nw.	nw.	w.	w.	nw.	nw.	nw.	nw.	nw.	nw.
Osceola, Wis.	11	s.	s.	n.	n.	s.	s.	s.	s.	n.	n.	n.	s.	s.
Grantsburg, Wis.	11	nw.	nw.	sw.	se.	ne.	sw.	sw.	sw.	sw.	nw.	nw.	nw.	nw.
<i>Upper Minnesota River Valley Group—</i>														
New Ulm	14	nw.	nw.	s.	s.	s.	s.	s.	s.	nw.	nw.	nw.	nw.	nw.
Bird Island	16	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.
Milan	14	nw.	nw.	nw.	se.	se.	se.	nw.	se.	nw.	nw.	nw.	nw.	nw.
<i>Minnesota River Watershed Group—</i>														
New London	14	nw.	nw.	nw.	se.	se.	se.	se.	se.	se.	se.	nw.	nw.	se.
Long Prairie	14	nw.	nw.	nw.	se.	se.	nw.	nw.	se.	se.	nw.	nw.	nw.	nw.
Morris	17	nw.	nw.	s.	s.	s.	s.	s.	s.	s.	s.	n.	s.	s.
Fergus Falls	13	nw.	nw.	nw.	se.	se.	se.	nw.	se.	nw.	nw.	nw.	nw.	nw.
<i>Southwestern Group—</i>														
Fairmont	15	nw.	nw.	nw.	nw.	nw.	s.	s.	nw.	s.	nw.	nw.	nw.	nw.
Worthington	13	nw.	nw.	nw.	s.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.
Lynd	14	nw.	nw.	nw.	nw.	se.	nw.	sw.	nw.	nw.	sw.	nw.	nw.	nw.
Gary, S. D.	11	nw.	nw.	nw.	sw.	se.	se.	se.	s	ne.	sw.	nw.	nw.	nw.

Table VIII. Average Hourly Wind Velocity in Miles

Stations	Length of record, yrs.	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Duluth	5	14.3	14.2	15.0	15.1	15.2	11.6	11.3	12.0	12.7	13.9	14.1	14.2	13.6
Moorhead	19	10.3	10.5	11.3	12.0	10.7	10.0	8.3	8.4	10.4	10.4	10.1	10.0	10.2
St. Vincent-Pembina ..	15	7.7	9.4	10.0	10.7	10.0	8.7	7.5	7.5	9.1	9.3	9.5	8.9	9.2
Two Harbors.....	6	9.0	8.2	9.7	9.4	7.6	7.4	7.3	7.2	8.0	8.3	8.7	8.9	8.3
La Crosse, Wis.	36	7.1	7.5	8.0	8.5	7.5	6.7	6.0	5.8	6.9	7.5	7.5	7.2	7.2
St. Paul.....	36	7.8	8.3	8.8	9.3	8.7	7.7	7.1	7.1	8.0	8.5	8.1	7.8	8.1
Minneapolis	18	11.5	11.6	12.3	12.8	12.1	10.3	9.9	9.9	11.6	11.7	11.0	11.2	11.3
Faribault	7	9.4	9.1	9.4	11.0	9.0	7.3	5.9	6.4	7.8	8.8	9.0	9.1	8.5
Collegeville	11	9.5	9.6	11.0	12.2	11.1	10.0	9.4	9.4	10.9	9.5	9.9	9.9	10.2

Table IX. Mean Relative Humidity in Degrees

Stations	Length of record, yrs.	January	February	March	April	May	June	July	August	September	October	November	December	Annual
		Duluth.....	8 a.m. 21 8 p.m. 21	83 86	83 86	81 88	76 84	76 79	79 84	79 86	81 87	82 87	81 84	82 86	81 84	81
Moorhead.....	8 a.m. 21 8 p.m. 21	77 86	75 86	77 88	65 84	64 79	69 84	65 86	69 87	71 87	72 84	76 86	80 84	81
St. Vincent.....	8 a.m. 4 8 p.m. 4	80 83	80 86	88 88	88 88	77 88	84 88	90 87	87 90	87 88	86 89	89 89	87 87	86
La Crosse, Wis.....	8 a.m. 21 8 p.m. 21	83 84	82 84	79 81	74 75	75 73	79 79	81 83	85 83	85 83	81 81	82 82	83 83	81
St. Paul.....	8 a.m. 21 8 p.m. 21	84 76	84 75	81 69	75 66	73 66	79 67	79 65	83 68	83 66	81 66	81 69	81 74	81
Minneapolis.....	8 p.m. 7	83	79	76	66	66	67	65	68	72	73	79	83	74

Table X. Number of Days with 0.01 Inch or More of Precipitation

Stations	Length of record, yrs.	January	February	March	April	May	June	July	August	September	October	November	December	Annual
		Lake of the Woods Group—												
Tower.....	9	5	4	6	5	8	9	10	8	10	7	5	5	82
Red River Valley Group—														
St. Vincent-Pembina...	25	7	6	7	7	8	11	10	9	8	7	7	7	94
Crookston.....	14	4	4	6	6	8	10	8	9	6	3	4	4	71
Moorhead.....	28	8	9	8	9	11	12	10	9	8	5	8	8	107
Upper Mississippi River Valley Group—														
Park Rapids.....	14	8	7	10	9	11	13	11	10	9	9	7	8	112
Lake Winnibigoshish...	15	6	4	7	6	10	10	9	8	7	5	6	6	83
Sandy Lake Dam.....	14	6	6	8	6	10	10	10	10	9	8	6	6	95
Lake Superior Group—														
Mt. Iron.....	14	5	4	5	5	9	11	10	9	9	7	5	6	85
Duluth.....	38	10	9	10	9	12	14	12	12	12	10	11	11	132
Lower Mississippi River Valley Group—														
La Crosse, Wis.....	36	10	8	10	10	12	12	10	9	10	9	8	10	120
Grand Meadow.....	15	6	5	7	7	12	9	9	8	8	7	6	6	90
St. Charles.....	12	5	4	6	6	9	11	7	6	8	7	5	4	78
Red Wing.....	10	5	6	6	7	11	10	7	7	8	6	5	5	82
St. Paul.....	38	9	8	10	10	12	12	10	10	9	9	8	9	114
Lower Minnesota River Valley Group—														
Shakepee.....	14	5	5	7	8	11	10	9	9	9	8	6	5	92
St. Peter.....	12	3	3	5	6	10	9	7	7	6	5	3	2	66
Winnebago.....	10	4	4	6	6	12	11	9	9	7	5	3	4	82
Middle Mississippi River and St. Croix Valleys Group—														
Minneapolis.....	18	8	7	9	9	12	12	9	9	8	9	7	8	107
Collegetville.....	14	6	5	8	7	10	12	10	10	9	8	6	5	96
Pine River Dam.....	15	4	4	6	6	9	10	8	8	7	6	4	4	76
Osceola, Wis.....	11	7	5	6	6	8	9	8	7	6	7	5	5	79
Grantsburg, Wis.....	11	5	4	5	6	8	7	7	6	5	4	5	6	68
Upper Minnesota River Valley Group—														
New Ulm.....	14	5	5	7	7	11	11	8	8	8	7	5	4	86
Bird Island.....	14	4	3	6	7	10	10	8	8	8	6	5	3	78
Milan.....	14	6	5	7	7	9	11	8	8	7	6	5	5	84
Minnesota River Watershed Group—														
New London.....	14	3	3	5	5	9	9	7	6	6	5	4	3	65
Long Prairie.....	14	4	4	6	8	10	11	8	8	8	7	5	3	82
Morris.....	16	4	4	6	7	11	12	9	9	8	7	6	4	83
Fergus Falls.....	13	11	8	11	9	12	15	11	11	10	8	7	10	123
Southwestern Group—														
Fairmont.....	15	4	4	5	6	10	8	7	7	7	5	3	3	69
Worthington.....	13	4	4	4	6	11	10	14	8	6	5	4	4	80
Lynd.....	14	3	3	5	5	8	9	7	8	6	4	3	3	64
Gary, S. D.....	11	3	2	3	5	6	5	6	5	4	4	3	1	47

The precipitation in the area embraced in the present report, as shown in Figure 12, increases from northwest to southeast, being about 25 inches in the northwest part and over 32 inches in the southeast. Although there is an increase on approaching Lake Superior the influence of the lake in increasing precipitation near its shore seems to be very slight, for in parts of Minnesota farther south where there is no lake influence a similar increase in the amount of precipitation is found in passing from northwest to southeast.

