
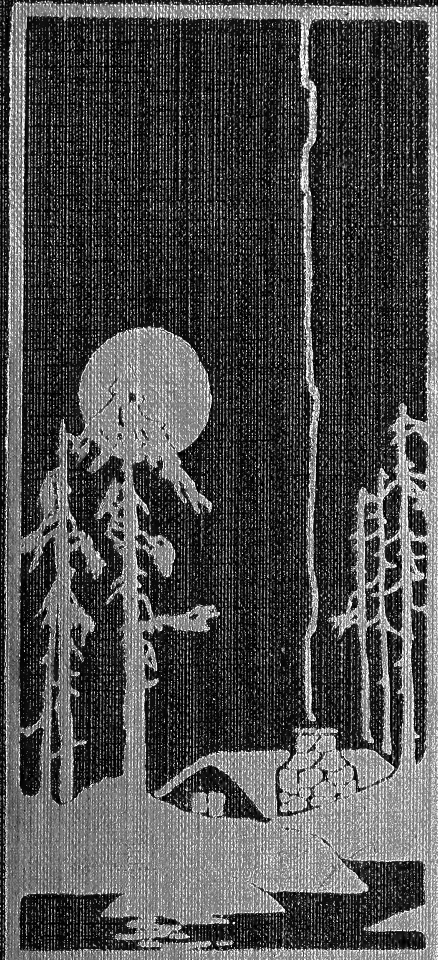


THE STORY OF THE NORTH STAR STATE

D. E. WILLARD

CYPRIPEDIUM.—The Moccasin Flower.

STATE FLOWER OF MINNESOTA.

THE

Story of the North Star State

BY

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PREFACE

Minnesota is a State of varied natural resources. Within the boundaries of the State are the oldest lands in the world, the oldest known geologic formations,—the ancient granites, and the youngest formations,—the glacial deposits.

The purpose of this book has been to set forth in simple language the scientific story of this great land. The story ought to be both interesting and valuable, for upon a proper understanding of the facts depends the best development of the natural resources of the State. Such a story might be dry and tedious. It may be as interesting as a romance. It depends upon how the story is told. To be scientific a treatise does not have to be hard. Scientific facts do not necessarily need to be expressed in technical language. Many-syllabled words sometimes conceal ignorance. The most profound facts of science may be stated in simple and readable language.

Whatever may be said of the style and language of this book the subject should be interesting because it is vitally important. The fertility of the soil is not a matter of chance but a product or result of activities that have been long going on. The best method of approach to an understanding of the soil is through a study of the way by which the soils were formed. The best use of the soil is learned by knowing the nature of the soil. The present volume treats of events that have occurred by which these results have come about. It is an attempt to explain the history of the soils, the rivers and lakes, the forests and the mines. It is the story of the land.

"The Story of the North Star State" is intended for the great reading public of Minnesota. The natural resources of soil, of rivers and lakes, of scenic beauty, of mines, of rocks, and of forests ought to be of interest to every citizen.

The book is intended for use as a text-book in schools. The rising generation ought to know the State and its resources. The author has had many years' experience in educational work. It is his opinion, based upon observation and experience, that in the curricula of our schools not enough time is devoted to the study of our own State and its resources. It is hoped that the present volume will supply in some measure the need for a text that deals with home geography.

Few books of the character of the present volume have, within the author's knowledge, been written about any State. This book has not been modeled after the work of any other, but has been written to supply what the author regards as a definite need.

Several years ago the author published "The Story of the Prairies," a popular treatise on the prairie State of North Dakota. The author had then but recently left the University where as a student he had occasion to consult many dusty volumes, and to read many pages of tedious technical matter. "The Story of the Prairies" was written in protest against the unnecessarily hard, dry, and technical treatment of the subjects studied. If a writer knew what he wanted to say why could he not say it in common simple language such as could be readily understood by one of average intelligence?

The reception that has been accorded that book has far exceeded the author's expectations. It is now in the ninth edition. It is widely used in the schools of North Dakota and is in the libraries of most of the large cities of the country. It has found readers in nearly every State in the Union, in Canada, and many European countries. The general plan of "The Story of the Prairies" has been followed in the present volume.

In the final chapters, under the title "Geology from a Car Window," is given a traveler's view of what has been described in the foregoing pages. It has been attempted to point out what any observer can see as he goes; to aid the reader who travels to know what he sees at the time he is looking at it. It is intended that these chapters shall serve as a kind of laboratory guide illustrating and pointing out the features of the landscape that have been described.

There are those who travel yet do not see what they look at. There are those who look out from a car window and see only grass. A hill is taken for granted as a hill; a river as a river. Often it is not realized that there is a reason for every hill, and a history of every river, that the stones that lie in the field are not there by accident but are the result of definite processes.

To the pupils in our schools it is hoped that "Geology from a Car Window" will be of assistance in the study of local home geography. The character of the landscape about every railroad station in the State is described. Thus local examples of the geologic features that have been described in the preceding chapters are specifically pointed out. It is thought that the descriptions in these chapters will be of value to the general reader for reference as well as an aid to observation in traveling, and will be of local interest in the study of home geography in the schools.

In the preparation of several chapters the author has had most valuable assistance from Dr. Frederick W. Sardeson, geologist to the Minnesota State Securities Commission. Dr. Sardeson has had wide experience in the field on Federal and State surveys, and his intimate knowledge of the glacial geology of the State has made it possible to present a more complete story than could otherwise have been done. Unpublished notes and records as well as his published papers have been freely drawn upon. The author wishes to acknowledge Dr. Sardeson's contribution to these chapters, and to express his appreciation of the cooperation extended.

The author wishes to express appreciation to Dr. F. J. Alway, head of the Division of Soils, University of Minnesota, for reading in manuscript the chapter on the Soils of Minnesota, and for suggestions, advantage of which was taken in revising the manuscript, and also to Mr. Carlos Avery, State Game and Fish Commissioner, for very kindly reading and making suggestions on the chapter Out Doors in Minnesota, and for the loan from his department of cuts used in illustrating this chapter.

The author's thanks are extended: to Mr. W. T. Cox, State Forester, for permission to go through the files of photographs in his office and to select those desired, a number of which appear in the text; to Professor W. H. Emmons, director of the Minnesota Geological Survey, for the loan of cuts which have been used; to the director of the U. S. Geological Survey for cuts from U. S. Publications and for photographs very kindly supplied from negatives in the files of the survey at Washington.

In the preparation of the chapter on The Dalles of the St. Croix use has been made of Professor C. P. Berkey's Handbook, and acknowledgment is made of material drawn from this source.

The author wishes to acknowledge his indebtedness for the use made of Bulletins 12, 13, and 14 of the Minnesota Geological Survey, and the accompanying maps, by Leverett and Sardeson. The text and maps of the bulletins have been freely drawn upon in the discussion of soils; and the maps have been constantly used in checking the author's observations in travels over the State and as a direct source of information in preparation of the chapters "Geology from a Car Window."

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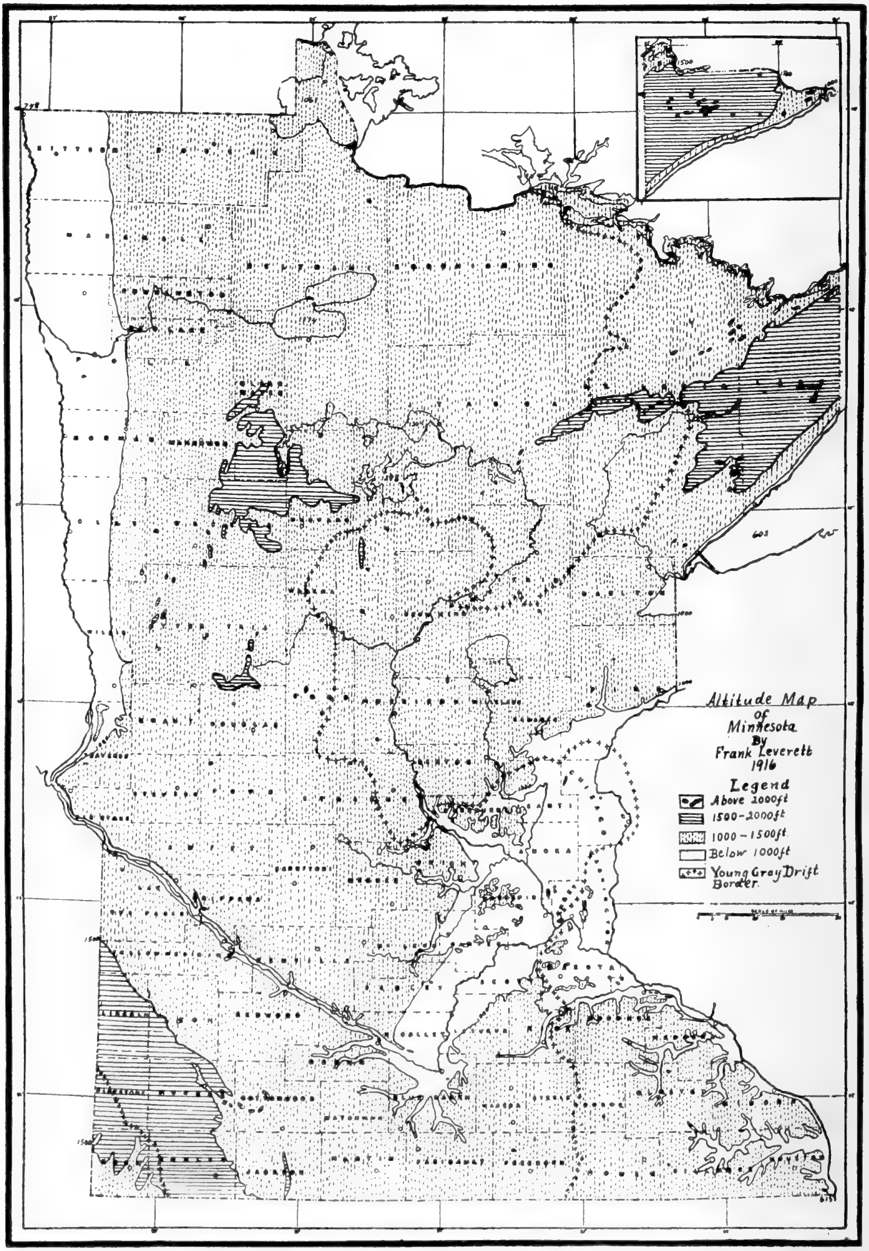


FIG. 2. Altitude Map of Minnesota.

The Story of the North Star State

CHAPTER I

THE LANDSCAPE

Introductory. How many of the readers of this book understand what is meant by the words Landscape Geology? Everyone has seen a landscape, but we often hear people speak about geology as though that meant rocks and stones and minerals and therefore is hard and dry. It is true that geology deals with rocks and stones and minerals, among other things, and sometimes it is hard and dry. But arithmetic and grammar, history and geography, are sometimes "hard and dry" also. It may not be the fault of the subject that it is uninteresting. The trouble may be in the way it is taught.

If, after the reader has studied this book, he finds geology "hard and dry," the trouble will not be with the subject, and probably not with the reader. If the author has not made the landscape, the fields, the roadside, the school grounds, the river, and the lake, more interesting because we have come to know more about them and to see something more in them than mere rocks and stones, sand and water, then it is his fault and not that of the subject.

Meaning of the Landscape. We have all seen a landscape, but have we ever thought what the landscape means? Has it ever occurred to you, that every hill, every level tract, every valley, every hollow or lake basin, has a meaning? We speak of the land surface as the landscape. Has it ever occurred to you that this landscape came to be the way you see it today through a long series of processes?

The land surface is not the same today that it was yesterday. Tomorrow it will be different again from today. The land surface is changing all the time. These changes are going on very slowly, to be sure, but they nevertheless go on. They have been going on during the countless ages of the past, and will continue so long as the earth stands.

The landscape of Minnesota is the expression of all that has gone on since the primitive crust of the earth first appeared above the waters of the primeval ocean. The wind and the rain, frost and sunshine, began their task of leveling down the landscape as soon as it appeared above the sea.

The land surface—that is all of the earth's crust that is above the level of the sea—is being weathered, eroded, worn down by the natural action of the elements. One of the most active of the natural processes by which land surfaces are worn away is that of running water. Other agencies also do active work in changing the form of the landscape. Sometimes natural agencies also pile up portions of the surface materials as well as lower them or wear them away. Wind piles up fragments of earth into hills, called dunes. Ice in the form of great glaciers has piled up masses of clay, sand, gravel, and boulders into hills, called moraines.

What we see all about us is today's landscape, not yesterday's nor tomorrow's. It must not be thought there is any very abrupt or noticeable change from day to day, but because one cannot see the change from day to day does not alter the fact that change is going on. Yesterday and tomorrow in a geologic sense are but relative terms. "One day is with the Lord as a thousand years, and a thousand years as one day."

The Types of Hills. At first glance at the landscape of Minnesota it may seem as though there is not much system, that the hills and hollows, plains, lakes, and marshes are distributed with no particular system or order. A little study, however, will soon show that this is not the case; that the landscape is the result of an orderly, although complicated, system of processes, and these processes have been going on for long ages. However, if we go back to inquire into the causes that have worked, the problem will not be as difficult as may at first appear. And, indeed, the reader may come to the conclusion that the history of the making of Minnesota's landscape before men appeared upon the earth is quite as interesting as the history of what has transpired since man came upon the scene.

Minnesota is not what would be called a hilly state, yet it has about all the kinds of hills there are. The hills of Minnesota may be divided into the following classes: (a) Hills of erosion, or those that have been formed by running water; (b) Hills of glacial deposit, masses of earth materials piled together by moving ice; (c) Hills of glacial erosion, those that have been carved out of the landscape by the digging and scooping agency of moving ice; (d) Hills of wind-blown sand; (e) Loess hills, masses of fine grained material borne by the wind and deposited as dust; (f) Hills of uplift, higher parts of the crust of the earth pushed up by forces within the earth; (g) Volcanic hills, formed by violent explosion or upheaval from within the earth.

These seven types include the more important kinds of hills that exist anywhere in the world. The processes by which these hills have been formed are the processes by which hills have been formed since the beginning of the world.

Hills of Erosion. The side of a valley is a hill. If valleys are close together, they are parted or separated by hills. When it rains on the land, water runs down the hillsides and down the valleys. That is how the valleys and hills, that is, hills of erosion, are made. Everyone has seen how a plowed field, a road grade, or a bank of earth is torn up, washed out, gullied, or ditched by storms. After many storms a ditch may grow to be a larger gulch. That is how such erosion valleys as are found in southeastern Minnesota came to be. The difference between the valleys in southeastern Minnesota and the gullies or gulches in the fields, is that the former have been a good deal longer in the making, and they are therefore larger.

Hills of erosion have been formed by running water. They are generally parts of a plain which have not yet been removed by erosion of streams. Such are the hills in southeastern Minnesota. In this part of the state the plain has been cut into by streams. The landscape is no longer a smooth plain, but is intersected by many deep valleys along the streams.

Go down one of these valleys and it will be observed that rock layers or strata nearly horizontal in position frequently extend along

FIG. 3. Valley of the Mississippi at Minnesota City.

the hillsides. When wells are dug or bored, these same layers are found to underlie the hills. These rock layers or strata once extended across the valleys from one side to the other. There were then no valleys. Once the tops of the hills on either side of the valley were connected by a plain. Rain water gathered into streams and the streams carved away the earth materials. This valley is a valley of erosion, and the hills on either side are hills of erosion. In the course of time, if the order of Nature is not interrupted by some great earth change, these hills will be all washed down and destroyed by the same process that formed them. In other words, ultimately this landscape will be reduced to a plain. The high plain is being cut down to a lower plain, and until that work is completed, there will be hills.