CHAPTER III

AGRICULTURAL CONDITIONS AND LAND CLASSIFICATION IN THE NORTHEAST QUARTER OF MINNESOTA

GENERAL STATEMENT

The northeast quarter of Minnesota lies within the area of mixed coniferous and deciduous forests (Figure 3), and was heavily wooded, except in some of the muskeg swamps, and in narrow marshy strips bordering lakes and streams. The sandy and loose-textured soils are occupied largely by pine forests, while the clayey or heavier classes of soil carry usually a mixed growth, embracing deciduous as well as coniferous trees.

Agricultural development is as yet very limited in all parts of this area. In most localities farming has begun within the past ten or fifteen years. The clearing of stumps, draining of swamps, and opening of roads, each require much labor and thus retard a rapid agricultural development. The region is, however, sufficiently well watered, and large areas of it have a soil productive enough to give adequate returns for the expenditure of labor required to bring the land under cultivation. This region is not affected by drouths in late summer such as often cut short the pasturage in districts farther south and west. Very little feeding is, therefore, required until the pastures become snow-covered.

Railway facilities are good in Carlton and much of Aitkin County and over the territory lying between the Mesabi Iron Range and Lake Superior. Koochiching County also has fair railway advantages. There is urgent need for a railway leading northeastward from Duluth through Lake and Cook counties. At present the Minnesota and Northeastern, used largely for lumbering operations, furnishes an outlet for southern Lake County. Boat service is maintained along the shore of Lake Superior from May 1 to November 30, thus furnishing an outlet for the produce of Cook as well as Lake County.

The larger part of the population of this northeast quarter of Minnesota is along the shore of Lake Superior and the mining towns on the iron ranges and in villages scattered along the railways. Not more than twenty per cent of the population are engaged in agricultural pursuits. Of this population a considerable part combine other pursuits with farming and are employed part of their time in the cities or in logging camps. Year by year, however, a larger percentage of the farmers are giving their entire time to farm development.

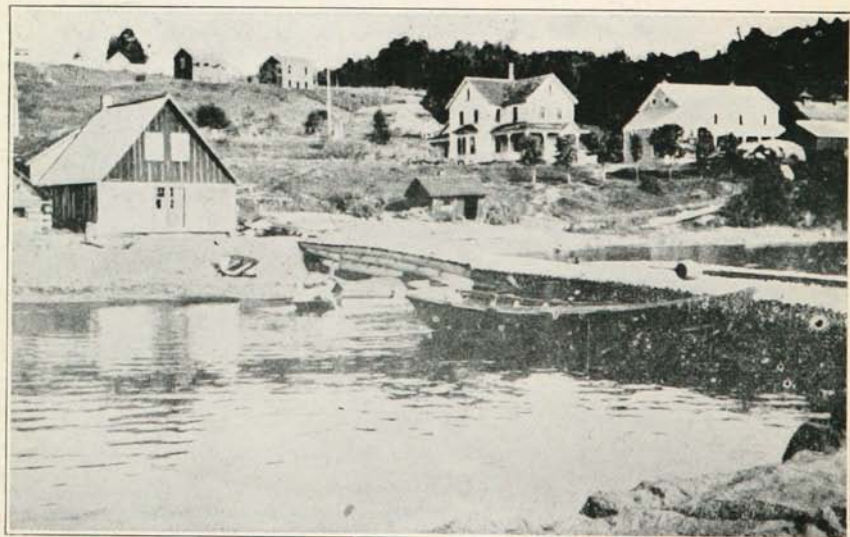
The three counties north of Lake Superior each have large areas with rock hills which carry only a scanty cover of drift. The scanty soil combined with the steepness of slope renders them of little or no agricultural value. These rocky lands are largely embraced in the National Forest and yield better returns from their forests than could be obtained by farming them. These three counties have, however, certain advantages, because of their frontage on Lake Superior. A narrow strip along the lake shore should become a profitable one for the growing of vegetables and even of hardy fruits, which can be readily marketed by boats running to Duluth. The loose-textured soil of this belt also adapts it for the growth of garden truck.

Swamps are numerous in every county in the northeast quarter of the state, and there are extensive muskegs in western St. Louis, Koochiching, and Aitkin counties. The drainage surveys have shown, however, that in the largest swamps as well as in the smaller ones the surface slope is generally sufficient to insure effective drainage. The soil of the swamps also is generally of such a nature as to be very productive when drained. The water courses which have developed in and near these swamps by natural drainage have in most cases channels of sufficient capacity to carry off all water which would be discharged into them from the ditches necessary to drain the swamp areas. A considerable improvement in the drainage and reduction of the area of swamp lands may easily be effected by removing obstructions from the natural water courses, such as old beaver dams and the fallen timber and other obstructing material. Such obstructions are found in nearly all of the small stream channels throughout the area. Large areas of these swamp lands are held by the State, and many projects for their reclamation have been worked out by the State Drainage Engineer and embodied in his report for 1906.

There are wide differences in the character of the glacial deposits in northeastern Minnesota. The cause of some of these differences was the peculiar relations of the deposits to the melting ice, and some were caused by differences in the rock material contained in the drift. Drift laid down under the ice naturally contains a considerable amount of fine clayey or loamy material along with the coarser rock constituents. But drift laid down at the edge of the ice has in places had the fine material largely removed by the waters discharging from the ice border, and the coarse material is thus concentrated into beds of gravel and cobble. There are places, however, where lakes were held between the ice and the higher country outside, or in regions where the escape of the water was inadequate. In such places a fine sediment was laid down outside the ice on the beds of the lakes or ponded waters.



A. GARDEN PLOT OF ANTHONY GASCO ON LAKE HARRIET, LAKE COUNTY
PHOTO BY A. H. ELFTMAN



B. FARM ON SHORE OF LAKE SUPERIOR AT LUTZEN, COOK COUNTY
TERRACING MARKS HIGHER LAKE LEVELS

The temporary Lake Aitkin, which occupied the district traversed by the Mississippi in its course through Aitkin County, deposited a fine and highly productive sediment over much of its bed. The flat land in the St. Louis basin, covered by Lake Upham, now carries deposits of fine sand and silt over a wide area in western St. Louis and northeastern Aitkin County. It embraces the extensive muskeg swamps of that region.

On the bed of Lake Duluth, at its southwest end, in Carlton County and neighboring parts of Wisconsin, there is considerable clay, but in a narrow strip exposed on the north side of Lake Superior there has been in places a removal of the fine material and a concentration of coarse material in the bars and beaches of the lake.

Lake Agassiz extended from the Red River basin and plains of Manitoba as far east as the northwest part of the area herein described (Plate I). All of Koochiching County except a strip two to eight miles wide on its southern border was covered by this lake. It also covered about twenty townships in the northwest part of St. Louis County. The part in Koochiching County has a nearly plane surface and a considerable deposit of fine lake sediment except on the immediate borders of Rainy Lake and small areas in the southeast part of the county where rock knobs are exposed. The lake deposits with heavy soil extend up Little Fork valley into St. Louis County and are found in narrow lowland strips among the rock hills in northwestern St. Louis County. The greater part of this lake area inside the limits of St. Louis County, however, has a rocky surface much of which was swept bare by the action of the lake waves, and thus rendered of little value for agriculture.

The kind of rock material contained in the drift depends to some extent upon the direction from which the ice invaded this region. As already indicated the studies of the deposits have brought out the interesting fact that the ice invasions came from three directions, the northwest, the north, and the east. The invasion from the northwest was by ice which covered much of Manitoba and spread over a great part of northern Minnesota. It brought in deposits of drift containing large amounts of limestone which the ice had gathered in its passage across limestone formations in Manitoba. This is known as the Keewatin drift, since the ice started from the region formerly called the Keewatin district of central Canada (but now largely included in Manitoba). It is also known as the gray drift, this term having been applied by Winchell and his associates in their reports in the Minnesota Geological Survey. The color is gray, however, only in the unoxidized portions, and the surface of the drift, that has been oxidized, has a brown color. There are also places in the vicinity of the Mesabi Iron Range, where on account of the introduction of reddish material from the iron formations, it all

presents a red color. The color name, therefore, becomes rather confusing when one attempts to apply it widely. For this reason the term Keewatin drift is used in the present report.

The border of the Keewatin drift is indicated on Plate I and also on Figure 2. On the northeast it lies only a few miles south of the Canadian line from the mouth of Rainy Lake eastward to Nameokan Lake in St. Louis County. It then leads southward to the west end of Vermilion Lake. Then after a slight eastward turn in the Little Fork drainage basin it swings southward and comes to the Mesabi Iron Range near Chisholm. But the high part of the range from there westward about to the Itasca County line seems to have stood above its limits. On passing over the range into the basin south of it the Keewatin ice spread out widely over the St. Louis drainage basin and also down the Mississippi to the edge of Crow Wing County. The southwest limits run through northwestern Aitkin County and thence westward across Cass County to the south of Leech Lake, passing beyond the limits of the area under discussion. In the district covered by the Keewatin drift the glacial deposits are exceptionally rich and of a less stony character than in districts to the east and south which were covered by drifts derived from other sources.

Ice invaded the northeast part of Minnesota also partly by a westward movement of the Labrador ice sheet through the Superior basin and partly by a southward movement from the district of Patricia in the neighboring part of Canada. A part of the drift deposited by these invasions is called the Superior drift and the other part the Patrician drift. Both of these drifts have a reddish color owing to the large amount of red rock material incorporated in them, and they embrace what is termed the red drift of Minnesota in the reports of the Winchell Survey.

The relations of the Patrician ice movement to the Superior and Keewatin ice movements are somewhat complex. The Patrician movement extended over eastern Minnesota southward a little beyond St. Paul into Scott and Dakota counties, and covered at least one third of the state. It is found to have done so before the movements from the Keewatin and Superior ice fields had reached into northeastern Minnesota, for territory which it occupied was later invaded to some extent by each of these ice fields, and the deposits of the Patrician ice are overlain by the Keewatin and Superior drifts in such regions of overlap. The borders of the drift of the Superior and of the Keewatin ice approach each other closely for a few miles in southwestern St. Louis and northwestern Carlton and the eastern edge of Aitkin County, and the Patrician drift is there found beneath one or the other of them. (See Plate II A and II B). Farther south in Aitkin and neighboring counties, as shown in



A. SHORES AND ISLANDS OF VERMILION LAKE



B. CROSS RIVER MEANDERING THROUGH A SPRUCE SWAMP IN ITS HEADWATERS

Figure 2, the Patrician drift is at the surface. It is also at the surface at the northeast in St. Louis, Lake, and Cook counties between the drift of the Keewatin ice field and that of the Superior lobe of the Labrador ice field. The precise relations of the Superior lobe and Patrician ice in the district north of Lake Superior will be taken up in the discussion of Lake County. Attention is accordingly directed here only to the differences in the character of their drifts.

In the drift brought in by the Superior lobe there is on the whole a large proportion of loamy material in which the coarse crystalline rocks are imbedded. The soil is what might appropriately be termed stony loam. It becomes more gravelly on its northwest edge in the headwaters of Cloquet River because of the discharge of water there along the ice border. The drift deposited by the Patrician ice is generally very stony because of the derivation of its material from the crystalline rock formations over which the ice passed, and which do not readily break down into clayey material. The contrast between it and the drift of the Superior lobe is, however, less striking than between it and the drift of the Keewatin ice sheet, and there are places where the drift of the Superior lobe is fully as stony as that from the Patrician ice. The larger amount of loam in the Superior drift is due in part to the ponded conditions of water along the northwest edge of the Superior ice lobe, there having been ready escape for water along only a part of the border in the headwaters of Cloquet River. It is thought, however, that the formations over which the Superior lobe passed, such as the diabase of Beaver Bay and certain gabbro rocks contributed more material that is easily reduced to clay than did those formations found in the area over which the Patrician ice sheet passed. It was in connection with the retreat of the Superior ice and the Keewatin ice that the glacial lakes, Duluth and Agassiz, noted above were formed.

DESCRIPTIONS OF COUNTIES

In the descriptions of counties which follow the county taken first is in the northeast corner of Minnesota, and after that counties to the west and south to the southern border of the area are discussed. A few data from the census of 1910 are presented in addition to the results of the land classification on a geologic basis.

COOK COUNTY

The recent studies in Cook County were mainly in the part near the shore of Lake Superior where farming has been begun and roads opened. Data concerning the less accessible areas have been obtained from the geological reports of the earlier Geological Survey and from Dr. Arthur

H. Elftman, a member of that survey, who also in 1913 assisted in part of the work in Lake and Cook counties.

Bare rock or rock with a very scanty drift covering occupies about one third of the area of the county, mainly in the north part, and mainly within the limits of the National Forest. But there is also a strip of rugged land known as the "Sawtooth Mountains" which lies near the Superior shore westward from Grand Marais. Several townships in the eastern end of the county are also rugged and thinly covered with drift.

The lakes of Cook County, including those along the Canadian border, are estimated by Mr. George A. Ralph,¹ to cover 274 square miles, while the swamps embrace 135 square miles. Their combined area, 409 square miles, is over one fourth of the county. This, together with the rough and rocky areas, amounts to nearly 60 per cent of the county. Of the remaining 40 per cent a considerable part can not be brought under cultivation except at great expense in clearing of stones and stumps. It may, therefore, prove to be more profitable in forest than under cultivation.

The tracts of heavy drift embrace some moraines, the position and extent of which may be seen by reference to Plate I. Parts of these moraines have a very rough surface with sharp knolls inclosing small swamps. More commonly the glacial deposits are gently undulating with slopes easy to cultivate. The part along the shore which was covered by the waters of Lake Duluth and lower lake stages down to the present Lake Superior, includes numerous gravelly ridges or beaches formed at different levels corresponding to the successive lake levels. The slopes between these gravel ridges have wave-washed drift consisting largely of coarse material. Very little fine sediment was deposited by the lake on this part of the shore. The soil, however, has proved to be productive in the growth of vegetables and cereals.

The prevailing type of soil in the tracts of heavy drift is a stony loam. This is true of moraines, till plains, and of the part within the limits of Lake Duluth. Dr. Elftman reported that there is a strip of heavy drift embraced in flat areas among rock hills on the south side of Pigeon River in Ranges 3, 4, 5, and 6 E. in which a clayey drift is found, which, when cleared and drained, is likely to become valuable agricultural district. It lies partly within the limits of Lake Duluth, but at the west the deposits are somewhat higher than the level of that lake. They may, however, have been laid down in ponded waters along the ice border.

Agricultural development is at present mainly in a narrow strip scarcely five miles wide along the shore of Lake Superior. There is a belt about ten miles wide lying north of the "Sawtooth Mountains" from

¹ G. A. Ralph. *Engineer's Report on Topographical and Drainage Survey, Minnesota, 1906.*



A. FIELD OF OATS ON KEEWATIN TILL PLAIN IN ST. LOUIS COUNTY



B. DAIRY FARM, ST. LOUIS COUNTY

Cascade River westward to Temperance River and northward to Brule Lake, in which the drift cover is heavier than to the north. Parts of this may be suitable for agriculture. The roughness of surface, stony character of the drift, and the likelihood of frost in this depression back of the Sawtooth range give the area of thicker drift but little advantage over the rocky area to the north for crop raising, but it should give good returns in forest. The flat areas of heavy drift along Pigeon River, noted above, are also as yet undeveloped, and are likely to remain so until a railway line is constructed which will give an outlet for the produce.

From the census of 1910 it appears that the number of farms had increased in the preceding decade from 36 to 146. Of these, 115 have an area of between 100 and 175 acres, and two have an area over 500 acres. On many there has been very little cultivation of the soil, the average acres of improved land per farm in 1910 being only 10.7. Thus far the market facilities are restricted mainly to the season of boat traffic on Lake Superior which runs from May 1 to November 30. The Minnesota and Northeastern Railroad, however, has now extended its line to the southwest part of the county and thus opened winter connections with Duluth. Vegetables are as yet grown more extensively than cereals but the census returns show that oats, wheat, barley, and rye, have each a good yield per acre.

LAKE COUNTY

In Lake County a strip several miles wide along the shore of Lake Superior in which the principal settlement occurs was examined in detail. Lines of traverse were also carried into the unsettled parts of the county, lumber camps being used as a base from which to work. Dr. Arthur H. Elftman, who joined in part of this investigation, also greatly aided by supplying information concerning the character of soils in several townships in the northern half of the county which he had examined geologically some years previous under the direction of Professor N. H. Winchell. Information concerning the character of land inside the limits of the National Forest was obtained also from the foresters located there.

The northern part of the county, as far south as Tp. 61, is a very broken district with rock knobs among which are lakes and swamps. It carries only a thin coating of glacial drift on the hills, and there is very little easily tillable land. The greater part of this rocky area is included in the National Forest. There are other bare rock ridges in the southern part of Lake County within the limits of the glacial Lake Duluth which owe their bareness in part to the work of the lake waves in removing the drift covering. These rock outcrops are numerous in the southern part of the county for several miles back from the present shore

and up to an altitude of 800 to 1,000 feet above the level of Lake Superior. There are several townships lying between these rock ranges and those of the northern half of the county in which the drift is so heavy as to nearly conceal even high rock hills and ridges. There are also flat areas among the exposed rock ranges near the shore of Lake Superior in which heavy deposits of drift occur.