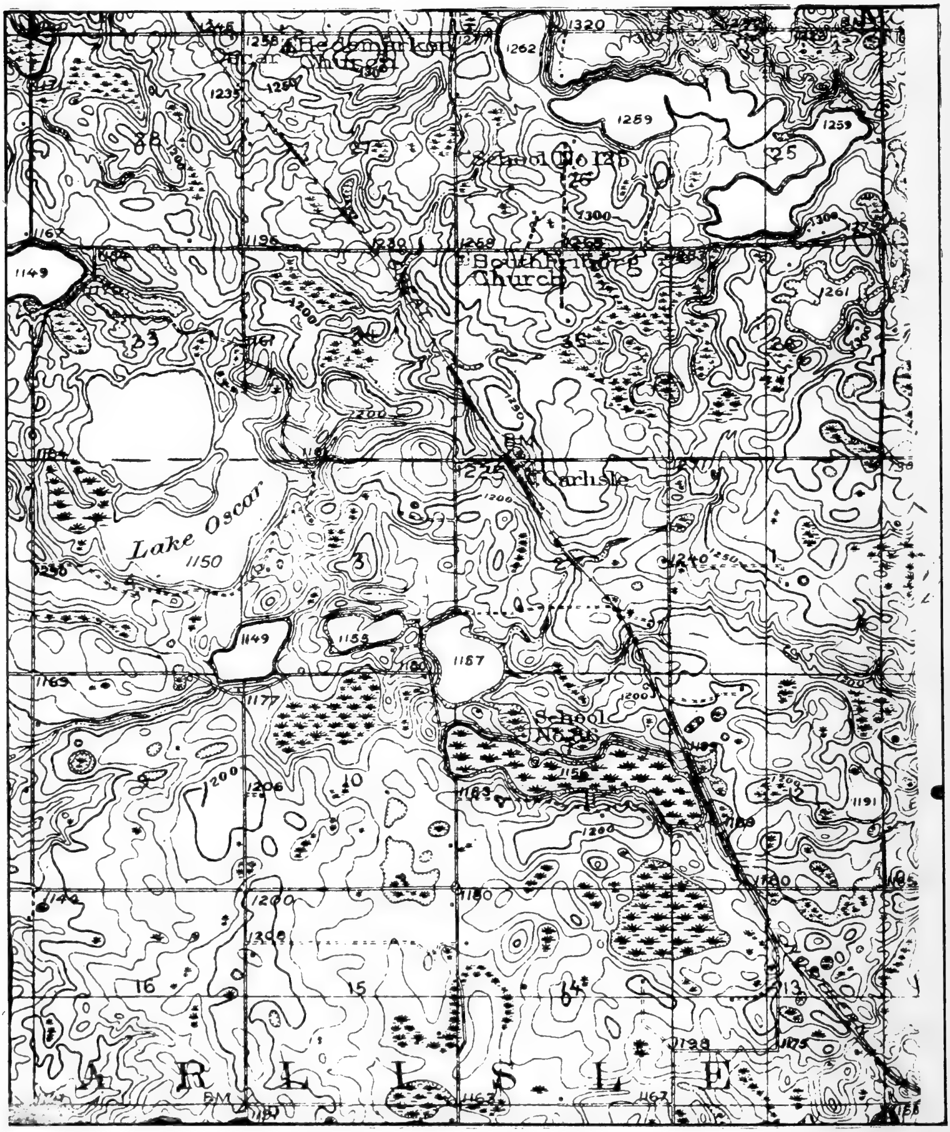


FIG. 4. A Fragment of Topography in the Lake Park Region.

The slopes that form the sides of the valleys, that is, the hillsides, are more or less covered with a mantle of soil. Soil is made up of the broken fragments of the rock of which the hills are composed. In other words, the plain was once rock. Its surface has crumbled into soil. It has been cut into by streams because the rain fell on the plain more rapidly than it could soak into the soil, hence it had to run off. In running off it carried particles of soil and rock with it. By and by all the hills will have been carried away particle by particle. This then will be a new plain at a lower level than the old plain. The sea may break in over it. If, in the lapse of ages, that plain is raised by some great change of the earth, the erosion of hills will begin again just as it was begun this time.

A glance at the map of southeastern Minnesota shows that this region is well drained. It is the oldest part of the **landscape** of Minnesota, but it is not the oldest **land** of Minnesota in point of years or ages. Streams have worked back from the Mississippi until the whole plain is marked by valleys. The ridge road from Winona to LaCrosse winds to and fro in the effort to keep up on the surface of the old plain. On this undulating prairie surface there are few stones. Descend by one of the intersecting roads into one of the valleys and it will be observed that there are many stones. Sometimes after a heavy spring rain the road may be in places washed so that it is a pavement of stones. These are the harder fragments of rock that have fallen down from the hillsides. Ledges of rock project from the hillsides. These may be undermined by the removal of other softer rocks beneath, and, aided by frost, the fragments break off and fall down as stone.

Hills of Glacial Deposit. Throughout a large district of central and southern Minnesota occur hills of variable size and of very distinctive character. They differ entirely in appearance from the hills in southeastern Minnesota. There is no general uniformity in their height. They are often not separated by valleys, but rather by hollows without outlets. They are sometimes stony in character, the stones being of great variety and nearly all rounded in form. Rocks in horizontal layers or strata never occur in these hills. They are mounds or piles of earth carried, or "drifted," by glaciers from Canada, and thrown down wherever the end of the glaciers happened to be at different times.

The "drift" landscape is often very rough and irregular. The hills vary in size from little knolls a few feet in height to massive hills 150 feet, or more, in height. Their sides are often steep, and the tops always rounded in outline. They are made up of clay, sand, gravel, cobbles, and boulders. Some of them are almost entirely made up of clay with few stones, and again they are composed of mixed clay and boulders. Frequently they are sources from which gravel and sand for road building and other purposes are obtained. Many times the sands and gravels of which the hills are made up are distributed in beautiful layers, the material having been assorted by water when they were laid down.

The landscape in these hilly regions in some districts is strewn with larger and smaller stones or boulders. In other localities there are very few large stones. The stones, when broken, are many times seen to be made up of beautiful crystals. If fragments from these stony hills are

FIG. 5. Second Growth Norway Pine on Stony Morainic Ridge, Cass County.

compared with bed-rock outcrops in the vicinity, they are found to be totally different in kind from rocks of the outcropping ledges. It is worthy of note, however, that the rock ledges which are of the same kind as these boulders are located, in a general way, to the northward of the boulders. It is frequently observed also that where there is an outcrop of some hard rock, boulders will be seen of the same kind of rock southward from this outcrop. This would seem to suggest that the boulders have been broken off from these ledges and moved southward. And, in fact, this is what has happened.

These boulders and also the sand and gravel grains are of many kinds. Granite, quartzite, hornblende, limestone, porphyry, slate, and many other rocks and minerals, the names of which would be hard and too numerous to mention, are found mixed in the most complete confusion.

These field observations suggest that there has at some time in the history of the past been a great stirring and mixing process by which the surface of the landscape has been changed and modified. These rocks are called drift rocks, and the hills are known as drift hills, because they have been moved or drifted to their present location from other places.

Scattered among these knoblike hills are hollows, sometimes deep and kettle-like, sometimes like broad flat pans. These hollows may or may not contain water. Many thousands of Minnesota's most beautiful and attractive lakes are in hollows or basins of this character, and they are lakes because more water gathers in them than evaporates. Many of these lakes and ponds are without outlet. Some overflow all the time, others only at certain seasons.

In southeastern Minnesota, where the hills have been formed by erosion of running water, all the valleys or hollows have outlets. There are no lakes. The rocks are of one kind, and are in definite layers or strata. Among morainic hills, as in the Park Region, on the other hand, the hollows are without drainage outlets, and lakes are everywhere. The stones are of every variety known in regions to the northward; they are in broken fragments always with their corners rounded and distributed with every degree of irregularity. In southeastern Minnesota the hills are carved out of the landscape by running water; in the Park Region the hills have been dumped upon the landscape by ice in promiscuous confusion.

Hills of Glacial Erosion. Another class of hills marks the landscape of Minnesota, particularly in the northeastern portion of the State. These hills, while related to the "dumped" hills just described, differ from them in that the hills are made of rock fixed in position and generally of one kind of rock. These contrast somewhat sharply with the hills of glacial deposit just described. Hills of this character occur notably in the vicinity of Carlton in Carlton County, near the city of Duluth, in the neighborhood of Vermilion in St. Louis County, also in the country about Rainy Lake.

These hills are generally composed of hard rock. Hills of this character are without erosion valleys between them. Their surfaces are rounded and smooth, and such hills are like gigantic rounded boulders, of one kind of rock, but each is in position just where the rock was before the ice sheet passed over. Many of them are erosion hills re-shaped by the rubbing which the glaciers gave them.

Hills of glacial erosion are generally composed of hard rock, because otherwise they would not have withstood the wearing, breaking, and crushing power of the great ice sheet. Irregular surfaces generally when passed over by the ice sheet tended to be leveled down. The harder the rock over which the ice passed the more stoutly it withstood the wearing action of the ice. However, when a harder place in the rock floor was encountered, the less hard rocks surrounding would naturally give way more readily, and this would tend to cause a hard hummock or even a hill to remain. As the ice of the glacier continued to move, hard hills became obstacles to the ice. Ice in the form of glaciers moving in great masses develops currents in passing obstacles, something after the fashion of rivers. Glacier ice will move up over an obstacle when it can do so and keep its surface level, as in the case

Fig. 6. Shores and Islands of Vermilion Lake.

of a stream of water. When the movement of the ice is obstructed by obstacles, it plows out a hole, something as water passing over a cataract excavates a hole in the river bed. The currents of ice formed as it moves **around** an obstacle dig harder, thus hollows between or near the obstructions are formed, and the buckling on the near or "stoss" side of a hill causes increased erosion on that side. Thus rock basins and rock hills of erosion were formed.

Hills of Wind Blown Sand. The wind is sometimes an active agent in shaping the landscape forms. Sand and dust borne by the wind and drifted into piles form dunes. Dune topography may be recognized sometimes in places where the sand no longer drifts with the wind. North of Minneapolis and St. Paul are tracts of typical sand dunes, also north of Brainerd, east of Fort Ripley, south of Little Falls, southeast of Richardson, and at Zimmerman. The sands that make up those dune areas came from the flood plain of the Mississippi while this river was flooded by water from melting glaciers. The glaciers are gone, the river is quiet, and the dunes are no longer active owing to the growth of vegetation which forms a covering sufficient to hold the surface sand and dust in place.

Active dunes are found in a few places in Minnesota, as east of Fridley and Coon Creek, and northward along the Great Northern Railway, and in two places north of Elk River. In these open or active dune tracts the sand grains creep with the wind and form the characteristic hills and sinks which distinguish a wind-blown landscape. "Active" sand dunes are literally moving hills. The hills do not move bodily, but they progress slowly in the direction of the prevailing wind. The sand grains may be rolled, or they may be taken up bodily by the wind and carried and deposited. The size of particles moved depends upon the velocity of the wind. The formation of dunes, however, does not altogether depend upon the sand grains being taken up by the wind. Just as in stream currents pebbles are rolled on the stream bed, so sand grains that are too large to be lifted bodily and carried may be rolled by the force of the wind. The grains thus carried, or rolled up the windward slope, stop on the lee side. Thus active dunes move in the direction of the prevailing wind.

There are two general types of dunes, those that are of fine, dusty sand, and those that are of coarser material. Minnesota dunes are mostly of the dusty variety. The dust holds moisture, hence such dunes are fertile. A few only, in Minnesota, are coarse and barren.

Active dunes are without soil or grass upon them. If grass and bushes once creep up over a dune, it is thenceforth a dead one. Dust gathers in the grass and soil is formed, and unless fire or drouth again destroys the vegetation, the sand and dust cannot move. If the farmer carelessly plows up the land where there is dune topography, and lets the fall and spring winds whip the surface, clouds of dust fly off while the coarser sands begin to pile up into windrows, the beginnings of dunes. Nearly all of the Minnesota dunes were dead before settlers came here, and it is a good idea to keep them dead.

The dune sands of the counties of Anoka, Isanti, Sherburne, Benton, Morrison, Crow Wing, Chisago, and Washington came from the flood plains of glacial rivers which were formed by the waters from the melting glaciers. The glaciers have long since melted away, the rivers have become smaller modern streams or have degenerated into sloughs. The dunes were formed before vegetation had covered the landscape. The old dune topography remains, but the dunes are mostly "dead" except where the covering of vegetation has been destroyed.

Loess Hills. A peculiar type of hills occurs in southern Minnesota known as loess hills. These hills are thought to have been formed from dust carried by the winds, which settled in grass and woods until a thick coating was formed. Loess hills are well developed south of Red Wing and Cannon Falls to Goodhue and Zumbro Falls; about Plainview and east of Rochester; about Lewiston, Harmony, Canton, and east of Caledonia; also in the southwestern corner of the State in Rock County, south and west of Luverne and about Manley and Hills, and extending into South Dakota and Iowa. The hills are spoken of as loess hills, although the hills are generally not made of loess, but only capped or covered by it.

The material known as loess is a grey, porous, soft earth, and generally caps the hills where it occurs. Water soaks into this material readily. The slopes of the loess hills are smooth and stoneless. As in case of the Minnesota dunes, the loess is an old deposit. Already in Minnesota rains have leached the soluble parts of this fine porous dust soil, and a clayey soil has developed upon the surface. On clay soils water collects but does not quickly soak into the soil so that run-off and erosion becomes more active than on a new loess surface. Thus as time goes on these peculiar hills tend to lose their original character because the caps of loess on the hills have become clayey and have begun to wash down the slopes. Where loess occurs in thick beds and streams cut into it, erosion goes on very rapidly owing to the softness of this material, and once a cutting stream gets started in it, it cuts down with great rapidity.

Volcanic Hills and Hills of Uplift. Volcanic hills, and hills formed by the upward thrust of the crust of the earth, occur in northeastern Minnesota. The rugged, rocky hills in the western part of the city of Duluth were formed by volcanic outburst or explosion from the deeper parts of the earth. The bare rocky hills between West Duluth and Carlton and northward to Scanlon are also of this character. The hard rocks of which these hills are formed are known as igneous rocks (igneous from a Latin word meaning fire). The rocks were formed from highly heated masses of rock materials that were forced out from the earth's interior. Hills in Cook County are of this character also.

On the other hand, the Mesabi and Vermilion Ranges in St. Louis County and the Cayuna Range in Crow Wing County are hills which were formed by upthrust of "solid" portions of the earth's crust. The northeast part of what is now Minnesota was among the earliest parts of the North American continent to be formed. It is a part of the first formed land surface in the world. These hills have been so much worn down by erosion and by weathering and by the grinding of the great continental glaciers which have passed over them, that they are now mere remnants of what have been vastly larger hills or mountain ranges.

The surface of northeastern Minnesota includes the highest points in the State. In Cook County some hills rise to 2,200 feet above sea level, or 1,600 feet above Lake Superior. This high land is rocky and stony, that is, the hills are of bed-rock strewn with stone fragments. The rock ribs of the hills are either bare or sparsely covered with glacial boulders. This rocky and stony highland extends across Lake County into St. Louis County, where it divides. One "range" extends north of Vermilion Lake nearly to International Falls. Another range runs south of Vermilion Lake, westward to Grand Rapids. Another runs to Duluth and Carlton parallel to the shore of Lake Superior. This last is a rock ridge with the stony glacial highland moraine on its top. Between these rocky and stony ranges which run out like fingers from the northeastern point of Minnesota, there are flat, wide valleys. It is interesting to note that the eastern end of ancient Lake Agassiz, the lake which occupied the basin of the Red River Valley, occupied the flat basin of Little Fork River between the Vermilion and Mesabi Ranges. The valley of the St. Louis down to Brookston is broad flat, and mostly swampy. It includes the old glacial Lake Upham Basin.

Plains. In the northwestern part of the State, in western Kittson, Marshall, Pennington, Polk, Norman, and Clay Counties, the landscape appears to the eye almost perfectly flat. Broad level reaches extend away until earth and sky meet in a level horizon.

This plain or prairie was the floor of a great body of water. This Red River Valley plain, famous for its wheat fields, was formed by the deposition of finely broken rock or mud on the bottom of a great glacial lake.

Extending across Beltrami and Koochiching Counties is a great wet plain known as the Beltrami Swamp. Other wet plains or swamps occur, but this is the most extensive plain of this kind in the State. These wet areas are classified as bogs, muskegs, swamps, and marshes. (See Chap. VIII.)

Prairies. The most wide-spread and important type of plain in Minnesota is that commonly called "prairie." The "prairies" of Minnesota as dinstinguished from lands of similar character on which trees grow naturally (forests) will be considered in another place (Chap. VII). The broadly rolling or undulating plains that make up a great part of southern and central Minnesota owe their character to the action of the great ice sheets. The prairies, as also much of the gently rolling forested territory, are what is called ground moraine. The soil and subsoil to a depth of many feet is a deposit made by the great ice sheets. To the action of ice, as we shall presently see, the landscape forms of Minnesota are largely due.

Glacial Valleys. The land surface of the State is still further marked by valleys that are long, wide, and deep, and that seem to bear no direct relation to any modern streams. Many times these valleys are occupied by streams, but generally these streams are small in comparison with the size of the valleys they occupy and they are often very sluggish, and frequently do not erode their bottoms or banks. It is plain that these valleys were not made by the streams that today occupy them.

Sometimes lakes lie in these valleys. The valleys and the lakes have no relation to modern drainage. They are relics of an earlier age. The agency that caused them has ceased to be. The waters that came from the melting of the great ice sheets that once lay over the landscape had to escape somewhere, and these long, often broad and deep valleys, which are are a marked feature of the landscape, tell of the great floods of water that once flowed across the land.

Rocky Lands. Hills of glacial erosion have been referred to before. These are of such importance in northeastern Minnesota that a further word may be said about them here.

FIG. 7. A Fertile Valley North of Vermilion Lake at Half-way House.

A tract of rough, rocky land extending across Cook, Lake, and St. Louis Counties includes hills of glacial erosion, but many of the rocky hills are remnants of larger hills and of mountains which have been worn down by weathering and by the action of great glaciers which have passed over them. The surface of the landscape is naked rock over considerable areas, with hollows and lakes, swamps, and meadows interspersed. Much of the landscape is a desolate, rocky waste. Boulders of huge size are strewn in wild profusion. Myriad lakes in which fish abound are often without outlets. The country is almost without drainage.

The rock formations are the oldest in the State and in the world, yet the landscape is young. Drainage has hardly developed beyond the stage of infancy. Except the region bordering the north shore of Lake Superior, where streams descend from the highland to the lake basin some hundreds of feet below, the region is undrained. Hundreds of lakes lie in basins that have been hewed out of the hard rock floor. One of the oldest mountain ranges in the world was here. There remains the worn down remnants of mountains and hills which were formed by volcanic outburst or broad crustal upheaval of the earth. Weathering of the rocks has been going on here since the world began, and great glaciers have rasped and worn and polished the hills that remain.