The greater part of Lake County was covered by Patrician ice which came in from the north, there being only a strip fifteen to twenty miles wide next to Lake Superior which was covered by the Superior ice field. Each of these ice fields produced a great system of moraines which become interlocked in the eastern part of Lake County. The system formed by the Patrician ice field leads westward from Tps. 59 and 60 R. 7 W. across this county into St. Louis County, covering much of Tp. 59 R. 8W. and Tp. 60 Rs. 9, 10, and 11W. The several headwater branches of Isabella River start in this morainic system and Stony River has most of its course among its ridges. Between the constituent morainic ridges there are narrow strips of gravel plain formed as outwash from the ice border in the course of the development of the morainic system. The amount of drift in this morainic system is several times as great, square mile for square mile, as in the district to the north of it, in the northern half of Lake County.

A morainic system of the Superior lobe, which joins as a correlative of that of the Patrician ice field just described, leads from their place of junction, which is in Tp. 59, Rs. 7 and 8W, southwestward parallel to the shore of Lake Superior through Lake County into St. Louis County. Its inner border is twelve to fourteen miles from the Lake while the outer border is usually sixteen to eighteen miles. Its position may be seen by reference to Plate I. The highest land areas in Lake County are at the junction of the morainic systems, there being a few knolls on the moraines, which by barometric measurement, exceed 2,000 feet above the sea. Each of the morainic systems descends in passing westward from there to the St. Louis County line to an altitude of about 1,700 feet along their crests. The inner border of the Superior lobe, which is considerably lower than the crest, is, however, generally above 1,500 feet.

In topography the great morainic systems are rough and approach in that respect the rock areas of the northern part of the county, there being numerous hills 50 to 100 feet high with steep sides difficult of cultivation. For this reason settlements in Lake County have thus far avoided these morainic systems.

There are several townships lying between these two great morainic systems in western Lake County which are covered by drift belonging to the Patrician ice movement, the ice having melted there prior to the de-



A. BREAKING GROUND AT MEADOWLANDS



B. STOCK FARM AT MEADOWLANDS



C. FARM PREMISES AT MEADOWLANDS

velopment of the morainic systems. Scattered drift knolls and ridges are found in these townships but they do not appear to form definite morainic belts. The greater part of the surface is nearly plane and much of it is swampy. This district was traversed by lines of glacial drainage which ran away from the great morainic systems toward the southwest. The headwaters of Cloquet and St. Louis rivers are in channels which were developed along those lines by the escape of the glacial waters. The swamps are largely underlaid by sand and gravel deposits brought in by the glacial drainage.

On the slope toward Lake Superior there are narrow strips of moraine developed as the ice border halted in its retreat into the Superior basin. They are far less conspicuous, however, than the great morainic systems above noted.

From the junction of the two great morainic systems in T. 59, R. 7W. northeastward into Cook County where the two ice fields were coalesced they did not form moraines. Instead, the ice fields appear to have blocked each other's movements almost completely and to have become ramified near their junction by tunnels through which the water formed by the melting of the ice flowed and deposited gravel and sand in the tunnels. After the ice was all melted these deposits of gravel and sand settled down on the underlying drift-covered surface, and remained there as steep sided gravel ridges called eskers. In Plate IV A one of these ridges which is 90 feet high is shown and it will be noted that the crest is barely wide enough for a wagon track. Eskers are found quite commonly in the glaciated districts. In this locality they are found at the junction of two ice fields but such eskers occur frequently inside the area of a single ice field. They formed when ice movement had practically ceased and where the ice had become ramified by tunnels. Eskers furnish good material for road building rather than good soil. They are of great value for road material, especially in districts where there is a clayey drift.

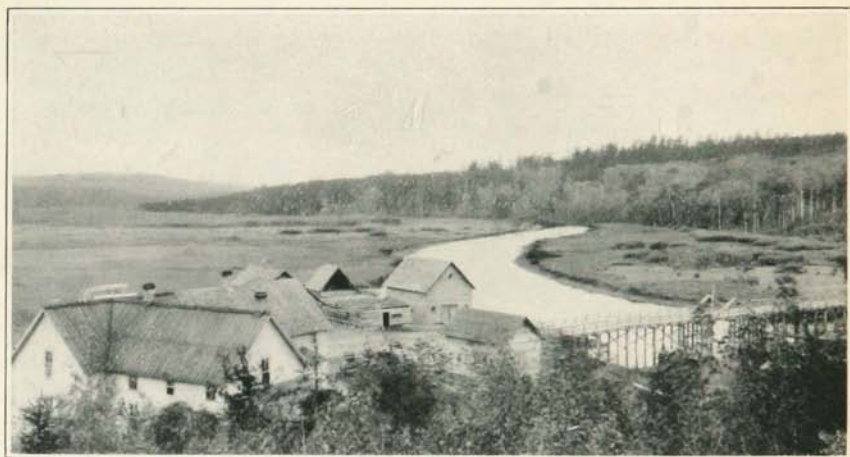
The waters of Lake Duluth are found to have extended back to a distance of four or five miles from the present shore of Lake Superior in the region from Knife River as far northeast as Beaver Bay, though for several miles southwest from Beaver Bay a rock ridge lying back only about two miles from the shore rose slightly above the lake level. From Beaver Bay northeastward the waters of Lake Duluth extended only one and a half to two miles back from the present lake except in narrow inlets in the valleys of Baptism and Manitou rivers. Rocky ridges bordering Lake Superior have greater breadth from Beaver Bay northeastward than they have to the southwest. The beaches of Lake Duluth are ill-defined in these rocky areas but are distinctly seen in the form of

definite gravel ridges where the shore was of glacial deposits. These ridges occur at various levels marking the successive lake stages down to the present shore. The highest shore is not far from 550 feet above Lake Superior. It shows a slight rise from southwest to northeast in its course through the county.

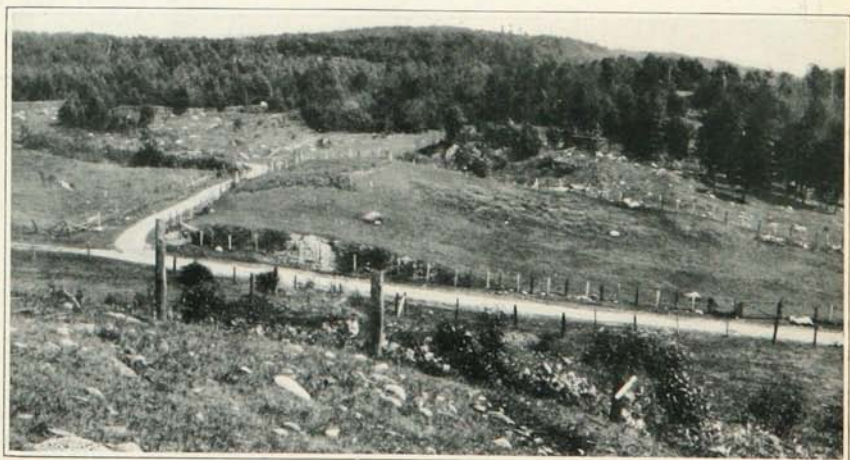
The rough areas of rock ridges and hills are estimated to occupy about 40 per cent of the area of Lake County. The lakes occupy about 12 per cent and the swamps, as estimated by the State Drainage Engineer, embrace 297 square miles or 14 per cent of the county. There thus remains only about one third of the area of the county occupied by the better classes of land. Of this a large part is stony loam with numerous cobblestones as well as bowlders in the soil and on the surface. A narrow strip with heavy clay soil and relatively few stones is found along and near the shore of Lake Superior in the southwest part of the county below the level of the highest beach of Lake Duluth. A looser-textured clay loam with only a moderate number of stones included is found above the level of Lake Duluth in Tp. 54, R. 10W., Tp. 55, Rs. 9 and 10W., and Tp. 56, R. 9W. This district is traversed by the Minnesota and Northeastern Railroad, which thus gives it an outlet for the marketing of products. Both of the great morainic systems are very stony but the one formed by the Superior lobe appears to contain somewhat more loam in the soil than that formed by the Patrician ice field. The district lying between these moraines in the western part of Lake County is also very thickly strewn with stony material, except along lines of glacial drainage, where some deposits of gravel and sand occur.

Nearly all the farming settlements in Lake County are in the two areas of clay and clay loam above noted which lie near the Lake Superior shore, and principally within ten miles of it. There are, however, two settlements more remote. One in the western part of the county in the vicinity of Toimi Post Office has a few settlers. The main settlement of about 75 families is in the adjacent part of St. Louis County. Another in Tp. 59, R. 8W. just west of the junction of the two great morainic systems above noted has about 40 settlers. This settlement has the distinction of being the most elevated one in the state, the altitude being between 1,800 and 2,000 feet. Notwithstanding the high altitude, and remoteness from the lake, cereals and vegetables have been grown with marked success. The soil is a stony loam with considerable sandy admixture both in this settlement and the one around Toimi. There are also a few settlers northeast of Ely in Tp. 63, R. 11W., and a few in Tp. 62, R. 10W.