Why this, the oldest land in the United States and the world, should be one of the youngest landscapes, invites to a study of the great agency, ice, by which the most profound changes that have affected any land have been wrought. This great story will be studied in later chapters and explanation of some of these wonderful things in this wonderful land will be attempted.

Drainage. A glance at any good map of Minnesota reveals at once some very remarkable features about the land surface. The most casual study of the map reveals that while the State has many rivers, yet much of the land is not drained. A closer study shows that many rivers and streams which are themselves small and sluggish, occupy valleys often of immense size. Lakes lie close upon the banks of streams, yet the lakes are not drained. Lakes are not infrequently connected by streams during seasons of high water, and separated by swamps or marshes the remainder of the year. Water may flow through a channel from one lake or depression to another at one season, and in the reverse direction at another. A stream may take its origin in a higher plain and flow away and disappear upon or in a swamp or marsh. A river may flow in a given direction for many miles, then make an abrupt turn, flow in a widely different direction, perhaps doubling back upon its own course. The St. Louis River meanders through a marsh for many miles and then suddenly (at Floodwood) plunges down into Lake Superior; the Mustinka River flows in an eccentric course, going first due south, then later, as the Bois des Sioux, due north; Rum River starts south from Mille Lacs Lake, then turns abruptly east and north away from its proper course to the Mississippi via the St. Francis and Elk Rivers; Snake River, after starting south

FIG. 8. Garden Plot of Anthony Gasco on Lake Harriet, Lake County.

for Rice Lake and the Seven-mile Swamp to Rum River, runs away to the St. Croix; Straight River is the crookedest of all (it was named for a Mr. Straight); the Zumbro and its branches form a complicated system in getting to the Mississippi. The great Mississippi River is said to have its source in Itasca Lake, yet beyond Itasca Lake are Lake Desoto and others, and beyond these the ultimate source of the river is lost in a labyrinth of marshes and swamps so that the real source or beginning of the Father of Waters may not even in this day of geographic knowledge be said to be known.

Covering an area of many hundreds of square miles in Beltrami and Koochiching Counties, the great Beltrami Swamp lies high above the Rainy River to the north and the great Red River of the North to the west, yet this vast area is a swamp or marsh because of lack of drainage. In other words, the water fails to flow away down hill. *Red Lake, the largest body of water wholly within the State of Minnesota, lies at an elevation of 110 feet above Rainy River, less than 40 miles to the north, and 570 feet above the level of Lake Superior, yet this great body of water has no outlet that can in any proper sense be said to drain it.

(*Red Lake 1,174.5 feet above sea level. Lake Superior 602 feet. Lake of the Woods 1,061.3 feet.)

Rainy River is little more than a greatly elongated lake, its waters reaching almost by a continuous channel to Lake Superior on the east and yet flowing west into Lake of the Woods and Lake Winnipeg. It would be possible to travel in a canoe from one of these great bodies of water to another. It would be possible to travel by canoe from Lake Winnipeg to Lake Superior. No argument is needed to show that this is in no real sense a drainage stream. It is a great elongated basin filled with water.

These remarkable things are not the result of accident. Nature's processes are not accidental. The explanation of things about the earth makes up the science of geology. The history of the changes by which these things have come about weaves into a great story. This is the purpose of this book. Do not be frightened lest the history should be hard and dry. If it is hard and dry it is the fault of those who tell the story, not of the story itself.

CHAPTER II

HOW A RIVER BEGINS

Hills and Valleys. Every one who reads these pages has seen a valley, and also what may be called hills. Maybe the valley was only a ditch or small coulee on the prairie and the hills only little banks one or two feet high. But the importance of things is not always measured by their size. Maybe you have been where there are great rugged hills and broad, deep valleys. Whoever has seen hills has also seen valleys. Have you ever thought that there might be a necessary relation between the hills and the valleys? Perhaps you have been accustomed to thinking of the earth as "made" in the beginning with oceans and continents and mountains, with plains and rivers of water flowing through them, and have never questioned but that these have always been so. But a little observation and reflection at once teaches that this is not so, for you have not failed to see that the river is constantly changing the land,—a little soil is being washed into the valley from the banks along its sides with every rain and this is carried down the stream. Streams transport materials by carrying them or shoving and rolling them along their bottoms.

Perhaps you have watched the sand and pebbles creeping down stream on a gravelly bottom, and wondered how long this process has been going on, and when it was that soil and sand **began** to be carried down stream. And then perhaps you wondered if the stream would ever stop carrying away the soil and sand toward the ocean. By and by you began to think that this carrying away process must have begun as soon as there was any land on which rain fell; and so also you concluded that this constant wearing away of the land, called erosion, will keep on as long as there is any land left above the level of the sea. It occurs to you that likely this has been going on ever since the beginning of things and you perhaps begin to wonder if the land will not all be carried away in time and you wonder if there has not been more land here sometime which has been carried away. When you think that "the beginning" was a good while ago you are forced to conclude that a good deal of land has been carried away. And when you think that the land which is nearest the rivers is the first to be carried away, and that the hills and higher lands are but the parts which are farther away and have not yet been carried away, you see that the river or running stream is the agent which is doing the work of carving and fashioning the landscape.

The river is water seeking its level. The rains loosen the soil on the banks of streams so that it, too, seeks a lower level, or falls. The energy of the sun causes water to evaporate and rise as vapor. This forms the clouds, and the clouds are blown by the winds and carried over the land. Then they fall as rain and again form rivers. Then the rivers, as we have seen, flow off the land and carry with them the soil or fine parts of the earth, the materials of which the hills are made. So long as the sun furnishes heat the waters will be evaporated, and clouds will be formed, and rains will fall upon the earth, and rivers will flow into the seas. And so the endless cycle goes on, has been going on through the long æons of the past, and will continue to go on through the lapse of ages to come. And so the continents are being gradually worn down and carried into the seas. The "everlasting hills" are not everlasting. They tarry but a day when time is measured in geologic cycles. In truth, "one day is with the Creator as a thousand years, and a thousand years as one day." The little rivulet which runs by the school-house playground or along the roadside is doing the same kind of work in carrying away the land to the ocean as the river, only on a smaller scale. But it is only a question of time till the level prairies will give way to the hilly landscape, and finally the hills will yield to the constant wearing of the streams. When the landscape has been thus worn away so that the land is but little higher than the ocean level, then it is said to have reached its base-level of erosion.

Beginnings of a Landscape. If a new continent were imagined to arise out of the ocean, upon which were no rivers, no valleys or hills, its surface sloping uniformly to the sea, how would rivers get started? It must be that they would form in some way, for there are rivers or streams on all continents where rain falls. All the water there is on the land in lakes or streams or in the soil comes from the rain which falls upon the land. A large part of the rain water percolates into the soil and rocks of the earth. Some of it collects in low places and forms lakes, pools, and marshes. From these a good deal evaporates and goes into the air to form clouds again.

Now, where will a river have its beginning? Where will a definite stream channel first appear? Will it start from the interior and flow toward the sea? What will start it? Does any more water fall on the land in the interior than nearer the sea? Since the land is higher than the sea, the land waters will tend to move toward the sea. Where are the waters which will reach the sea first? It is plain, the waters nearest the sea. And since moving water always cuts a channel, or erodes the land over which it flows, the first soil to be carried to the ocean and deposited on its bottom as sediment will be the soil which was at the margin, or edge of the land, and the beginning of a channel or valley will be at the edge of the land. The next water to get to the sea will be that which fell on the land near to the edge but a little farther inland. Then that from a little farther inland still, and so on, till finally the water from the interior will get down to the shore.

But where now has the valley been cut most? Where is the largest part of the river? Where did the river begin?

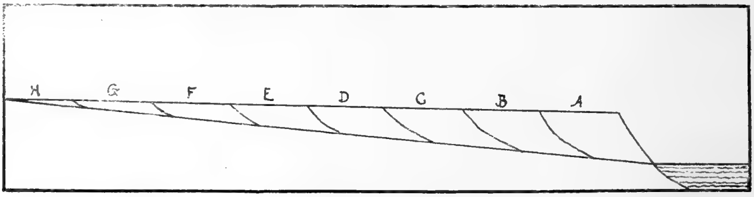


Fig. 9. Diagram Showing How a Valley Begins at its Own Mouth.

If we indicate a series of small areas extending from the seashore toward the inland by the letters **a, b, c, d, e, f, g, h,** the waters which fall upon **a** will be the first to reach the sea; those which fall upon **b** will be next, taking advantage in their course of the channel made by the waters of **a**; those falling upon **c** will be the next, and these will go down by the channel made by **a** and **b**; and **d** will in turn reach the sea coursing down the channel made by **a, b,** and **c,** making the channel deeper and wider by erosion; and at length **e, f, g** and **h** will reach the sea.

Let us now compare one part of the valley with another from **a** to **h.** How do the amounts of water which have gone over each area compare? Suppose we say the water which falls upon one area is one volume. Then if the whole length of the valley is the distance from **a** to **h,** and if we suppose all the water which falls on each area to go down the valley, the water which passes over **a** will be seven times as much as passes over **g,** that which passes over **b** will be six times as much as passes over **g,** five times as much over **c** as over **g,** and so on, while from **h** will pass only the water which falls upon that area.

Where there is the most water, other things being equal, there is the greatest erosion. Where then has the greatest channel been formed? And where is the river largest? And finally, where does the valley of a river begin, in the interior of the continent or at its own mouth?

Let us now think of the series of areas, **a, b, c, d,** etc., as a thousand, and the extent of each area to be large. From the farthest and highest part of the continent the waters may be thought of as a long time in reaching the sea. There will be then a broad and deep valley nearer the sea, and it will be smaller and smaller as we go inland, and on the thousandth area, or the summit of the continent, it will be only a place where rain falls, with hardly a beginning of a coulee.

Let us now go out upon the level prairies and look at the coulees and see what we can observe of the workings of a river system. Let us see if we can find any examples of what we have just been studying. If we select a day when it has been raining for some time so that the land is well covered with water, we shall be able to see in reality what we have been seeing in imagination. Here on the prairie, cutting through level wheat fields, is a coulee, a little valley having steep sides, growing wider down stream and narrower up stream, its sides becoming less steep towards the mouth and more steep towards its head. In the bottom of this trough or notch in the prairie trickles a tiny stream. Can it be that this stream has carried away the earth which once occupied the space where is now the trough or coulee? Strewn along the bottom are boulders, sand, and gravel, the heavier masses which could not so easily be carried away by the waters and which were in the soil or earth which has been carried away. If we go out upon the land some distance from the coulee and look across it we shall see that the whole trough of the young valley is below the level of the surrounding country. On the level prairies of the Red River Valley you could imagine a great board or plank to extend across from the prairie on one side to the prairie on the other. The Grand Canyon of the Colorado River is but a great coulee cut down by the river deep into the plain. The materials of which the great Colorado plateau is made are of such kind that the moving waters cut it away rapidly, and the walls on either side are steep and high. Canyon is another name for a young valley.

Let us now go along the bank of the coulee and see if we can discover how the valley got started. All about upon the level prairie we see water standing in sheets from recent heavy rains. If we ask ourselves if the prairie will by and by be dry again we shall certainly answer that it will, for it has often been very wet before and has become dry again. Where did the water go? It soaked into the ground, or a part of it did, and some of it evaporated, and went to help make clouds. But how about the water which was near by the edge of the coulee? Some of it fell down the side into the trough carrying with it always some soil. If it chanced that there was a depression or lower place in the prairie, and there always are such places, this hollow was filled with water, and if the low place is so near the coulee that its waters break over the edge and fall down the side, or if a little rivulet on the bank of the coulee should cut back into the edge of the little "lake" and tap it, then its water would be drained. But in falling down the side of the coulee the water cuts a little channel, and when it rains again the water which falls in this hollow, or lake, will run into the valley through the little channel formed before, cutting this deeper. If this depression were a large one the little channel would become a feeder to the larger stream which made the valley, and it would then be called a tributary to the valley.

If we go down the course of the coulee to see where it ends we shall see that it discharges into a larger stream, or maybe runs into a lake. If it joins a larger stream then it is itself a tributary to the larger stream.

How then did the coulee or young valley get started? In just the same way as the branch or tributary, for the coulee is only a branch of a larger stream. How does a coulee or valley increase its length? If you watch a little rivulet by the roadside when it is raining hard you will see that the head of the little stream pushes back toward the land as the water from the land falls over into the little valley. The stream grows longer by pushing its head back into the land and forming a little valley as it goes.

After this fashion have rivers been developing since time began. Not that this is the way by which our rivers have been formed; in fact it is not. It is the way streams would develop if not disturbed by other agencies.

An "old" landscape is one upon which streams have become fully established, after the manner just described, and which is well drained. On such a landscape the lower courses of the valleys are deep and broad, and the streams meander over wide flat bottoms. Further up stream the valleys are more narrow, and a cross-section of the valley is more V-shaped. Where the land is all well drained the hills are rounded on their tops, and are generally lower than the original land surface. Farther up stream the hills tend to have flat tops, and they may reach to the height of the original plain. Such landscapes are seen in southeastern Minnesota.

The land of Minnesota has not remained constantly above sea level since dry land first appeared. Where were dry lands the seas have come in and new deposits of sand and mud have been laid down over the old land surfaces.

But what has affected the landscape of Minnesota most noticeably so far as we are directly concerned has been the passing over the land surface of great glaciers by which the drainage systems have been destroyed and the landscape again made young. New water courses have been thrust upon the landscape by the flood waters which came from the melting ice. Upon most of the landscape of Minnesota drainage systems have not become established since the great ice sheets destroyed the former drainage. Most of the streams are not drainage streams at all, but are elongated pools often occupying large valleys that were made by the flood waters from the melting ice sheets.

Thus while the processes just described have been in operation since dry land first appeared above the primeval oceans, and while these are the processes by which drainage streams do develop today, and have always developed, yet we shall see that most of our streams are not drainage streams in any proper sense of the term, but are modern streams following in old-established courses that were developed under a totally different set of conditions from those that prevail today. The processes are going on today, as they have been going on from "the beginning." Most of the landscape of Minnesota is young. It is not drained. There are many rivers and streams that merely meander over the bottoms of ready-made valleys. They do not drain the land. In time the land will all be drained, —unless something interrupts the process.

CHAPTER III

THE WORK OF LAND ICE

Conditions Under Which Glaciers Form. Suppose more snow should fall upon the land than melts. What would happen? What if this condition should continue for many years and centuries? If more snow kept coming every winter and the depth of snow became greater year by year, after time enough (and time is long in geologic history), we could imagine the earth buried underneath a great mantle of snow and ice many feet in thickness, and indeed many rods in thickness, becoming great enough even to be expressed in terms of miles.

What would be the effect upon objects upon the surface of the earth if the snow became many hundreds of feet in depth all over the landscape?

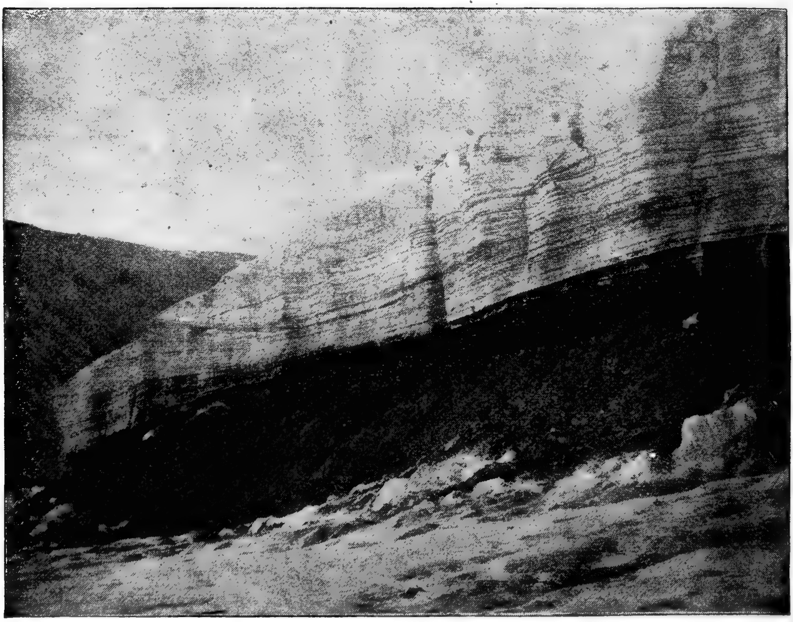


FIG. 10. Showing Formation of Moraine and Stratification of the Ice.
Photograph by Prof. T. C. Chamberlin.

What must result from such a condition may be observed on high mountains above the snow line. Snow gathers until of its own weight it moves outward from the center of accumulation. Such a moving mass of snow and ice is called a glacier.

The condition for the formation of glaciers is that more snows falls than melts. The behavior of snow and ice in glaciers can be studied by direct observation in Switzerland, Italy, Norway, in Greenland, in Alaska, and in the Rocky Mountains of our own country.

Ice which flows down the slopes of mountains forms Alpine glaciers, so named from their occurrence in the Alps Mountains. If you have been on the top of Pike's Peak, or in Glacier National Park, in the hottest months of summer, you have seen great patches of snow and ice among the crags and pinnacles above the snow line. The summers are not warm enough to cause all the snow to melt, and so it continues to gather in the hollows among the clouds and craggy peaks. When enough snow gathers so that its weight becomes sufficiently great, the lower portions become more like ice than snow. If the amount of snow is sufficiently great it will by and by begin to move slowly down the mountain.

Most of Greenland is covered by a great glacier a mile or so thick. Owing to the fact that it does not owe its origin to an accumulation of snow on high mountains but rather to a continuous accumulation on a broad land surface, this is known as a continental glacier.

It is observed that when snow accumulates either on high mountains or on a continental plain as in Greenland, and glaciers move away from the center of snow accumulation, it is in the form of ice. That ice should **flow,** blue, hard, brittle ice, may at first seem strange. But truth is stranger than fiction. It is a matter of observed fact that snow does become ice and ice does flow. We are accustomed to think of ice as a brittle substance, and we know that when struck a sharp blow it will break into pieces. When, however, ice under great pressure is acted upon slowly and steadily for a long time, it not only does not break into pieces as a brittle solid, but actually flows very much as a mass of resin or cold thick pitch will flow if given time, bulging out on all sides from the pressure due to its own weight.

How Ice Behaves Under Great Pressure. Let us consider in detail how ice behaves in very great masses. A cubic foot of ice weighs about 52 pounds. Let us imagine two blocks of this size placed one upon the other. The bottom one sustains the weight of the block resting upon it. If 10 blocks are piled one on top of the other in a column, then the bottom one will sustain the weight of those that are above it. The pressure on the lower surface of the bottom block will be that due to the weight of 10 blocks, or 520 pounds. If we imagine the blocks to be piled to a height equal to the highest building, say 200 feet, then the pressure upon the bottom, due to the weight of 200 foot cubes of ice, would be 10,400 pounds, or more than 5 tons.

Now suppose that the entire land surface for many miles in every direction were covered with ice to a depth of 200 feet. Each square

FIG. 11. Showing Moraine which is being Crowded upon by the Moving Ice.
Photograph by Prof. T. C. Chamberlin.

foot of land would sustain a pressure equal to the weight of 200 foot cubes of ice. The bottom cube in every such imaginary column would be prevented from crushing because there would be more blocks around it, each one trying just as hard to crush.

Now in parts of the country where there are high mountains, as the White Mountains in the State of New Hampshire, drift boulders and pebbles on the tops of the these mountains show that the ice covered their tops, or, in other words, the thickness of the ice was so great that the high mountains were buried. Some of these mountains which were so buried are more than a mile high, that is, their summits are more than a mile vertically above their bases, and drift boulders and gravel are found upon their sides and up to and on their very summits. The ice must, therefore, have been more than a mile deep in those regions.

It is thought by geologists that there was once ice on some parts of the North America continent more than 2 miles deep. What then must have been the pressure upon the lower layers due to the weight of the ice? One mile is 5,280 feet. The pressure expressed in pounds upon the bottom of each square foot where the ice was one mile deep would be 5,280 times 52 or 274,560 pounds, or more than 137 tons.

Since the ice cannot crush, being hemmed in on all sides under the same pressure, the stress upon the lower portions of the mass can only express itself by a flowing movement in the direction of least resistance, which will be outward from the common center of the mass or the center of the snow field. Under such conditions of great pressure, ice behaves like a thick, viscous substance, somewhat resembling pitch or thick tar.

An Illustration. Let us imagine a large cask or barrel filled with hard pitch. It appears solid, and if a piece of it is struck a sharp blow it will break much like a brittle rock or a piece of ice. Suppose we should knock the barrel to pieces and leave the pitch standing in a great block. It will have the form of the inside of the barrel. But let it stand for some time, say a week or a month, and it will be seen to have bulged out at the sides near the bottom. Leave it longer. The mass no longer has the

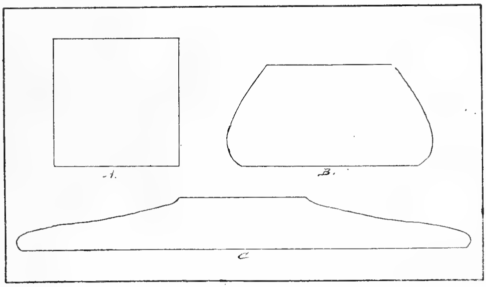


Fig. 12. Diagram Showing Flowage of Pitch.

form of the inside of the barrel. It is flattening down and broadening out at the base. Leave it for a still longer time, for a year maybe, or even two years, and it will have flattened out so that no one would ever think that it had once had the form of the inside of a cask or barrel.

Now, suppose such a block of pitch is left to stand on a level floor. It would flatten out and flow over the floor from the pressure due to its own weight. If there were some marbles or small stones lying upon the floor scattered about or in little heaps, the pitch would flow over these and shove them along with itself. If the block of pitch were on the cellar bottom where there were small hollows it would fill these and push on over them. If there were small gravel stones in these hollows some of these would be shoved along up out of the hollows and pushed over the uneven surface.

If we now can imagine the pitch to disappear by some means without disturbing the pebbles it had moved over the cellar bottom, we should find these pebbles to have been shoved into a somewhat irregular row near where the edge of the spreading pitch had been.

In much the same way the ice flowed across the continent, filling the valleys and crossing the hills as the pitch flowed over the cellar bottom and filled and crossed the hollows and hummocks. The great pressure from the accumulation of snow in the interior of the continent caused the outward flow. In the interior of the continent the ice melted on the land when it had flowed southward into the warmer climate of lower latitudes. Off the coast of New England the edge of the great ice-sheet pushed off into the sea. In the latter case the rock fragments carried by the ice were thrust off into the sea. But in the former case, where the ice melted on the land, the broken rock, some of which had been ground to fine powder and small fragments in the form of gravel and sand, together with the large boulders, were left where the melting ice dropped them.

The Great Ice Invasion of North America. Nearly all of the northern half of North America has been covered by great fields of ice. In all of the northern States from North Dakota to Maine and the Atlantic Coast about New York City occur boulders, sand, and clay, and ridges and peculiar rounded hills. Such hills and ridges, together with sand, clay, and boulders, are seen from Alexandria to Fergus Falls along the Great Northern Railway; about Hackensack and Walker on the Minnesota and International Railway; Itasca State Park and southwest to Detroit, and south in the Lake Park region to Battle Lake, Underwood and Fergus Falls; in a belt extending 60 miles northeast from Carlton parallel with the north shore of Lake Superior; about Lincoln and Cushing on the Northern Pacific Railway; between Albany and Holdingford on the Soo Line; and between Albany and St. Joseph on the Great Northern Railway. These are hills which mark halting places in the movement of the great ice sheet, the places where the end of the glacier stood when slow movement of the ice was balanced by melting. The ice melting there left the materials which were being moved by the glacier, and these are the materials of which the hills are composed. Such hilly tracts are known as moraines. Those formed at the end of the glacier, marking the limit of the glacier's advance, are known as terminal moraines.

When ice lay upon the landscape to a depth of perhaps half a mile, we have seen before that the pressure of the lower layers was very great. The ice was cold, hard, and brittle, just as we know it, only that in great masses it has the property of slow flowing motion. Irregular surfaces on the landscape would naturally obstruct the movement of the ice. The ice in turn would act with great force upon the projecting rocks. Observations of existing glaciers show how fragments of rock are broken off from obstructing hummocks, and these fragments become embodied in the moving mass of ice.

Materials Carried in the Ice. Large masses of hard rocks were thus broken off and carried along with irresistible force. There was much

FIG. 13. A Striated and Polished Boulder.

rubbing together and grinding of fragments carried in the ice with those under the ice and with the rocky floor beneath. When there were rough places on the rocky surface, these were ground and smoothed, and the fragments which were torn away were shoved and carried along with the moving mass. Stones carried in the ice were smoothed and polished. Such smoothed and polished fragments are common among glacial gravels and boulders. In fact, nearly all the boulders in the fields are smooth, at least the sharp, angular corners have been rounded, and many of them are distinctly polished. It is common also to find boulders and pebbles not only smooth, but having straight lines cut in their surfaces. These lines were caused by the stones being shoved against hard rock surfaces. Rock surfaces and boulders or pebbles having marks made in this manner are said to be "striated stones," and the fine lines or furrows are "striæ."

Boulders and stones which were carried or shoved along the bottom of the ice upon a stony or a hard rock floor received severe treatment Not only were their rough corners ground off, but many of those which were less hard and, indeed, many of those which were very hard, were ground to powder. Much of the clay of our fields is rock flour thus ground up by the great ice-mill.

Action of Ice on Surfaces Passed Over. While these rock fragments which were carried along by the moving ice were being thus ground to powder, what was the effect upon the underlying bed-rock? Figure 15 is a photograph of the striated and polished surface of hard quartzite rock. Such striated and polished rock surfaces occur in many places in Minnesota. Examples may be seen on the volcanic rocks at Taylors Falls; at Lester Park and other places in Duluth; on the smooth polished knobs of rock at Carlton; on the surface ledges of limestone quarries at Minneapolis and St. Paul, Northfield and Mankato; on exposed surfaces of granite rocks at Granite Falls; on quartzite rock at New Ulm.

When a hummock or little hill chanced to lie in the path of the glacier and its width and height were great enough so that it could not be broken off, the ice surrounded and flowed over it. Such a hummock would be combed and rasped by the ice and by the pieces of rock carried in and under the ice. If the hummock withstood this harsh treatment,

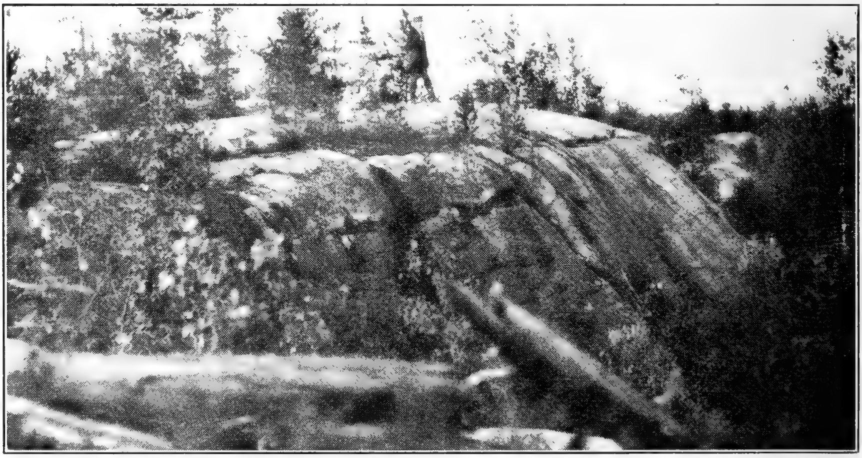


FIG. 14. Hard Rock Surface Smoothed and Polished by Ice, Northern St. Louis County.

when the glacier disappeared by melting the little hill or hummock might look something like the polished hummocks at Carlton. Figure 16 shows a granite pebble on which are several polished and grooved surfaces or planes.

The ice moved in a general way from north toward the south. The snowfields or centers from which the glaciers which crossed Minnesota came are far north in Canada. In their movement southward vast quantities of soil or broken rock were moved across what is now the international boundary. This was long before any tariff regulations had been made, or any reciprocity treaties negotiated. We got a valuable inheritance of limestone from what is now the Province of Manitoba. This, ground to fine flour and mixed in our soils, is one of the reasons why

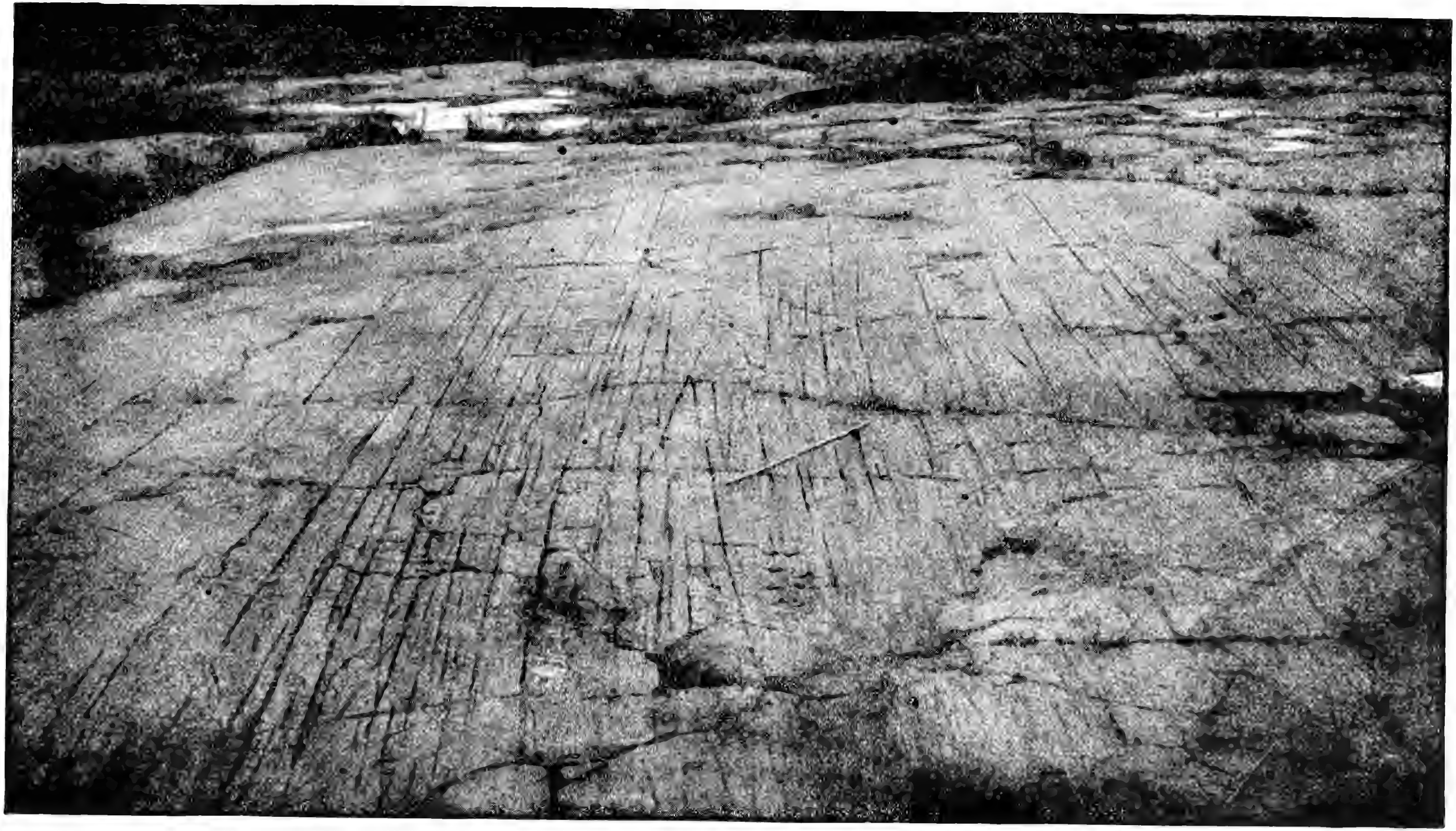


FIG. 15. Photograph of Striae on Quartzite, Big Sioux Valley, S. D., West of Rock County. *U. S. Geological Survey.*

wheat growing is profitable in Minnesota, and, indeed, is one of the most valuable soil ingredients.

Moraines. Stones and various fragments of earth are carried down by alpine glaciers, and as the ice melts when it gets down into the valleys,

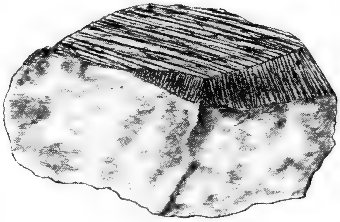


FIG. 16. Granite Pebble, Showing Ice Planing and Striae.

or down the mountain sides where it is warmer, it leaves the stone fragments which have been carried or pushed along. These materials are left in irregular heaps and piles, and are known as moraines, from a French word meaning "a heap of stones." At the edge of the ice, where the rate of melting just about equals the movement onward so that, while

FIG. 17. Islands in Rainy Lake, Remnants of Hills Smoothed and Polished by Glacier Ice.

the ice moves continuously, the **end** of the glacier stands still, there comes to be a gathering place of broken stones, earth, and soil, which were carried by the ice. These are dumped in heaps and irregular ridges. Small fragments of rock, sand, clay, and soil from the land surface are all piled together in great confusion. Hollows occur between these knolls and ridges, small and large, round and irregular, deep and shallow, and some of them are filled with water from the melting ice.

This whole affair—the heaps and piles of earth and broken stones, the irregular ridges, the hollows and lakes—makes up what is called a terminal moraine. It is called terminal because it is at the terminus or end of the glacier.

On the sides of glaciers stone and soil gather from the grinding of the ice against the hillsides along which it passes, and from crags falling upon the edge of the moving ice. Often these materials form long ridges or piles which extend for long distances along the edge of the ice-stream or glacier. These are sometimes upon the ice and being carried along with it, and sometimes they occur as ridges skirting the edge of the ice

FIG. 18. Gray Drift Moraine North of St. Paul. *Photograph by F. J. Alway.*

but upon the ground. Such a line of broken rock and soil is a lateral moraine, so named because formed on the side of the glacier.

It frequently happens in mountains where glaciers exist that two or more smaller streams of snow-ice from higher up the mountain run together lower down and form one larger ice-stream, just as the branches or tributaries of a river run together to form a larger river. On the sides of each of these branch or tributary glaciers there are lateral moraines. When, therefore, two such streams come together two lateral moraines meet, like the two parts of a letter V, and below the point of meeting the two ridges become one, and this continues down the course of the larger stream, but in the midst of it and not at the side or edge. The two lateral moraines which unite form a single ridge like the stem of the letter Y, and this is known as a medial moraine, because it is carried on the middle of the glacier.