A single farm has been opened on the east shore of Harriet Lake in Tp. 60, R. 6W. by Anthony Gasco, a view of whose premises is given



A. FERTILE VALLEY NORTH OF VERMILION LAKE AT "HALF-WAY HOUSE"



B. FARM ON THE STONY PATRICIAN DRIFT AT TOWER

in Plate V A. This farm is at an altitude of nearly 1,800 feet or but slightly lower than that of the settlement in Tp. 59, R. 8W. When visited, on September 15, 1913, there had been no killing frost. Sweet corn, pumpkins, cucumbers, lettuce, turnips, cabbage, beets, tomatoes, and potatoes were all in flourishing condition, as well as cultivated flowers of many kinds. In the year 1912 Mr. Gasco raised \$300 worth of garden truck on less than five acres.

The census of 1910 reports only 1.7 per cent of the county, or 34.8 square miles, to be in farms, and only 10.7 per cent of the farm lands to be improved. The crops grown in 1909 were valued at \$47,187. Of this \$15,659 were for vegetables, and \$18,742 for hay and forage. The cereal crop is rated at only \$323, there being but 15 acres reported. There has been considerable advance in the development of farms since the census of 1910 was taken, yet it is still true that only a small part of the land that is suitable for cultivation in Lake County has been developed.

ST. LOUIS COUNTY

St. Louis County of which Duluth is the county seat, embraces more than one third of the northeast quarter of Minnesota, its area, according to the Census of 1910, being 6,503 square miles. It extends from the west end of Lake Superior northward to Rainy Lake on the Canadian border, or from T. 48N. to T. 71N., a distance of fully 130 miles. Its north and south ends are irregular, but for 88 miles, from T. 52 to T. 66 inclusive, the county has a regular width of 60 miles. It is traversed by several railway lines radiating from Duluth. Only one of these, the Duluth, Winnipeg and Pacific, extends through to Canada. Several lines have termini in the Mesabi Iron Range.

Nearly all the county is a tableland standing 600 to 900 feet above Lake Superior, or 1,200 to 1,500 feet above sea level. The Mesabi Iron Range and the associated rock ridges rise in places to 1,800 feet above the sea. A prominent moraine in the southeast part of the county is about 1,700 feet where it enters from Lake County, and the bed-rock surface there attains an altitude of about 1,600 feet. The rock surface has an altitude of 1,500 to 1,700 feet along much of the eastern part of the county. The altitude decreases westward in the district on each side of the Mesabi range. That range reaches its highest elevation of about 1,800 feet in the central part of the county.

For a distance of 30 to 35 miles south from the Canadian boundary, or as far south as Pelican, Vermilion, and Birch lakes, the drift is very scanty on the hills and ridges. The Mesabi Range is very thinly coated with drift in places, though its south slope and the portion west from Chisholm carry a relatively heavy coating. Between the Mesabi Range

and Vermilion Lake, in the drainage areas of Sturgeon and Little Fork rivers, there is generally a heavy cover of drift. The drift cover is heavy also south of the Mesabi Range, except in a narrow strip fronting on Lake Superior where bare ledges are conspicuous. These ledges are chiefly in T. 49, R. 15W., T. 50, R. 14W., and T. 51, R. 13W. The drift of this county was brought in from the three ice fields discussed in the introductory statement. The Superior ice lobe covered the county from the direction of Lake Superior as far northwest as the valley of Cloquet River. The Keewatin ice field extended into the county from the northwest covering about twenty townships north of the Mesabi Iron Range, and a still larger area in the St. Louis basin south of the range. It did not, however, override the portion of the Mesabi Range in this county, but came across the range in Itasca County, and then spread eastward along the south side of the range, in St. Louis County.

The ice from the Patrician district covered the northeastern part of the county as late as the time when the other two ice fields were occupying the southern and western portions, as just described. The morainic system of the Patrician ice sheet, which is correlated with the great morainic system of the Superior lobe, as indicated in the discussion of Lake County, continues into St. Louis County to Vermilion Lake. From that lake northward the Patrician and Keewatin ice fields may have been nearly confluent along a line lying not far from the Vermilion River. Extensive areas of Patrician drift in eastern St. Louis County and along the Mesabi Range are a little older than these great morainic systems, and, as already stated, the Patrician drift of southwestern St. Louis County and neighboring districts was encroached upon by the Superior and Keewatin ice fields and to that extent its drift deposit lies buried beneath their drifts. (See Plate II A and II B.)

The lakes of St. Louis County are estimated to occupy 365 square miles, not including those along the Canadian border. The great majority are less than one square mile in area, but there are a few of considerable size within the limits of this county. The area of Vermilion Lake is about 70 square miles, of Lake Kapetogama fully 30 square miles, of Pelican Lake 20 square miles, and of Trout Lake 11 square miles.

The swamp lands of St. Louis County, as estimated by the State Drainage Engineer in his report for 1906, occupy 1,862 square miles, of which 372 are open swamp with little or no forest growth. Much that is now classed, and which appears in the Land Survey plats as swamp land, will drain naturally when cleared of brush with but little aid by ditching. It is estimated that the rock hills and ranges of St. Louis County embrace an area of nearly 1,700 square miles, or somewhat more



A. FARM ON CLAYEY KEEWATIN DRIFT EAST OF COOK



B. PIONEER MARKETING AT COOK

than one fourth of the county. The area of dry land with thick drift cover is, however, still larger than the rock areas, being estimated at 2,600 square miles, or about 40 per cent of the county.

The area covered by Lake Duluth in this county is only about 100 square miles, the highest shore line being in places scarcely a mile back from the lake. In the eastern part of the county, however, the distance increases to fully five miles.

The most extensive class of soil in St. Louis County is the stony loam. This is the dominant type in the great morainic system of the Superior lobe which runs southwestward across the southern part of the county, though included among those morainic ridges there are nearly level areas in which a somewhat heavy clay with comparatively few stones occurs. (See Plates XII A, XII B.) The Patrician drift in the eastern part of the county is as a rule exceedingly stony both in the ridges and on the level areas. On the Mesabi Range the drift is in places so thickly set with boulders as to form a literal pavement. (See Plate XV A). In the district between the Mesabi range and Vermilion Lake there are rough and stony morainic strips (see Plate IX B) between which are nearly plane areas part of which are of sand and gravel and part of stony drift similar to that in the moraines.

In the St. Louis basin, south of the Mesabi Iron Range, there are several classes of soil. A strip several miles wide immediately south of the iron range has a clayey till with relatively few stones imbedded in it, which was deposited by the Keewatin ice sheet. (See Plate II B.) This kind of drift is also present on the south side of St. Louis River in several townships lying east of the Duluth, Winnipeg and Pacific Railroad, and north of White Face River.

Another extensive deposit in the St. Louis basin is a fine sand which borders the river for most of its course from the crossing of the Duluth and Iron Range Railroad down to the crossing of the Coleraine branch of the Duluth, Mesabi and Northern Railroad, and which also spreads westward to within a few miles of the Mesabi range in the drainage basin of Swan River. This sand apparently underlies a considerable part of the muskeg in the western part of St. Louis County.

From the crossing of the Coleraine branch of the Duluth, Mesabi and Northern down the St. Louis and Whiteface valleys there is a deposit composed more of silt than of sand which seems to have been laid down in Lake Upham, the lake which once occupied this area and discharged through the St. Louis River below Floodwood. The same deposit is exposed along the Floodwood River for many miles above its mouth, and is found to underlie the muskeg swamps for some distance north and west of Floodwood. The Meadowlands Experimental Farm in T. 53, R. 19W. lies within the limits of this silt deposit, (see Plates VIII A,

VIII B, and VIII C), and a farming district in the vicinity of Floodwood is also developed within it.

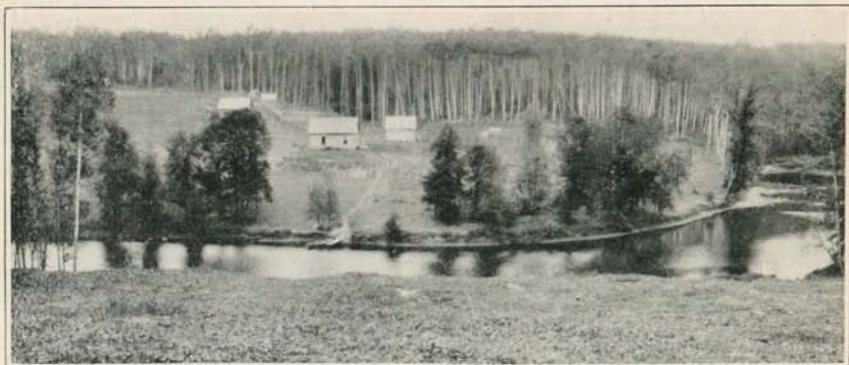
In the area covered by Lake Duluth fully 80 of its 100 square miles have a clayey drift in which stones are relatively scarce compared with their number outside of the lake area. About 10 square miles are embraced in rock ranges in which the drift has been nearly all washed away by lake action. The remaining 10 square miles are occupied by drift of a stony and sandy character. This kind of drift is found chiefly from Duluth southwestward.