At the bottom of the glacier, on the ground which the ice passes over, pieces of rock which are broken off from projecting crags, loose fragments of stone lying upon the surface of the ground, and soil, are shoved along and ground under or near the bottom of the ice. This material is shoved into hollows and ground to powder on the hard bottom. When the glacier melts back and uncovers this material, or when the glacier disappears altogether, as many glaciers have done, this is left as ground moraine.

There are thus four forms of moraines formed by alpine glaciers, terminal, lateral, medial, and ground. These forms are not always sharply separated from each other. These forms of deposits from alpine glaciers are of interest to us because similar deposits formed by continental glaciers occur on a very grand scale in Minnesota, and in other northern States.

It may be assumed that the glaciers that once spread their great masses over Minnesota behaved in much the same way as glaciers behave that now exist in Greenland, in Alaska, and in the Alps of Europe. Modern glaciers move over the land and push ahead during certain seasons or periods of years; then in turn the front of a glacier may retreat at times when the ice at the edge or end of the glacier melts more rapidly than the mass of the glacier advances. This is spoken of as the advance and retreat of the ice front.

Now while the ice of a glacier does advance with a slow flowing motion, in the nature of things it cannot retreat or move backward any more than a river can flow back up-stream. However, the front or edge or end of the glacier may retreat or move back up its course by reason of the fact that the ice melts more rapidly than it moves ahead. If melting were for a season more rapid than the onward movement of the ice, then the **edge** of the ice would slowly retire backward. In doing this the glacier leaves a load of earth, sand, gravel, boulders, and clay to show where it had been. If the edge of the ice for some time stands at nearly the same place, alternately advancing and retreating, there would be long lines of earth heaps or ridges of materials, forming what has been called a moraine. If the ice melted back somewhat rapidly there would be uncovered what had been carried under the ice, scattered boulders, gravel, sand, and clay, as a flat area between the moraine and the ice front. If the forward movement of the ice and the melting should now nearly balance for a time, so that the ice front became nearly stationary again, here would be formed another morainic ridge.

If this should occur again, this formation of a moraine would be repeated, and so there might come to be a series of morainic ridges more or less nearly parallel to each other. If, however, the ice should move ahead more rapidly than it melted away at the front, the ice would override these ridges, levelling them down and pushing their materials along. This melting back and pushing ahead has occurred a great many times, as a study of the terminal moraines of our State and of other northern States shows. Wide moraines are really a number of narrow ones close together, where advance and retreat of the ice front many times in succession caused the terminal moraine to become not a simple line or long

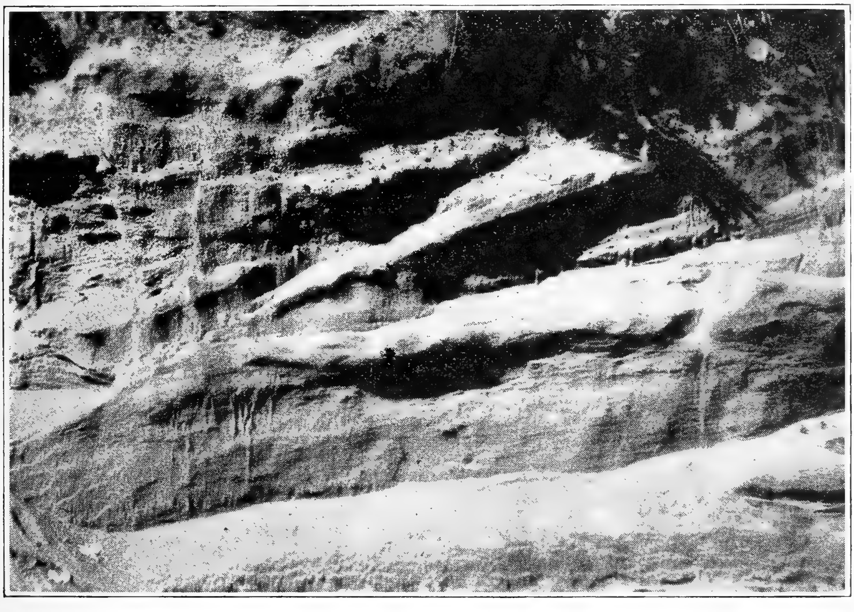


Fig. 19. A Section in a Sandy Morainic Hill.

heap of earth and stones, but a belt of such materials. Again, moraines could be piled upon one another, and as not all the earth and stones of the hills and ridges would be shoved along in front of the advancing ice, one moraine would be run over by the ice, and another upon it, and thus the depth of the material in a moraine-belt became often very great. Thus the terminal moraines which mark the places where the edge of the great ice sheet stood are not merely single ridges of earth and stones, but are belts of ridges and hills.

The hills may be of all sizes and all heights up to 150 feet or even 200 feet. Between them are little hollows and large hollows, "kettles" they have been called, sometimes containing water, sometimes dry, and sometimes what were first lakes have given place gradually to marshes or "hay meadows." Sometimes the hills are long, graceful swells, and sometimes their sides are very steep. So also the hollows may be round or they may be elongated and irregular, and they may be deep or shallow. Sometimes the hillsides are strewn thickly with boulders, and sometimes no pebble larger than a toy marble can be found.

Till-Plains. One of the most important of the deposits formed by the continental glaciers is that of earth materials that were carried or shoved along in and under the ice, and which, when the ice finally melted, were

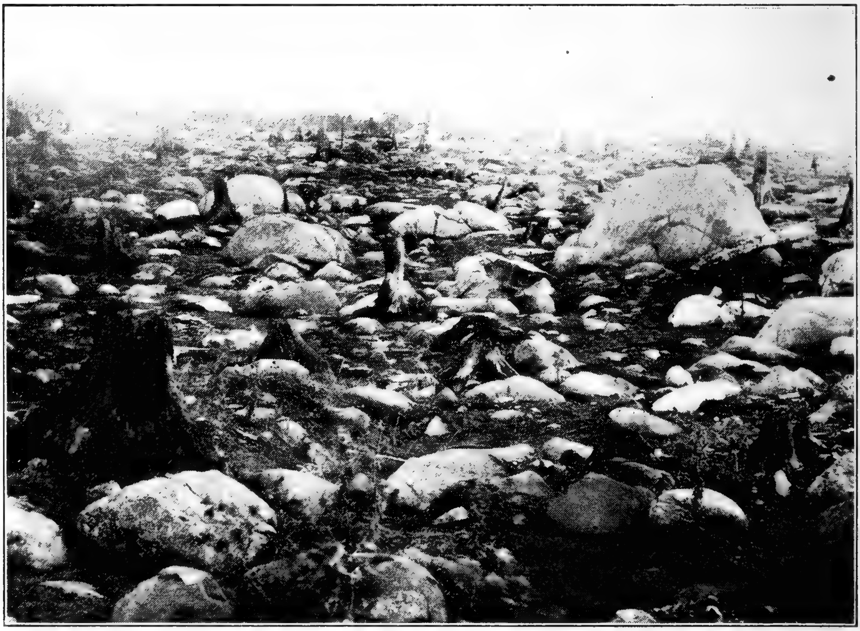


FIG. 20. Boulder Strewn Till-plain, Carlton County.

left in the form of broadly rolling or gently undulating plains. These are the ground moraines of the continental glaciers, known also as till-plains, and the earth materials of which they are made up are known as till. These till deposits, or ground moraine, make up the greater part of the "prairies" of the northwestern States.

The materials of the till-plains or ground moraines consist of soil and rock fragments that were gathered up by the ice as it moved over the land, and fragments of rock broken from ledges by the ice. These materials were mixed and ground up by the ice, being rubbed together and shoved over hard surfaces. The finest product of the great ice-mill was clay and next to this in fineness is rock flour or silt. All sizes of rock fragments from those of clay and silt to gravel and boulders are included in these deposits. As much water from the melting ice took part in the deposition of the materials carried by the ice, there frequently occur stratified layers of sand and gravel in the deposits. The unstratified clay deposits are known as boulder clay because of the occurrence of boulders of all sizes irregularly distributed through the clay.

Till-plains or ground moraines are sometimes strewn with boulders,

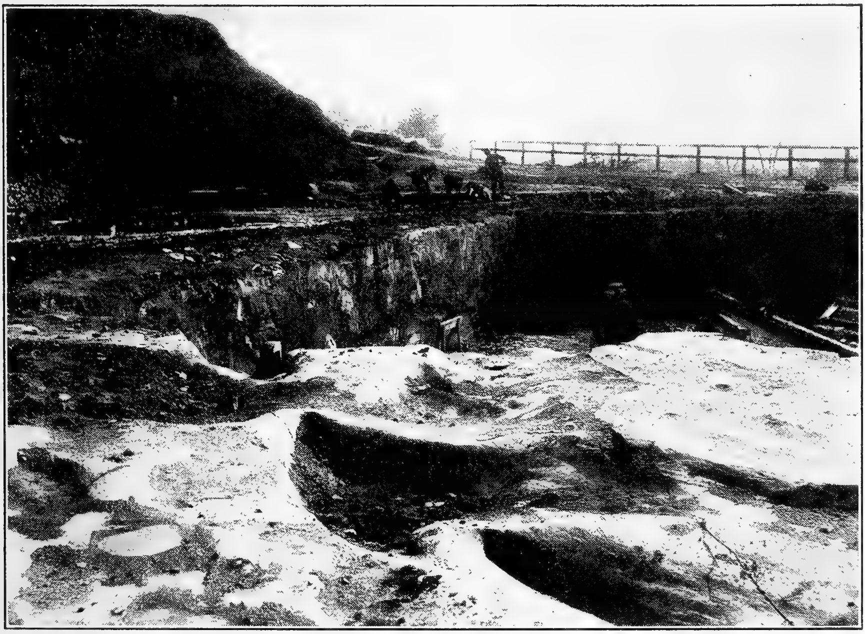


Fig. 21. Surface of Platteville Limestone Smoothed and Grooved by the Kansan Ice Sheet. *U. S. Geological Survey.*

Quarry South of the State University, Minneapolis. The Limestone is Overlain by Hard Kansan Till.

and such are frequently spoken of as boulder plains. By whatever name called and whatever mixture of boulders, pebbles, sand, silt, and clay, these are the deposits from the great ice sheets that were laid down and ridden over by the ice, being carried at the bottom or in the lower portions of the glaciers.

Outwash Plains. The melting of a continental glacier resulted in a tremendous amount of water that had to escape somewhere. Streams formed on, in, and under the ice. Such streams carried much silt, sand,

and gravel. The deposits made by these ice-waters often extend for many miles away from the moraines that formed at the glacier's edge. The materials carried by these ice-waters were deposited over wide areas. Such deposits are known as outwash plains. Such plains are generally smooth and nearly level. The soil of such lands is commonly sandy in character, and deposits of gravel are common below the surface, often a surface deposit of silt forming the upper layer.

The broad nearly level plain between Robbinsdale and Anoka is an example. The Northern Pacific Railway traverses such a plain from Anoka to St. Cloud, and another from Little Falls to Brainerd and Pine

FIG. 22. Outwash Plain of Gray Drift West of White Bear.

River. The Soo traverses an outwash plain from Paynesville to Brooten and Glenwood. Another extends from Cyrus, on the Morris branch of the Northern Pacific, southward to Benson, on the Great Northern. Another extends from Ortonville eastward to Appleton and Montevideo. One of the most extensive in the State extends southward from Park Rapids and Nevis to Wadena, Staples, and Motley, and southward in plains of varying width to Long Prairie, Parker's Prairie, and Battle Lake. Other examples of outwash plains are the Hamline Prairie at St. Paul; Rosemount and Farmington east to Hastings; the sandy plain at Pierz; at Deerwood; at Emily; north of Mille Lacs Lake and extending westward to Cass Lake and Bemidji; and south of Moose Lake to Sturgeon Lake, Willow River, and Rutledge.

Eskers. Streams of ice water sometimes formed channels in and under the ice before they emerged at the front. If the gravel bed deposited by such a stream was left when the glacier retreated or melted away, this appears as a long gravelly ridge. Such a ridge is known as an esker.

Eskers generally occur in association with terminal moraines. They are not as important as outwash plains, but because of their striking appearance, they are worthy of consideration here. They have a good deal the appearance of giant earth walls built as with design. Sometimes they are so uniform they are made use of as naturally graded highways.

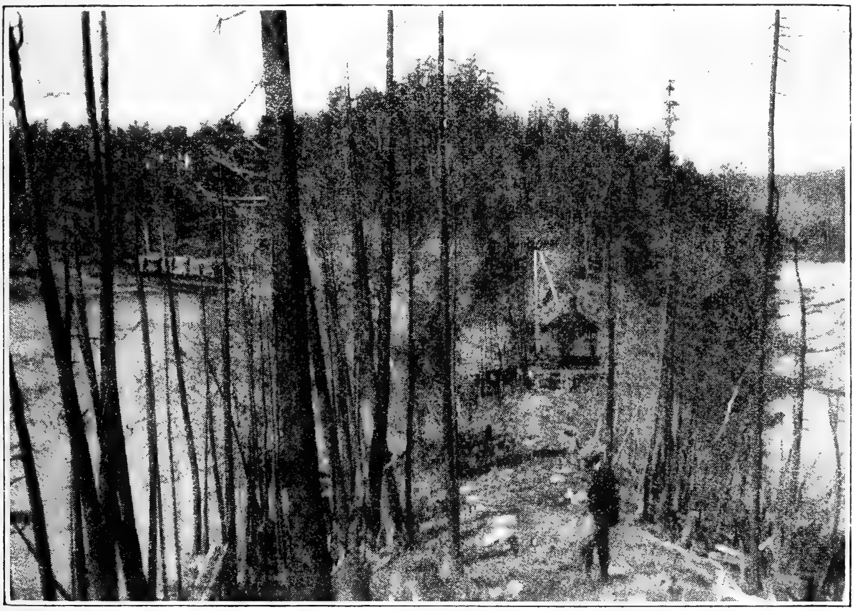


FIG. 23. Esker Between Lakes in Eastern Lake County.
Photograph by F. J. Alway.

Eskers are common sources of gravel for railroad ballast and other uses. An example of one is that used by the Northern Pacific Railway at Darling. Other examples of eskers are south of Perham; north of Richdale; east of Pine Lake; and near Foley and Mora.

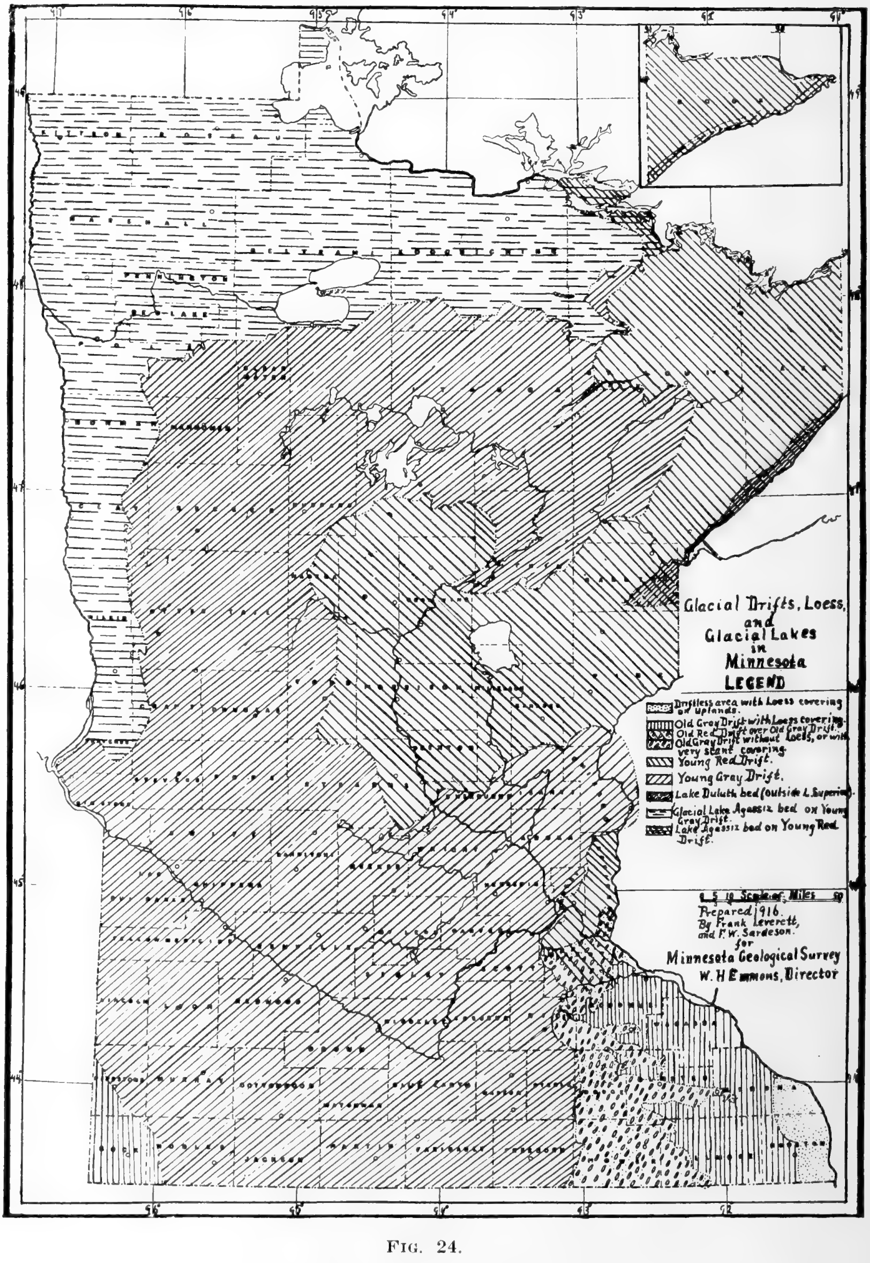

Glacial Drifts, Loess, and Glacial Lakes in Minnesota
LEGEND
Driftless area with Loess covering on uplands.
Old Gray Drift with Loess covering.
Old Red Drift over Old Gray Drift.
Old Gray Drift without Loess, or with very scant covering.
Young Red Drift.
Young Gray Drift.
Lake Duluth bed (outside L. Superior).
Glacial Lake Agassiz bed on Young Gray Drift.
Lake Agassiz bed on Young Red Drift.
Scale of Miles
Prepared 1916.
By Frank Leverett, and F. W. Sardeson.
for
Minnesota Geological Survey
W. H Emmons, Director

Fig. 24.

CHAPTER IV.

THE GREAT ICE SHEETS IN MINNESOTA

Ice Invasions in Minnesota. At one time glaciers covered nearly half of North America. These glaciers left their record in the changed appearance of the landscape. During the glacial period, conditions prevailed such that vast ice fields developed over what are now provinces in Canada and moved southward over the United States. All of the United States, north of the Missouri and Ohio Rivers, west to the foot of the Rocky Mountains, and east to Long Island, bears evidence of glaciers or great ice sheets having passed over the land. The glaciers started from east, south, and west of Hudson Bay, and flowed or moved out in all directions from their centers. Movement in a southerly direction from these centers reached Minnesota.

The center of ice accumulation west of Hudson Bay is called the Keewatin center, or ice cap, from the Canadian province of Keewatin, and the glaciers that came from this center are spoken of as Keewatin glaciers. Eastward of Hudson Bay over Labrador was another center of ice accumulation, and glaciers from this ice cap are called Labradorian glaciers. South of Hudson Bay in the territory embraced in the old province of Patricia was another ''center'' of ice movement and the glacier that moved southward from this ice cap is called a Patrician glacier.

All the glaciers which invaded Minnesota came by one of three routes. Those from the Keewatin ice cap came by the low valley of the Red River of the North and then down the Minnesota and across to the Des Moines Valley, and in doing so the ice followed the lowest land of the State. The glacier from the Labrador ice cap came along the Lake Superior Basin and spread into Minnesota and northern Wisconsin. The one glacier from the Patrician ice cap came from the high land north of Lake Superior, southward across the Iron Ranges, and then pushed a lobe or tongue of ice down the valley of the Mississippi. It would be a good guess that if a glacier ever invades Minnesota again from Canada, it will come by one of these three routes. They are the natural routes for glaciers.

It has been explained, in Chapter III, that ice in the form of glaciers moves in a manner comparable to the flow of a thick viscous substance. The great ice mass flowed over the landscape, filling the valleys and overriding the hills. One of the properties of ice in great masses is that it disregards the minor topographical features of the landscape, crossing valleys which lie athwart its course and moving up slopes. When the ice in its slow movement came upon a broad and deep valley that had its main axis somewhat parallel to the movement of the ice, the glacier followed, in a general way, the course of the valley.

Thus the ice from the Keewatin ice cap moved southward up the valley of the Red River of the North and down the valley of the Minnesota. Tongues of ice from the Labrador ice cap were deflected westward through the basin of Lake Superior and thus reached Minnesota. Similarly ice from the Patrician glacier which entered Minnesota was turned westward by the deep valley of the Superior Basin.

The Greenland Ice Cap. To understand how glaciers could form to the north in Canada, and flow up grade over Minnesota let us look at the conditions in Greenland at the present time. The annual snow fall in Greenland is very great. The center of Greenland is 9,000 feet above sea level, and practically all that height is supposed to be snow and ice. The snow which gathers is weighted and packed down by the piling up of more snow on top until it forms one great glacier.

Greenland is a large island, or small continent, and it is nearly totally covered by glaciers, all from the piling up of snow. The glaciers push out into the sea and break off, forming icebergs. All of the icebergs of the Atlantic Ocean, thousands of them, blocks of ice thousands of feet thick and a mile square, and larger and smaller, are glacier ice from Greenland.

Greenland has not always had the same climate that it has now. This is shown by fossil leaves in the rocks. So, also, its glacier is undergoing change. The Norsemen who settled Greenland, A. D. 983, may be supposed to have settled on the east coast where there was probably a strip of ice-free land then, just as there is now on the west coast. The glacial ice cap has been moved over, or changed in position relative to the land in Greenland. Such a change in less than a thousand years, suggests to us how it is that Labrador was once covered by an ice cap and shows all the marks of glaciers, but has no glaciers there now. When there **were** glaciers all over Labrador, Greenland was probably a grass green island,—a literal elephant pasture!

If we imagine an ice cap like that of Greenland, 1,200 miles long and 600 miles wide, and nearly 2 miles thick, and then imagine that great ice cap placed on the west side of Hudson Bay, sending out its tongues of ice over the land instead of breaking up into the sea, then it is plain that Minnesota might be invaded from the Northwest by a glacial tongue from that ice cap. With such an ice cap as that of Greenland covering Labrador, then we can imagine how Duluth and New York both would be pushed off the map by glacial tongues coming from that glacial center.

The ice cap from which came the first ice sheet over Minnesota from west of Hudson Bay may have been not so great as the present Greenland ice cap, but instead of dissipating into the ocean, as the Greenland glacier does now, it shoved out over the land. The Antarctic glacier of the southern hemisphere is now greater in area than any that ever was on North America in the Ice Age.

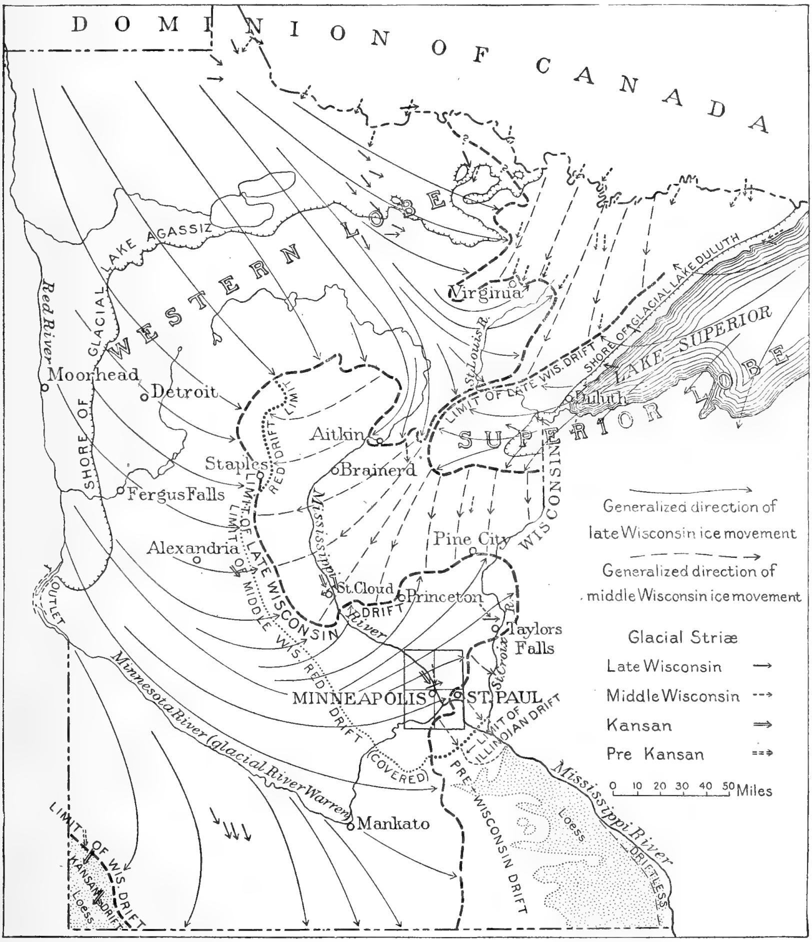


Fig. 25. Map of Minnesota Showing the Extent of the Glacial Ice Sheets, Direction of Ice Movements, and Shores of Glacial Lakes. *By Frank Leverett.*

The Ice Sheets in Minnesota. What is now the State of Minnesota has been over-run by glaciers at four different times. In other words there have been four ice invasions. The "Glacial Period," or "Ice Age" as it is sometimes called, was long. Ice did not cover the land all the time. Conditions changed so that the ice disappeared off from the land and then came again. The coming of a glacier is spoken of as an ice invasion, and the time during which the ice held sway is spoken of as a glacial stage. The time that elapsed after the ice melted and the glacier disappeared until another glacier came, or until another glacial invasion occurred, is called an interglacial stage.

In a sense we are still living in the glacial period in Minnesota, for the time since the close of the last glacial stage is not as long as some of the interglacial stages, and if we count four glacial stages of ice invasion and four interglacial stages when there were no glaciers here then we are now living in the fourth interglacial stage. Whether there will be another glacial stage here or not we do not know. Greenland is in the midst of a glacial invasion right now, but it seems very improbable that a "tongue of ice" from the Greenland ice sheet will ever reach Minnesota. When Labrador was covered with ice as Greenland now is tongues of ice did reach Minnesota at two different times.

Between the four stages of ice invasion, that is, in the interglacial stages, the glaciers entirely melted away. In the first glacial stage the ice covered all the area of Minnesota except a small area in the extreme southeastern corner of the state, in what is now Houston and Winona Counties. The second invasion covered nearly the same area of the State, though not quite as much as before. During the third invasion only a small area was covered, or what is now Washington County and parts of Dakota, Ramsey, Chisago, and probably parts of Carlton, Pine, and St. Louis Counties. The rest of what is now Minnesota remained free from glaciers at that time. In the fourth and latest stage the whole area of Minnesota was covered except the southwest corner as far as to Pipestone and Adrian, and the southeast corner as far as Austin and St. Paul.

A small part of the area of Minnesota has been covered by glaciers in all four stages of ice invasion. The greater part of the State has been covered three times. The rest of the State's area has been covered twice, once, or not at all. Each succeeding glacier left characteristic deposits of "drift" where it had been. The "drift" of the latest stage covers the greater part of the area of each and all of the earlier deposits.

The Latest Ice Invasion: the Wisconsin. Three glaciers came into Minnesota nearly at the same time during the last glacial stage, and yet they did not cover all the area of the State. They were long, comparatively narrow "tongues" or branches from three ice-centers in Canada. One, which came from the west of Hudson Bay, from the province formerly called Keewatin, is spoken of as a Keewatin glacier. One which came from Labrador is spoken of as a Labrador glacier. One which came from north of Lake Superior, from the old province of Patricia, is called a Patrician glacier.

The Keewatin glacier, of the fourth and last glacial stage, came up the valley of the Red River of the North and down the valley of the Minnesota, and across into the Des Moines valley and as far south as Des Moines, Iowa. This glacier spread out eastward in Minnesota and westward into North Dakota. It carried and dragged along boulders, pebbles, and clay of many kinds, including limestones from Manitoba, all of which was left spread over the ground after this glacier melted away, in what is called a gray drift sheet. As soon as this glacier had reached its greatest extent in its advance southward it began to "retreat." That is, it melted at the ends and sides more rapidly than it advanced. Several moraines show that at different times it came back, or re-advanced, but it only pushed its edge forward enough to bunch up the drift deposit into a moraine each time. The position of these successive moraines shows that the ice edge was stationary many times during the final melting away of the glacier. Rivers springing from the edge of the glacier brought out gravel and sand, forming flat "outwash" deposits and gravel trains.

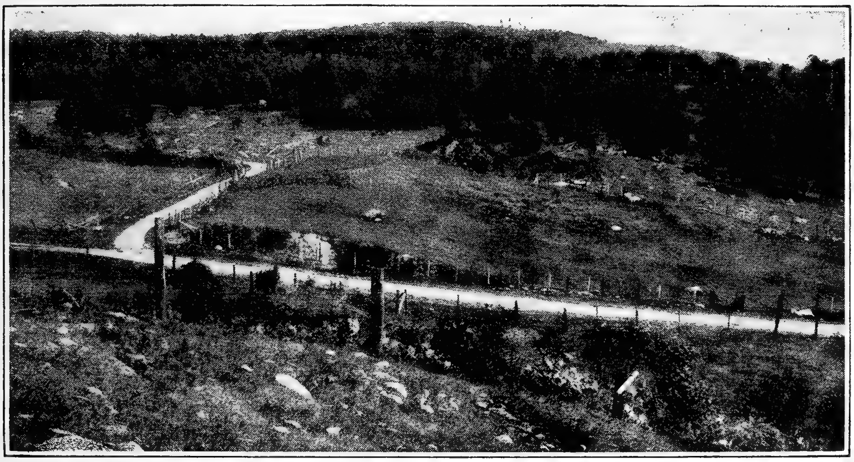


FIG. 26. Farm on the Stony Patrician Drift at Tower. *Photograph by F. J. Alway.*

The Labrador glacier pushed through the Lake Superior Basin and westward in Minnesota to McGrath and McGregor, in Aitkin County. It brought a pinkish or bright red drift without limestone over the area which it covered. Between McGregor and Lawler the edge of the gray drift from the northwest (Keewatin) overlaps onto the red drift from the east. This shows that the Labrador glacier reached its widest extent and began its retreat before the Keewatin glacier reached its widest extent. The Labrador glacier also left a succession of moraines showing that this glacier advanced several times during its retreat or melting away.

The Patrician glacier came from north of the basin of Lake Superior and pushed across northeastern Minnesota towards Minneapolis. It reached south as far as Belle Plain, New Prague, Lonsdale, Lakeville, Langdon, and Afton. It brought a lavender colored drift from Patricia, but after crossing the Iron Ranges in Minnesota this drift is red with iron, although not as bright red as the Labrador drift in Minnesota. The Patrician drift is the "red drift" described in Minnesota geological reports. The moraines of Patrician drift, as north of St. Paul, are rough stony rolling belts. Even where the Labrador and Keewatin glaciers

FIG. 27. Red Drift Moraine with Coating of Gray Drift North of St. Paul. *Photograph by F. J. Alway.*

rode over them they remain as rolling belts, as at Moose Lake and Grand Rapids. The Patrician glacier extended westward as far as Red Lake, Wadena, Sauk Center, and Paynesville, but its drift deposit is covered with gray drift at those places. The Patrician glacier had advanced and begun its retreat a little earlier than the Labrador and Keewatin glaciers. In fact, the position of their moraines shows that the end of the Patrician glacier was back near to the Canadian boundary at Hunter's Island when the end of the Labrador glacier was at Carlton, and the Keewatin glacier was at its greatest extension, at Des Moines, Iowa.

The Patrician glacier developed many large gravelly outwash plains. Examples are Hamline Prairie in St. Paul, Rosemount Prairie in Dakota County, the sandy and gravelly plain east of the Mississippi River from Sauk Rapids to Little Falls, north and west of Pierz in Morrison County, west of Emily and of Deerwood in Crow Wing County, and north of Mille Lacs Lake in Aitkin County. This glacier formed several eskers also, notably north of Little Falls,—gravelly beds of rivers in or on the glacier which were let down upon the ground surface when the ice melted. These have the appearance of giant earth walls. (See Chap. III.)

Pieces of iron ore and sometimes natural copper are found in the red drift. These fragments came from the Iron Ranges and copper formations in northern Minnesota and Canada. The agates which are abundant in the red drift came also from the copper-bearing rocks of Minnesota and Canada. Pieces of iron ore are sometimes found in the gray drift, but not copper or agates. On the other hand the red drift has few if any limestone boulders or pebbles, while the gray drift has many. Together with their color the red and the gray drift deposits as a whole are conspicuously different. It is useless to look for agates where there are many limestone pebbles, as many amateurs have discovered.

The color of the glacial drift is a simple matter, but is one that may be easily confused. Soil has formed upon the drift deposits since they were laid down by the glaciers. The soil is dark in color. Under the soil there is a rusted or "oxidized" brown layer of two to four feet. This has been formed at the same time as the soil and by the same weathering agencies. The rusty or oxidized top of the gray drift is brownish red in color, almost exactly the same in color as the fresh Patrician red drift. The oxidized top of the Patrician red drift, however, has a yellowish red or iron-rust color. This is also the color of the oxidized top of the Labrador red drift in Minnesota. At Minneapolis there is generally a black soil, then the red (oxidized) top of the gray (Keewatin) drift, then the fresh gray drift, and under this the fresh red (Patrician) drift (seen in excavations). The same red (Keewatin) subsoil over and the fresh red (Patrician) drift under the gray drift, is seen at Jordan, Excelsior, and other places.

In St. Paul, which lies outside of the Keewatin drift area, the black soil lies on a rusty red subsoil and under this is the fresh Patrician red drift. At Hinckley, in places where the great forest fires of 1895 burned the surface clean, the new black soil is one or two inches thick over the old burned surface, and under this are the rusty subsoil and the fresh red Patrician drift.