In the western part of the county on the borders of Little Fork River (See Plates X A and XI A) and the lower course of Sturgeon River there is an area of over 200 square miles of clayey deposits in which very few stones occur, and which is already being developed extensively, as the soil is productive and easily cultivated. A considerable part of this area as noted above was swept by a forest fire some fifty years ago. Less extensive clayey tracts, occupying perhaps 40 square miles (See Plate IX A), are found along the borders of Vermilion River from T. 65N. to Crane Lake in T. 67N., R. 17W. These clayey tracts are in the area once covered by the waters of Lake Agassiz and the material forming the soils may be in part a lake deposit. A large part also of the area covered by Lake Agassiz in northwestern St. Louis County is hilly and many of the hills have little drift coating. There are, however, among the hills, deposits of the calcareous clayey till of the Keewatin ice field, which promise to become productive when cleared and brought under cultivation.

The census of 1910 shows 426½ square miles, or 6.6 per cent of the area of the county, to be in farms, and of these 15 per cent is improved land. The amount of improved land has probably more than doubled in the five years since the census was taken. The crops of 1909 were valued at \$919,360. Of this about one third was in hay and forage. The value of the vegetables is placed at \$220,556, which is about nine times the value of the cereals of that year (\$24,449). The yield of potatoes averages about 150 bushels per acre for the 2,378 acres planted to that crop. Within the past five years many residents of Duluth have invested in small tracts of one to five acres on the hills bordering the city and are developing them rapidly in truck gardens.

KOOCHICHING COUNTY

Koochiching County, with International Falls as its county seat, occupies the northwest part of the area under discussion. Rainy Lake and Rainy River form its northern boundary and separate it from Canada. It is traversed from southwest to northeast by the Minneapolis and In-



A. CLEARING IN POPLAR FOREST ON LITTLE FORK RIVER, ST. LOUIS COUNTY



B. DITCHING A MUSKEG IN ST. LOUIS COUNTY



C. JACK PINE OVER 100 FEET HIGH AT STURGEON LAKE, ST. LOUIS COUNTY

ternational Falls Railroad and its northeast corner is crossed by the Duluth, Rainy Lake and Winnipeg Railroad. The Minnesota, Dakota and Western has a passenger line from International Falls to Loman, and a logging road south from Little Fork into Itasca County. The principal inhabitation is along the lines of the railways and along Rainy River. Boat service on Rainy River is maintained from International Falls down to Lake of the Woods throughout the summer season.

The area of the county is 3,141 square miles which was cut off from Itasca County in 1906. Three ranges of townships on its western side, embracing an area of 1,027 square miles, have been described in the report on the northwest quarter of Minnesota, *Bulletin 12*, Minnesota Geological Survey, the 94th meridian being the boundary between the area there described and the portion of the county here discussed.

The greater part of the county falls within the limits of the glacial Lake Agassiz, less than 12 per cent being above the level of the highest shore of that lake. Of the part lying east of the 94th meridian only 170 square miles of the 2,114 are above the level of Lake Agassiz shore lines. The area covered by the lake is nearly half swamp land. The better drained areas are chiefly a calcareous boulder clay composed of the Keewatin drift. Thin deposits of lake silt have been laid down over the flatter portions. These well-drained areas are largely found on the immediate borders of the streams, although in the eastern part of the county they extend more widely over the interstream areas. In the northeastern part of the county on the borders of Rainy Lake and southward to Lake Kabetogama there are rock hills with very thin deposits of drift on their slopes. South of these rock hills there are ridges of drift which seem to be composed mainly of Patrician drift but which are coated with the calcareous Keewatin drift. They appear, therefore, to be overridden moraines of the former drift. There are other ridges in the vicinity of the Minnesota and International Railroad from Little Fork southwestward for several miles which have a nucleus of Patrician drift and a veneer of Keewatin drift. A few miles farther southwest there is a morainic strip running from northwest to southeast which is crossed by the Big Fork River just below the mouth of Sturgeon River and which runs southeastward on the north side of Big Fork River past Big Falls and thence with slight interruptions to Little Fork River in the east part of T. 65, R. 25W. The same belt reappears between Little Fork and Net Lake rivers and continues southeastward into St. Louis County, passing just south of Net Lake and leading past the south side of Pelican Lake to the west end of Vermilion Lake. This morainic strip seems to have been formed in the main by the Patrician ice field but it carries a somewhat heavy deposit of Keewatin drift. For several miles in the vicinity

of Big Falls and in much of its course gravel and sand deposits are abundant, thus distinguishing it from the ridges farther north which are composed chiefly of bowlder clay.

The highest shore of Lake Agassiz is marked generally by a well-defined gravel ridge or beach. Numerous gravelly ridges are also developed at lower levels, some of which appear as narrow strips of dry land traversing the extensive swamps. These have served as lines for highways across the swamps.

Systematic surveys are being made for draining the swamps of this county (see Plate XIV B), under the direction of the County Surveyor, and roads will be constructed along each of the main ditches thus giving openings to the market for areas of farming land which are at present cut off by swamps.

Estimates have been made from field maps of the percentages of each of the several main classes of land in this part of Koochiching County east of the 94th meridian. Similar estimates given in *Bulletin 12*, page 61, show the percentages of the western part of the county.

Percentages of Classes of Land

	Square miles	Per cent of county
Moraine with sandy to gravelly loam soil.....	87	4.1
Overridden morainic ridges with clay loam soil.....	19	0.9
Till plain with prevailing clay loam soil.....	125	5.91
Lake washed drift with clay loam soil.....	731	34.57
Lake washed drift with sandy loam soil.....	42	2.00
Sandy and gravelly deposits of old lake shores.....	54	2.55
Hilly land with rock near surface.....	55	2.60
Interior lakes	16	0.75
Swamp lands	985	46.62
	2,114	100.00

The census returns for the entire county show that in 1910 only 3.6 per cent of the land area was in farms, and only 7.5 per cent of the farm land was improved. The rapid growth of International Falls has given a good market for farm products in the north end of the county and farms there are being rapidly developed. The clay loam soil, both in the till plains above the level of Lake Agassiz and in the till which has been washed by the lake, may be developed easily into first-class farm land. It has only a moderate number of bowlders and cobblestones except locally where the underlying stony Patrician drift comes to the surface or has been involved with the more clayey Keewatin drift by the readvance of the Keewatin ice over it.



A. FIRST CROP ON LAND STUMPED THE PREVIOUS YEAR AT EXPERIMENT FARM, DULUTH



B. HEAVY STEEL DISK USED IN PREPARING NEW SOIL



C. WINTER VIEW AT DULUTH EXPERIMENT FARM

ITASCA COUNTY

Itasca County, of which Grand Rapids is the county seat, is in the western part of the area herein described, and extends also west of the 94th meridian about 20 miles into the area discussed in *Bulletin 12*. The cutting off of Koochiching County in 1906 has reduced its area to 2,780 square miles. Of this, 470 square miles are west of the 94th meridian.

A line of the Great Northern Railroad crosses the southern end of the county. Other railway lines with termini in the Mesabi Iron Range extend into the southeast part of the county. The Minnesota & Rainy River Railroad has lines running into the northern part of the county which are used chiefly for logging purposes. One of these opens a market for farming districts around the thriving town of Big Fork. The Mississippi River has a low rate of fall and a sluggish current from Grand Rapids to Brainerd, and it is navigated by occasional boats between these cities.

The eastern half of the county is very diversified in topography and in soil. The Mesabi Iron Range runs across the southeast part of the county in a northeast to southwest course and has a moraine or other thick drift covering superposed on it throughout its course in this county. Its highest points in the eastern part of the county rise above the 1,600 foot contour, but the greater part of the range falls between 1,300 and 1,500 feet. There are only a few points at which natural exposures of the rock occur on this range. The large mine pits, however, considerably increase the area of exposure.

There are extensive till plains in the northeast part of the county from the Mesabi range northward. There are also a few rock hills and ridges as indicated on Plate I.