Soil is the mixed result of the decay of plants and the weathering of the top portion of the ground. The subsoil of rusty drift is also the result of weathering. A soil mantle has formed alike on the Keewatin drift, the Patrician drift, and the Labradorian drift, wherever these deposits are at the surface. There is no soil or "weathered zone" on the Labradorian drift where the Keewatin drift covers it, nor any soil or weathered zone on the top of the Patrician drift where this deposit is covered by either the Keewatin or the Labradorian drift. This means that the time between the depositing of these drift sheets was so short that the decay of plants and the weathering process did not form a soil on them. These three drift sheets have one soil covering in common, and they belong to one glacial

FIG. 28. Flax Field on Red River Clay Plain.

stage. This is known as the Wisconsin stage, and the drift deposits of all the glaciers of this stage are spoken of as Wisconsin drift.

The Third or Illinoisan Glacial Stage. The Illinoisan is a Labradorian red drift in Minnesota. That is, a great glacial tongue spread over Illinois and eastern Wisconsin, and a branch or tongue from it came across northern Wisconsin to the east side of Minnesota. It all came from a Labrador ice-field, and it brought red drift. There were no geologists here at that time and no man saw the ice, but the red drift any one can see, and its meaning is plain.

At Taylor's Falls a cut on the Northern Pacific Railway shows a vertical cross-section of the soil through all the drift that there is at that place down to the solid rock. At the top there is Keewatin gray drift, then the Patrician red drift, and below this a brighter red drift. There is, of course, soil or a "weathered zone" at the top or surface of the gray (Keewatin) drift, and another, a buried soil or "weathered zone," on the top of the lower of the two red drifts. The lower of the red drift deposits is the Illinoisan, and the rusty weathered zone at the top of it is the record

FIG. 29. Superior Red Drift over Patrician Red Drift near Cloquet. The Man Sits on a Boulder at their Junction.

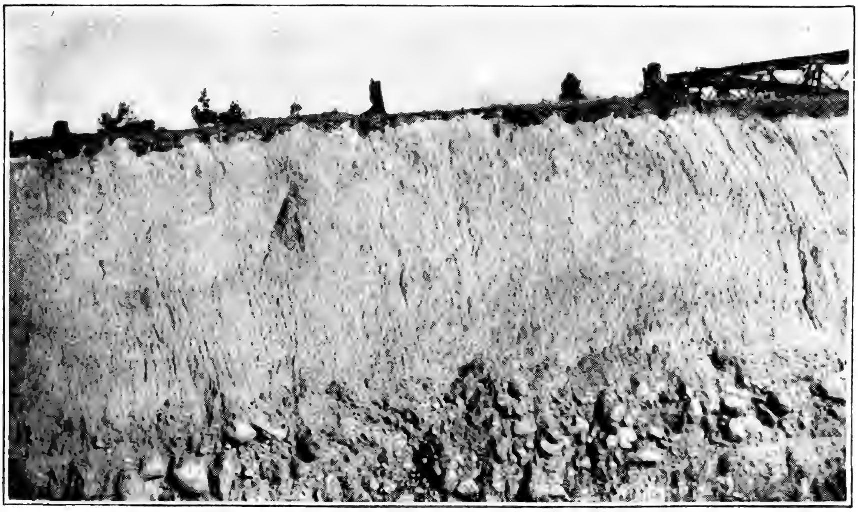


FIG. 30. Clayey Keewatin Drift over Stony Patrician Drift at Biwabik. *Photograph by F. J. Alway.*

of a time after the glaciers of the Illinoisan stage had disappeared or melted away and before any glaciers of the Wisconsin stage came.

In Dakota County, between Hastings and Cannon Falls, the Illinoisan red drift lies outside of where any of the glaciers of the Wisconsin stage reached, and it is not covered over by any of them.

The Second or Kansan Glacial Stage. At the Mahoning iron mines at Hibbing there are three drift sheets represented. None of them are complete because the rocky hills on the Range were left bare by the last glacier. The iron mines, however, are on lower ground and over them there is drift. Three drift sheets are seen at the Mahoning mine, two "gray" drifts with a "red" drift between them. All of the drift there is red in color because of the iron ore that has been mixed and leached into it, but the "gray" drifts are known by the limestones in them. The "red" drift has no limestones.

The three drifts at Mahoning do not include the Illinoisan red drift. That glacier did not get as far as that place. The three drift sheets are the Keewatin gray and the Patrician red of the Wisconsin glacial stage, and the Kansan. The Kansan is a "gray" drift here, as it is in fact everywhere. There is, or was, to be seen a buried peat-bog,—an ancient one,—at the Hibbing mine. This bog is under the Patrician red drift on the surface of the Kansan gray drift. It shows that plants grew over this country just before the glaciers of the Wisconsin stage invaded Minnesota.

In wells and deep cuts the Kansan gray drift is often found under the Patrician red drift, and always under the Keewatin gray drift in all parts of Minnesota. The Kansan is found under the Illinoisan in Dakota

FIG. 31. Old Red Drift Moraine near Hampton. *Photograph by F. J. Alway.*

County. It is found in Goodhue County and southward not covered by any other glacial drift, and likewise west of Pipestone and Adrian in southwestern Minnesota. Soil or peat beds are often dug up between the Kansan and other drifts overlying it.

The First Glacial Stage, the Nebraskan. The Kansan drift is not the first one, since there is found an older "gray" drift under it with soil, bog, lake bed, or other deposits, with logs of trees, shells, elephants' bones, and other deposits, between them. This oldest gray drift, sometimes called Nebraskan, was deposited by a glacier or glaciers which came from a Keewatin glacial center. It is filled with limestones as are all the other gray drifts. At the present time, however, this Nebraskan, or as it is often called Pre-Kansan drift, is mainly known in southern Minnesota, Iowa, and southward. It extends to the Missouri River and across the Mississippi from Iowa into Illinois. The first glacial invasion was very extensive in this region, probably greater than any other that followed it here.

CHAPTER V

AN EXCURSION TO SOME GLACIERS

A Glance into Norway. Norway furnishes many good examples of alpine glaciers. We cannot all go to Norway, or to Switzerland, or even to the snow-capped mountains of our own country. Since it is not possible for us to see the actual glaciers we may learn much from pictures.

FIG. 32. A Glacier and Terminal Moraines. *Photograph by A. Thorson.*

A glacier as it slowly moves down the mountain side is shown in figure 32. In the foreground is shown the dumping ground of the materials carried by the ice, the terminal moraine of the glacier. It is a belt and not a simple ridge. The distance across this belt of ridges, heaps and irregular mounds of boulders and miscellaneous rock fragments, gravel, sand, and earth, is about three-fourths of a mile, from the extreme foreground of the picture to the edge of the ice. Six morainic ridges can be seen, counting the one at the extreme front on which the top of a small tree appears.

Back of the dark appearing morainic ridge in the left of the same picture is a lateral moraine, marked vv. This is a sharp-crested ridge of broken stones, earth, and debris from the mountain side. At the places marked v along the side of the glacier are ridges and heaps of earth and stones 30 feet high, which belong to the lateral moraine of the glacier and are still being carried along with the ice. Dark patches along the side of the ice at the foot of the mountain side and extending up the glacier are also heaps of earth and stones belonging to the lateral moraine.

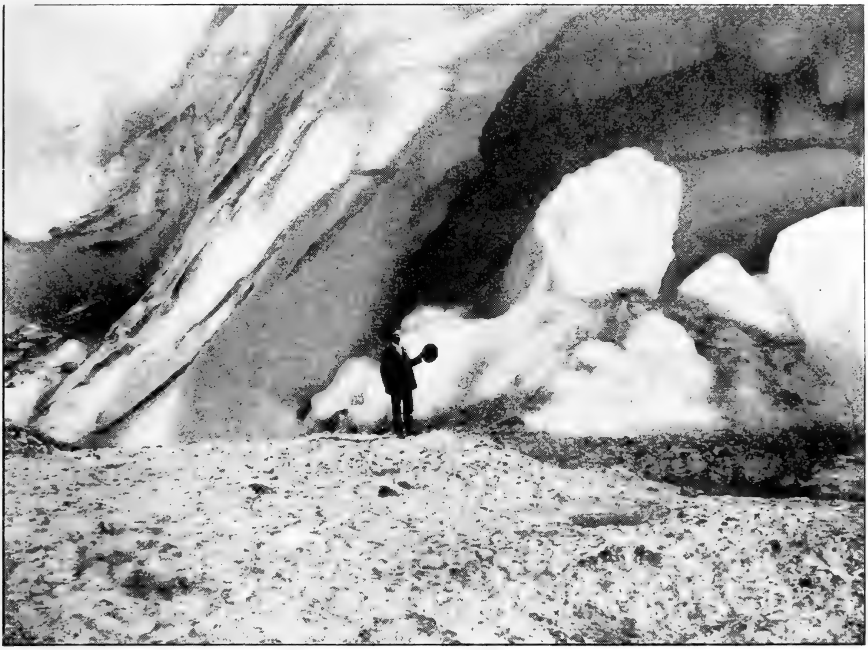


FIG. 33. Near View of Glacier Front Showing Ice Cave.

A near view of a small part of the front of the same glacier is shown in figure 33. A great cave has formed in the ice wall from melting, and a subglacial river here emerges from under the ice. The ice is clean, blue, and hard. The rugged surface of this glacier is shown in figure 34. The lateral moraine before referred to is the dark part running diagonally across the middle of the picture. The ice moves from the upper left corner to the center right of the picture.

FIG. 34. An Ice Cascade. *Photograph by A. Thorson.*

FIG. 35. Terminal Moraine, Front of Glacier, and Glacier in Distance. *Photograph by A. Thorson.*

A view of the glacier from the front is given in figure 35. Near the center of the picture is shown a part of the glacier where the ice is broken into a chowder by a fall or slide down a precipice about 3,000 feet. The precipice is shown just back of the white place in the center of the picture. The ice goes over this great cataract in immense masses crashing with tremendous force down over the rocky steep, making a noise like the heaviest thunder. The ice is not only shattered by the fall but it is shivered into snow-dust, and this loose mass of snow powder is what is seen in the center of the picture. Below in the foreground of the picture, the ice powder has become solid ice again, and appears as hard, blue, stratified ice.

Another view, a little to the right, is shown in figure 36. The morainic ridge is about 20 feet high, and is being pushed by the ice from behind. A river of considerable size flows away from the melting ice. Still another view of the same glacier front is shown in figure 37. This is a little to the left of that shown in figure 36. The stratified structure of the ice is here well shown. The morainic ridge near the ice is about 20 feet high. The moraine is being washed away by the ice-water.

The glaciers shown in the foregoing pages are in Norway. There was a time when Norway might be said to have been "in the glaciers." The glaciers which are now small and which are growing smaller, were once large, so large, in fact, that they carried blocks of Norway granite all the way to England. This, at first thought, seems a little startling, and it is natural to inquire how we know this. In the first place, there is no place in Norway where moraines of glaciers are not found. It is evident that the glaciers once reached down from the mountain valleys to sea level, for moraines occur far below where the glaciers have their ends, and are forming moraines today.

Moraines occur not only near the coast, but they extend away into the sea, or would if they had not been swept away by the waves and currents. That glaciers also covered the high mountain tops along the coast is shown by the smooth, bald, rocky tops of mountains along the coast. Grooves or striæ have been cut in these rocks and these show also the direction in which the ice moved.

For glaciers of Norway and Finland to carry off blocks of granite to England and north Germany, as it is claimed by European geologists they did, the glaciers must have been very large, as those of Greenland now are. Instead of speculating about European glaciers of bygone days, let us make an imaginary visit to Greenland.

Illustrations From Greenland. It might be an interesting question for debate whether the glaciers of Greenland are in Greenland or whether Greenland is in the glaciers! Greenland is twice as long and many

Fig. 36. Terminal Moraine and Ice Front Crowding Upon It.
Photograph by A. Thorson.

Fig. 37 Terminal Moraine Being Washed Away by Glacial Stream.
Photograph by A. Thorson.

times wider than Norway and yet it is covered nearly all over by ice and snow. If we were to land anywhere in the interior of Greenland we should see nothing but snow, a vast snow field. Under the snow is ice, consolidated snow made into glaciers. Whether this snow or glacier lies over the mountains or whether it lies over a flat plain, we cannot see, and we do not know. The top of the ice field is over 6,000 feet above sea level. For a guess, let us say that there are mountains in Greenland 3,000 feet to 5,000 feet high and that they are covered

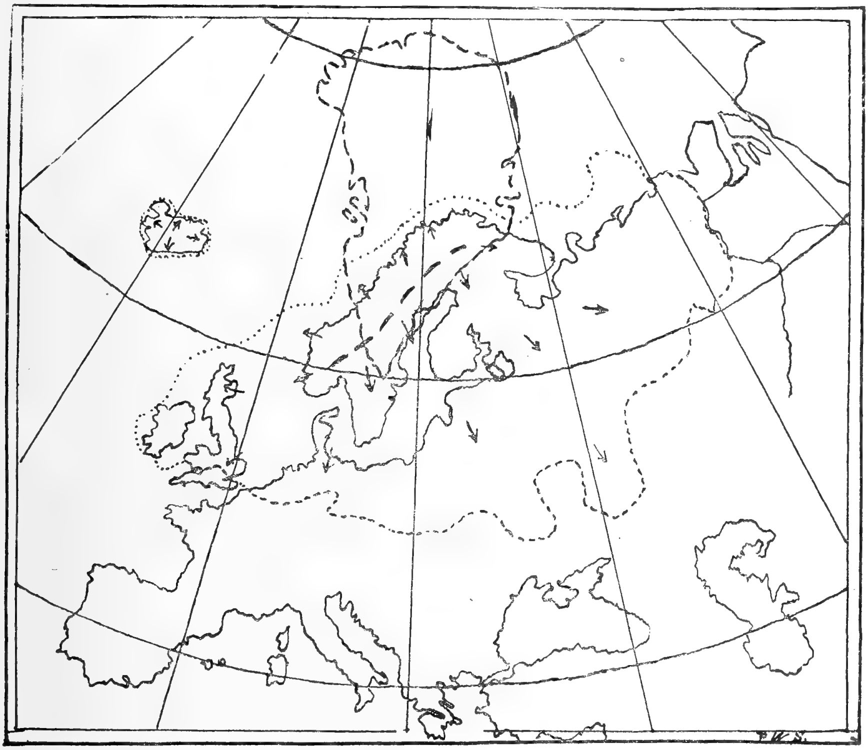


FIG. 38. Map of Europe Showing Glaciated Area. Glacial Center over Norway (dashed); Direction of Ice Movement (arrows); and Limit of Glaciation (dotted line). For Comparison the Relative Area of Greenland is Outlined (broken line) over Norway. *After Chamberlin and Salisbury.*

by glaciers, ice and snow, 2,000 to 5,000 feet thick. Where did all this ice come from? There is just one answer,—it came down year after year as snow. Along the west coast of Greenland some land extends beyond the edge of the ice or out from the end of it. The mountains in places stick out or up through the ice. In places the edge of the glacier is building moraines along the shore or a little way back from the shore in the mountain valleys. In other places the glacier pushes out its end or front into the sea. The east coast of Greenland is a great glacial ice shore covering up the land shore entirely.

When the Norsemen discovered Greenland and settled there, they very evidently discovered and settled on the east coast. That was in A. D. 983. There must have been more land showing and less ice on the east coast then than now. There probably was less land and more ice on the west coast then than now. At least the ice on the west coast is retreating at the present time. The wide, flat looking area of glacier on Greenland is called a continental type of glacier, as compared to the mountain type or alpine type, such as those now seen in Norway. The continental type of glacier is made of snow piling up in the interior and then flowing out by flattening due to its own weight,

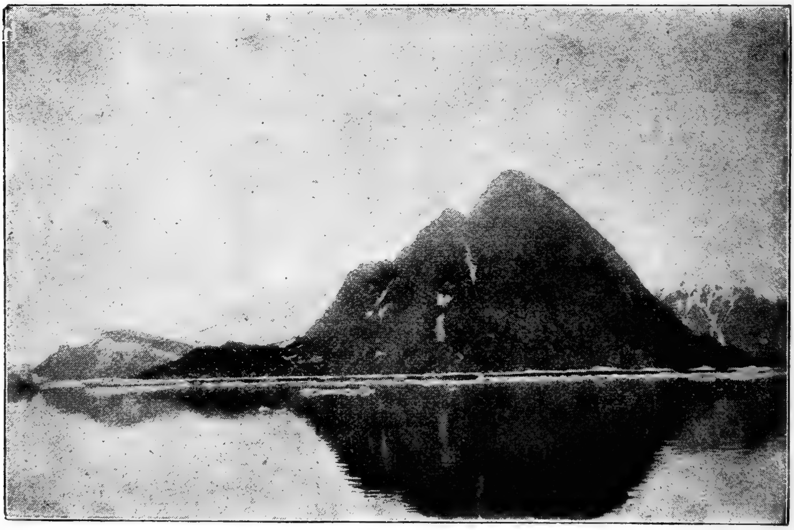


FIG. 39. Angular Outlines, Not Passed Over by the Ice Sheet.
Photograph by Prof. T. C. Chamberlin.

about the way cold molasses or thick tar would flow on a flat surface, only the movement of ice in glaciers is very slow.

In order to see how the Greenland glacier moves and how its surface edge melts away, we would need to visit it year after year to note its changes of front, and even then we could not get under the glacier to see how it works or moves over the land. We can only see the glacier at work at its edge. Greenland has not only a glacier great in area, but its glaciers make the bergs in the Atlantic. To measure up just how big an affair "Greenland's Icy Mountains" are, we need to add to the 700,000 square miles of Greenland's glaciers the innumerable icebergs of the north Atlantic Ocean. Icebergs are all fresh, they are never of salt water ice. They break off, acres at once, from the edge of Greenland and flow away into the sea.