The western half of the county has extensive tracts with level to gently undulating surface, much of which is poorly drained. These areas may be greatly improved by a moderate amount of ditching after the fallen timber and obstructions to drainage are cleared away. The extreme southeast part of the county takes in a few square miles of the great muskeg in the St. Louis River basin. Most of the southern part of the county, however, drains to the Mississippi River below where it crosses the Mesabi Range at Grand Rapids. The northern half of the county is drained to Hudson Bay. A few square miles in the northeast corner lie in the basin that was once covered by the waters of Lake Agassiz.

There are a large number of small lakes among the moraines and in the outwash gravel plains in this county, the combined area of which, as estimated by Mr. George A. Ralph, is 227 square miles. The swamps of the entire county are estimated to occupy 845 square miles, but the

area of the swamps can be greatly reduced at moderate expense and changed into fertile till plains. The soil of the till plains is diversified and ranges from fine clayey loam to a loose-textured stony loam. It was found impracticable to map with any accuracy the extent of each kind of soil in these plains. They are accordingly classed in the table below as till with mixed soil, and represented by the letters TM on the map.

The moraines are very largely of a loose-textured till with a liberal admixture of boulders and smaller stones gathered up apparently from the Patrician drift which underlies the Keewatin drift throughout this county. In some cases it is thought that the morainic ridges were formed by the Patrician ice field, for they seem to have but a thin veneer of Keewatin drift. This is especially true of those in the eastern part of the county.

The outwash plains are composed of sandy gravel. They are interrupted more or less by scattered knolls and gently undulating tracts with somewhat gravelly material not easily connected into definite morainic belts.

There are numerous places in the northeast part of the county where the relief of ridges is due in part to the altitude of the underlying rock, but there are only a few natural outcrops of rock. The areas in which rock is near the surface are estimated to amount to not more than 25 square miles in the entire county. This includes the places where rock is known to be within a few feet of the surface and the places uncovered by mining, as well as the natural exposures.

The estimates of percentages of different classes of land given in the table below are for the entire county, since only a small part of it was embraced in the estimates given in *Bulletin 12*.

Percentages of Classes of Land

	Square miles	Per cent of county
Moraines chiefly with sandy to stony loam soil.....	685	24.64
Till plains with variable soil.....	775	27.88
Gravel plains and other deposits of sandy gravel.....	225	8.10
Areas with rock near surface.....	25	.90
Lakes	225	8.08
Swamp lands	845	30.40
	2,780	100.00

The census of 1910 gives 6.2 per cent of the land area of Itasca County in farms, and of this only 12.6 per cent was improved farm land. The farms are developed chiefly along the Mesabi Iron Range in the vicinity of the mining towns. But there are also farming districts south of Grand Rapids, and a few farms are developed along the Great Northern Rail-



A. CORN WITH GOOD SIZED MATURING EAR,
AT DULUTH EXPERIMENT FARM



B. CORN SUITABLE FOR ENSILAGE AT DULUTH
EXPERIMENT FARM—FIRST CROP

way lines in the southeastern part of the county in the vicinity of Swan River, Goodland, Acropolis, and Bengal. As is natural in this region in the vicinity of mining towns, vegetables form the principal crops, and amount to about 30 per cent of the value, while cereals amount to only 4 per cent. Hay and forage in 1909 constituted 24 per cent of the entire crop values.

EASTERN CASS COUNTY

The part of Cass County west of the 94th meridian has been described in *Bulletin 12*, and an area of about 375 square miles east of that meridian remains to be described herein. This is a strip a little more than 10 miles wide and about 36 miles long. It is crossed centrally by the "Soo" Railroad on which is located the thriving village of Remer, the only village in this part of Cass County. The land surface is flat to gently undulating as far south as Remer and much of it is swampy. This part of the county was covered by the Keewatin ice sheet, and its southern limit was about five miles south of Remer at Big Rice Lake. The border of Keewatin drift deposits runs eastward from there to Shovel lake in Aitkin County. Railway cuts between Remer and Shovel Lake expose the Patrician drift beneath the Keewatin and show the more stony character of the former drift. The greater part of the Keewatin drift has a clayey to sandy loam soil with very few boulders and cobble stones.

From Big Rice Lake southward past Thunder Lake there is a prominent moraine of the Patrician drift which runs eastward, but becomes overridden by the Keewatin drift near Shovel Lake. It contains hills 50 to 100 feet high and is very stony as well as rugged. South of this moraine is a till plain several miles in width with gently undulating surface. This also is very stony but has a soil of sufficient strength to make excellent grazing land. South of this plain is another moraine running from Crooked Lake northeastward into Aitkin County. This also is rugged with sharp knolls and deep basins and its soil is very stony. A few settlers have located on and near it in the vicinity of Mae post office.

NORTHEASTERN CROW WING COUNTY

A small area of scarcely 250 square miles in the northeastern part of Crow Wing County lies in this quarter of Minnesota. It is a very diversified area, parts of it being strongly morainic, other parts of it gently undulating, and a strip in the vicinity of the Mississippi River which was covered by Lake Aitkin is very flat. The Keewatin ice extended a small lobe down the Mississippi valley into Crow Wing County as far as Rabbit Lake north of Cuyuna, but not more than 35 square miles of this county are covered by that drift. At its southwest end this area of Kee-

watin drift encroaches on a prominent moraine of Patrician drift which crosses the Mississippi River west of Rabbit Lake. The part north of the Mississippi has its western border along Little Pine River, there being an extensive gravel plain west of that stream from Emily southward. The moraine becomes diffuse east of Emily but is traceable north-eastward into Aitkin County. The part south of the Mississippi sweeps around the west and south sides of Mille Lacs Lake. A till plain with gently undulating surface and only a moderate number of surface boulders occupies the district northward from Emily to Outing and thence eastward through the northern edge of Crow Wing County into Aitkin County. Parts of this have a rich loose-textured soil. In the morainic areas there are scattered settlers who have selected the land that has relatively few boulders and easily cultivated soil. The area that was covered by Lake Aitkin lies mainly south of the Mississippi River and usually has a sandy soil except where covered by peat. The subsoil becomes clayey within the depth of a few feet and in places at only a few inches in depth and the land gives good returns under cultivation.

AITKIN COUNTY

Aitkin County lies mainly in the southwest part of the northeast quarter of Minnesota but extends also a few miles south of the median line of the state and embraces the north half of Mille Lacs Lake, the second largest lake in the state. The entire county is included in the present discussion. Nearly all of it is within the Mississippi River drainage, only a few square miles in the northeast corner being tributary to Lake Superior through St. Louis River. The area of the county is about 1,975 square miles, of which about 200 square miles is occupied by lakes. The area within Mille Lacs Lake is nearly 100 square miles.

A line of the Northern Pacific Railroad running westward from Duluth centrally across the county was for many years the only line of railway in it. But recently three branches of the Soo Line system have been extended across the county, one through the north half, another through the southeast part, and another near the line of the Northern Pacific through the central part. There is also a small railway line running from the Great Northern at Swan River to the thriving town of Hill City in the north part of the county.

Except in the vicinity of Aitkin, the county seat, the entire county is sparsely settled. There is a large amount of swamp land, it being estimated by Ralph that 828 square miles, or about 42 per cent of the county, is too wet for cultivation under present conditions. There are, however, large areas of wet land in the southern half of the county which will need only a slight amount of ditching to get rid of the surplus water after



A. SPRUCE AND POPLAR ON BED OF LAKE AGASSIZ WEST OF COOK



B. MUSKEG IN BED OF LAKE AGASSIZ NEAR BIG FALLS

it has been cleared of brush and timber. The subsoil of these wet tracts is chiefly clay with only a thin cover of peat and muck. The northern part of the county has extensive muskegs with thick deposits of peat, and wire grass marshes with a substratum of sand or silt. The place where these marshes and muskegs are was for some time after the disappearance of the ice occupied by shallow lakes which became drained with the cutting down of the valleys of the Mississippi and St. Louis rivers.

Each of the three drifts, Superior, Patrician, and Keewatin, are present in the county. The Superior drift covers several townships in the southeast part. The Patrician drift is at the surface in the western part of the county and underlies the other drifts in the remainder of the county. The Keewatin drift covers most of the northern half of the county and extends in places a few miles into the southern half. It does not, however, cover the Patrician drift in an area of high land in the northwest part of the county lying south and west of Willow River.

There are several areas of sharply ridged or morainic drift distributed widely over the county and occupying nearly one fourth of its surface. Their distribution may be seen by reference to the general map, Plate I. There are two moraines of the Superior lobe in the eastern part. All the other moraines were formed by the Patrician ice. Those in the northern half were also overridden to some extent by the Keewatin ice. As a result of this overriding the surface has, on the whole, been rendered smoother, but in a few places the later ice movement appears to have shoved up sharp ridges where the surface before had been less sharply ridged.

The sharp knolls and ridges of the moraines are usually composed of gravel and sand and of very stony till. Surface boulders are also numerous. Such land seems better adapted for grazing than for cultivation, though some good farms have been developed on hills in the southern part of the county.

The level or gently undulating tracts in the midst of the morainic areas, as well as the extensive plains separating the moraines, have usually a productive clay loam soil adapted for agriculture. This is clearly described by Warren Upham who says:

“The areas of till have everywhere a very productive dark soil, a foot or more in depth, in which the proportion of boulders and gravel is usually not so great as to hinder plowing. This soil is readily permeable to rains, and in dry seasons gradually yields its moisture to growing crops, so that they are rarely or never harmed by the moderate droughts which occasionally occur in summer. Gentle slopes and good natural drainage generally permit early sowing and planting, and the season of growth between the latest frosts of spring and the first in autumn is usually about four months, permitting a great variety of farm crops to be well matured and ripened. Only small parts of the till areas, consisting of morainic ridges and hills, have too abundant boulders and too steep slopes to be available for

cultivation; and these tracts, when cleared, are suitable for pasturage. Hay is a natural product of the district, for portions of many of the streams are bordered by moist lands from a few rods to a half mile in width, bearing a luxuriant growth of tall meadow grasses, which make one to two tons of hay per acre. Many of the swamps now inclosed by higher ground are capable of drainage by ditches and will then rank as the most valuable farming land."¹

There is a sandy plain covering from 50 to 60 square miles lying north of Mille Lacs Lake in Tps. 45 and 46 N. and Rs. 25, 26, and 27 W. on which numerous farms have been developed. The water table is very near the surface so that the crops are seldom seriously affected by drought. The soil, however, is much lighter than on neighboring till plains to the east. Another sandy area of a few square miles is found at the extreme end of the Superior lobe in Tp. 45, Rs. 23 and 24 W. Aside from this the area occupied by the Superior lobe in Aitkin County is nearly all clayey till; under present conditions much of it is wet and swampy, but may be largely reclaimed by ditching. Along the borders of the Mississippi, from the northern end of the county to where the stream leaves it on the west, farms have been developed. The soil is usually somewhat sandy but is underlain to some extent by a fine lake silt that was deposited in the bed of Lake Aitkin. This soil is, on the whole, as productive as the till areas, and has the advantage of being nearly free from stones. The extensive swamps bordering the Mississippi are rapidly changed into productive farm land when the surplus water has been removed by ditching.

The estimates of percentages of classes of land in the table below are necessarily only rudely approximate in the present sparsely settled condition of the county, and, as noted above, the percentage of swamp land will be very greatly reduced with only a moderate amount of ditching as soon as the land is cleared and the obstructions removed from the natural drainage.

Percentages of Classes of Land

	Square miles	Per cent of county
Moraines chiefly with stony to sandy loam soil.....	464	23 50
Till plains chiefly with clay loam soil.....	357	18.00
Sandy plains	121	6.10
Lakes	205	10.40
Swamps and marshes and muskegs	828	42.00
	1,975	100.00

According to the census of 1910 only 15 per cent of Aitkin County was in farms, and only one fifth of this, or 3 per cent of the county, was improved land. Corn and oats are the leading cereals and potatoes the

¹ Upham, W. *Aitkin County, Geology of Minnesota* 4:34. 1899.



A. VERY BOWLDERY LAND ON MESABI RANGE NEAR HIBBING. IT ONCE SUPPORTED A GOOD HARDWOOD FOREST



B. ROCKY AREAS IN NORTHEASTERN MINNESOTA. AMONG THE ROCK KNOBS TIMBER THRIVES

leading vegetable. Hay and forage form the principal crop on the farms, and in addition to this there is much wild grass put up as hay. Strawberries and raspberries are important small fruits. Apples and plums are grown successfully as orchard fruits. The prominent hills and ridges in the moraines have a topographic condition favorable for the growth of orchard fruits, since they often escape the frosts that affect the lower lands around them; but as yet very little use has been made of them for orchards.

CARLTON COUNTY

Carlton County is located at the southwest end of the Lake Superior basin, south of the western part of St. Louis County. It has an area of 867 square miles. The eastern portion, comprising less than half of the county, is tributary to Lake Superior, the western part being tributary to the Mississippi, partly through the Kettle River southward into the St. Croix and thence to the Mississippi at Hastings, and partly through Prairie River directly westward into the Mississippi in Aitkin County. Glacial Lake Duluth, which occupied the western portion of the Superior basin, covered fully 150 square miles in the southeast part of the county, chiefly in the basin of the Nemadji River. The St. Louis River enters the area that was covered by Lake Duluth at Carlton and runs near the north edge of that lake area to Lake Superior.

This county was covered by the Superior ice lobe, except a few square miles in the northwest corner in which both the Patrician and Keewatin drifts are exposed. The moraines of the Superior lobe run from northeast to southwest across the portion of the county lying north of the axis of the Superior lobe and the bed of Lake Duluth. The moraines south of the basin and bed of Lake Duluth have a nearly east to west trend in southern Carlton and northern Pine counties. The morainic areas occupy about one third of the surface of the county, not including extensive areas of outwash associated with them, which, together with the lines of glacial drainage embrace nearly one eighth of the county. It is thought that some of the more prominent moraines along the north side of the Lake Duluth area have a nucleus of Patrician drift of morainic character. The trend of the moraines of the Patrician ice sheet here is very similar to that of the moraines of the Superior lobe, but the ice laid on the northwest side of the Patrician moraines, or directly opposite the position which the Superior lobe presented to its moraines in this particular district. The Patrician ice, however, had melted away from its moraines before the Superior ice advanced over them.

There are extensive till plains in the western half of the county covering over 200 square miles. There are also extensive swamps in that

portion, chiefly among the morainic areas, but also to some extent among the till plains. Rock ledges are exposed chiefly along the valley of St. Louis River, and along Moose River below Barnum, there being only occasional outcrops of a few acres in a place elsewhere. There are relatively few lakes and their combined area is estimated to be but $9\frac{1}{2}$ square miles.

The greater part of this county has a rich soil of clay loam and sandy loam, and boulders are seldom so numerous as to greatly interfere with the cultivation of the land. A compact clay occupies much of the bed of Lake Duluth.

The United States Bureau of Soils has prepared a map and description of several townships in the northeast part of the county and of the neighboring part of St. Louis County, Minnesota, and Douglas County, Wisconsin. In this the area covered by Lake Duluth is largely classed as Superior clay. The sandier portions on the northwest border of the lake are classed in part as Superior silt loam, in part as Miami sandy loam, and in part as Miami fine sand. The morainic areas are classed chiefly as Miami stony loam, though areas in the vicinity of Barnum are designated as Barnum stony loam, and Barnum loam, and those near Sawyer as Miami sandy loam. The areas of outwash are largely classed as Miami sand, but they also embrace parts of the Miami sandy loam. They include also the Miami gravelly sandy loam found extensively from Cloquet southward to Otter Creek, and part of the Barnum stony loam from Atkinson to Mahtowa. The area mapped as Miami gravelly sandy loam north of Cloquet is very different from that south. It is a morainic area while that south of Cloquet is outwash. Reference may be made to the report on this area published as a part of the *Annual Report of the Bureau of Soils* for 1905 for descriptions of the soils and their agricultural possibilities.

The following table presents the percentages of classes of land as determined on the geologic basis. Owing to the lack of roads in certain parts of the county where settlements have not yet reached the estimates are necessarily only rudely approximate.

Percentages of Classes of Land in Carlton County

	Square miles	Per cent of county
Morainic areas outside Lake Duluth chiefly sandy and stony loam	273	31.50
Waterlaid moraines in Lake Duluth.....	26	3.00
Till plains, clay loam to sandy loam.....	212	24.40
Gravelly and sandy outwash and glacial drainage.....	102	11.80
Sandy plains in Lake Duluth.....	20	2.30
Clayey plains in Lake Duluth.....	111	12.80

Rock ledges	3½	0.40
Lake areas	9½	1.10
Swamp lands	110	12.70
	<hr/>	<hr/>
	867	100.00

The waterlaid moraines in the bed of Lake Duluth have considerable expression for a few miles west from Barker, the topography being nearly as sharp as that of landlaid moraines. In the remainder of the lake area, however, waterlaid moraines are very inconspicuous. They determine to some extent the course of streams tributary to the Nemadji River even where lacking in surface expression.

The census of 1910 reports 21.7 per cent of Carlton County to be in farms, of which 22.8 per cent is improved land. Oats, wheat, and barley are the main cereal crops, rye and corn being grown in less amount. Potatoes are the main vegetable crop. Apples and plums are successful orchard fruits, and berries of all kinds are found very productive. In this county, as well as in other parts of northeastern Minnesota, wild raspberries are very abundant and large numbers of the residents resort to the unappropriated lands for them in the berrying season.

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