Imagine now that the snow that falls on Greenland were to fall on Canada. Imagine that this snow compacted, as of course it would

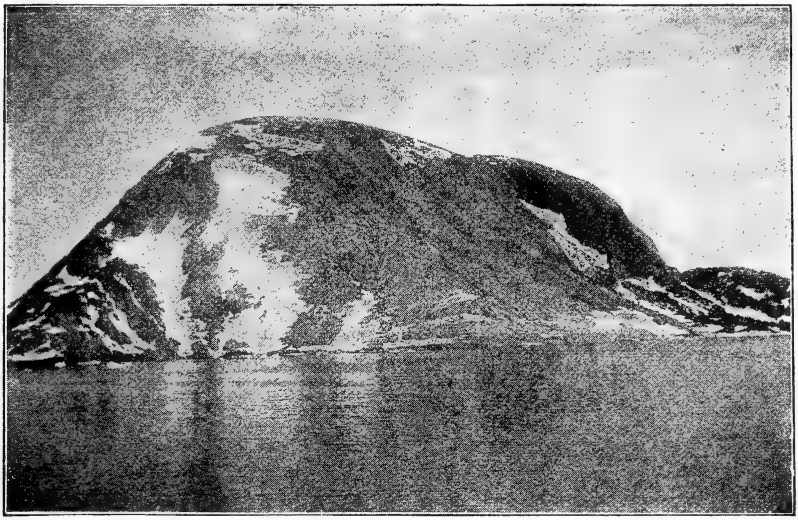


FIG. 40. Smooth Outlines, Showing Effects of Moving Ice.
Photograph by Prof. T. C. Chamberlin.

in Canada as it does in Greenland. Imagine further that it flattened by flowing out around the sides, and that none of its ice was dissipated as bergs into the ocean, then where would Minnesota be? That is just about what happened more than once in the so-called Ice Age.

CHAPTER VI

EXCURSIONS IN THE FIELD

Among the Boulders. Everyone has noticed boulders scattered over the prairies,—big boulders sometimes weighing several tons and smaller ones of all sizes down to "cobbles" weighing a few ounces, and pebbles of the size of marbles, and finally gravel and fine sand. A little study of the soil will show that it also is made up largely of tiny particles or grains of sand which are boulders reduced to small size. And the familiar clay which is so common a feature of the soil a little below the surface is but the still finer particles of broken rock so finely ground or pulverized as to make the separate particles not able to be seen without

FIG 41. A Joint Moraine Formed by the Meeting of Two Glaciers.
Photograph by Prof. T. C. Chamberlin.

the aid of a microscope. Boulders are seen scattered sometimes in groups or patches, sometimes a single one with no others near, and big and little are mingled in great profusion. Sometimes a sand pit is seen in which the sand is arranged nicely in layers; and occasionally a stray boulder is found in the sand, sometimes many of them. It has also been noticed that the boulders are very unlike in kind. Some of them when broken look very much like broken glass, often having a milky gray appearance. These are called quartz, or quartzite boulders. They are among the hardest of all the rocks commonly found in the fields or in quarries. It is the same kind of rock as that from which window glass is made. It is so hard that a freshly broken piece of it will readily cut or mark window glass. A steel knife blade will leave a black mark like a pencil mark on it. By remembering these things you can easily tell which are the quartz boulders in the field.

Another kind which is likely to be found in any group of boulders is one which when broken will show a rough surface with little blocks having a somewhat cubical shape, and colored pinkish or reddish, though sometimes white, and often flesh-colored. The surfaces of these little cubes are smooth and shiny, and reflect the sunlight so that they look very bright. These little blocks or crystals, for they are really crystals, are a mineral called feldspar. They may be so small as not to be easily distinguished, and sometimes the little shiny faces are one or two inches across. Mixed with these feldspar crystals may be seen little black specks or plates. These also vary much in size. When they are large enough they may be easily split with the point of a knife into thin scales. This mineral is soft and can be cut or scratched with a knife point. These are crystals of mica, and when they occur in large plates are cut up and split apart into thin pieces and used in coal stoves. The micas used in coal stoves are simply pieces cut out of very large crystals. The mica crystals seen in boulders are sometimes black, sometimes clear, sometimes brown, and sometimes greenish. But they are always soft and can always be split into thin scales. A third mineral which is always present in the kind of boulder we are now describing is quartz, the same quartz as has been before spoken of as making up some whole boulders. It has somewhat the appearance of broken pieces of glass, scattered through the rock among the feldspar and mica crystals. These particles of quartz are sometimes hard to distinguish from feldspar, but the faces of the little blocks are never shiny like those of feldspar, and it is never in little square blocks like feldspar. Then it may be remembered that quartz is very hard. Feldspar is hard, but not as hard as quartz.

These three minerals, feldspar, mica, and quartz, make up the rock called granite, and these boulders are granite boulders, the same kind of granite as is used for making tombstones and for building purposes. It is a very hard rock and is not easily broken. The action of frost and sun has little effect upon it, and it also takes a fine polish. These things make it very valuable for monuments and building purposes. A fourth mineral called hornblende is often found in connection with the three named, and this is somewhat like mica in appearance. It is, however, harder than mica and does not split into thin scales so easily as mica and it is generally in thicker masses, and is usually green or greenish-black in color.

These two kinds of boulders, quartzites and granites, are among the most common. These are the more familiar "hard-heads" which everyone has observed. Besides these, however, there are others which when broken do not present the glassy, milky, or grayish appearance of the quartzites nor the flesh-colored, red, brown, or specked appearance of the granites. Limestone boulders are common in Minnesota, and in most of the Northwestern States. These can be known by their softer character, and usually by being more affected by the action of sun and frost. They dissolve and crumble much more readily than the others. A good deal of the soil of North Dakota is made of ground-up limestone, and as we shall see by and by this material has helped to make our rich wheat fields and also to make our wells furnish hard water.

FIG. 42. A Fragment Far from Home. *Photograph by C. M. Hall.*

Still other boulders there are which have long, hard names which we do not need to describe here in particular, but only to say that there are a good many others and nearly all of them are made of hard materials so that they do not easily crumble or break. This fact of their being hard is important, for we shall see later that this helps to explain why they are here. They have not been broken up or dissolved, because they were so hard. But a fact that we should notice here is that these different kinds are found scattered almost all over our State and over other northern States as well; limestone, granites, quartzites, hornblendes, augites, cherts, and many others, large, small, and all sizes, mixed, and scattered singly and in patches, sometimes almost covering the ground and sometimes few and far apart, on the surface and deep in the soil below the surface.

This great variety in kinds, in sizes, and in the way they are scattered leads us to inquire how this has all come about, where have the stones come from and why are they so different in kind and size, and so curiously scattered? Why are huge boulders sometimes found on the tops of the hills as well as in the valleys? And again sometimes not even a good-sized pebble can be found for miles. Then again it is all sand for miles, suddenly changing to black sticky prairie.

It has not required any great skill in guessing to surmise that these stones, these huge boulders, and the great quantities of sand were not "made" where they are now found, that is, they did not in the first place belong here, but have been brought here by some means from somewhere else. These boulders, pebbles, and gravel, and even the sand grains are all rounded, while the rocks from our quarries or from ledges along streams where the bed-rock comes to the surface, are rough and angular. To explain how these things have come about a geological story will have to be told, a little fragment of the earth's history, of the manner in which a great change took place over a large part of North America, and which includes most of the State of Minnesota. A part of this story will be told in the chapters following.

An Excursion to Some Quarries. Just as it is necessary for us to see, feel, smell, taste, and hear in order to think about an object, so it is necessary for us to see, handle, break, dig, and walk over the fields, rocks, soils, hills, and valleys in order to understand the geography of our own neighborhood or State. But all parts of our State are like all other parts in many respects, and what is true of Minnesota is in a large measure true of other States and other countries. Since we cannot all visit all parts of our State, and still fewer can visit all the States or all the countries, let us first study our own neighborhood, and then from this we may be able to understand the parts we cannot visit from what those say who have seen parts we have not seen. He is a good scientist who understands thoroughly his own neighborhood. Let us then go out and pick up a basket of stones from the fields and roadsides. Let them be collected at random from the neighborhood, and let big and little and all kinds be gathered. If there is a patch of boulders in the neighborhood which are too large to be moved, look carefully at them where they are. In the collection we have perhaps one hundred, maybe two or three hundred, "specimens," yes specimens, for each one of these humble stones has its own story to tell, and strange as it may seem, scarcely any two of them will tell the same story. Can you find two which are exactly alike in shape or size? Or, what is more wonderful, can you find two in the whole collection which seem to be, when broken, exactly the same kind of stône? If we have two or three hundred specimens gathered from about the neighborhood, very likely if you try to sort them, placing them in piles so as to have each kind by itself, meaning by kind those which are exactly alike, we shall have a hundred or more piles!

Now if you have ever been in a stone quarry you have probably noticed that the stones which were being taken out by the workmen were all very much alike. If the ledge in which the quarry is located is deep, if the wall of rocks is high and you see many layers in order you may have noticed that they are not all alike, but if you look at different parts of the same layer, following it from one part of the quarry to another, you notice it is the same all along. The different layers may also be very much alike. You see no such differences in these layers, or strata as they are called, as you saw in the collection you made from the fields. If you have been in a quarry in Minnesota or Wisconsin or Iowa it may have been a limestone quarry you saw. Among the specimens you collected there are probably several limestone boulders. These, you will observe, are different in shape from the quarry blocks. The boulders are all rounded and smooth, while those freshly broken from the ledges are sharply angular.

If you have been in eastern South Dakota maybe you have seen the hard reddish building stone which is taken from the extensive quarries along the Big Sioux River. This rock is of quartzite, the same mineral as has been spoken of as making some of the "hard-head" boulders. This particular region of South Dakota has no other rocks in the quarries. It is known as Sioux quartzite and is famous as a building stone. The city of Sioux Falls gets its name from its location near where the Big Sioux River crosses an outcropping of this rock.

Now if we could dig down deep enough we should by and by come to bed-rock. In some parts of the State we should find this to be limestone, in other parts sandstone, and in others shale. If we should go north into Canada, away to Hudson Bay, for instance, or about Lake Superior, we should find the bed-rock to be like some of the boulders we have in our collection. In some places we should find granite, in other places quartzite, and hornblendes, and augites, and porphyries. So similar are the bed-rocks in those localities to the pieces or boulders which we have collected here, and so much do the scattered boulders look as if they had come from some other place, that we almost begin to wonder if in some way our boulders did not come from about the Hudson Bay or Lake Superior country. In a later chapter we shall see that there is reason for thinking that many of our boulders and a large amount of finer materials have really been brought from these far-off regions. All the boulders, pebbles, and sand-grains of our prairies and fields have come from other places where the bed-rock is the same kind of rock as these boulders. In other words these boulders are pieces broken off from the layers or strata of the bed-rock where these come to, or near to, the surface. They are fragments which have

FIG. 43. An Old Valley in Driftless Area of Minnesota.

been broken from many different quarries in many different places, and carried sometimes hundreds of miles to where we find them in the fields. Some of the pieces were very large and heavy when first broken. In the process of moving they have become a good deal broken, big blocks being broken up into small pieces, the corners worn off, and the whole surface made smooth.

When a large rock is broken into smaller blocks there are always some small fragments formed, and when a corner gets knocked off from a rock by striking against another rock more small fragments are broken off. The only difference between boulders and sand is in the size of the fragments. A boulder may be broken into several smaller boulders, and these may be again broken into pebbles, and these in turn are only larger grains of sand. They all get smoothed and rounded by being jostled and rubbed against each other and against other hard things which are in their way, or which are moved against them. Indeed, soil and the clays of the fields and hills are mostly ground-up rock. The softer boulders are more easily worn to powder and broken. The boulders, the larger ones, those which are well rounded and smoothed, and which have been quite correctly called "hard-heads," are the harder masses which have been broken loose from the bed-rock somewhere and by reason of their being so hard have not been worn out and made into soil. If you examine the grains of a handful of sand from a sand-pit you will find it to be made up of hard particles of stone. The grains will be largely quartz grains, and bits of feldspar, and other hard minerals. You will generally find but few grains of mica or limestone because these are softer and more easily ground to powder.

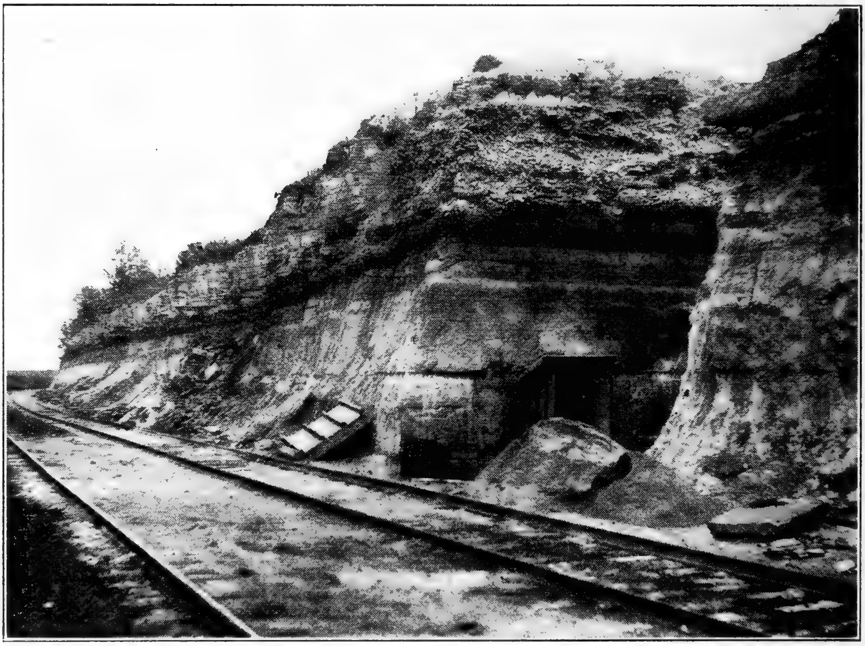


FIG. 44. St. Peter Sandstone Overlain by Platteville Limestone near Northtown, Northeast Minneapolis. *U. S. Geological Survey.*

Because the boulders, sand, and clay of our fields have come from somewhere else, have drifted here from other regions, this material is called "drift," and the boulders are often spoken of as "foreign" boulders or drift rocks to distinguish them from the rocks which have come from our own quarries or from the bed-rock near where the pieces are found.

All these materials, these many millions of tons of clay, boulders, sand, and gravel, and most of the soil also, which cover nearly the whole State, are drift, and the time during which this vast amount of work was being done is known as the Glacial Period. It was the last great geologic period before that in which man lives, the period of written history.

Stratified Gravel and Sand in Sand Pits. Probably all have seen a gravel or sand pit. Here the little fragments of stone we call gravel or sand are often arranged in beautiful layers, one above another. Some of the layers are very thin, perhaps only a small fraction of an inch in thickness, and again they are several inches thick, or even several feet. Occasionally, also, a boulder is found imbedded in the layers. The size of the particles in any particular layer or stratum it is noticed

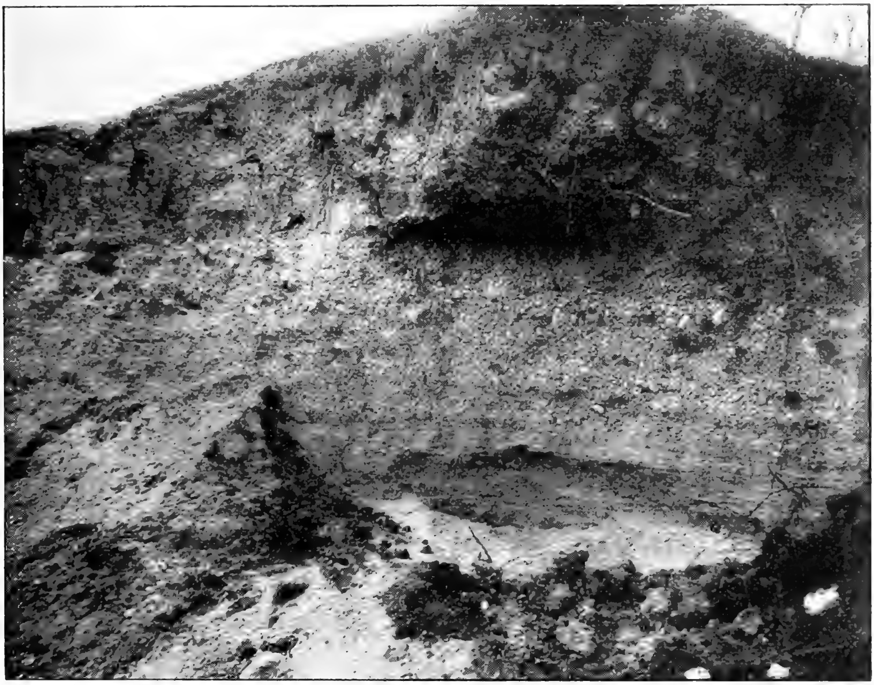


FIG. 45. Section in a Gravel Pit, Showing Stratified Sand Below, and Coarse Gravel and Boulders Above. *Photograph by Prof. Chas. M. Hall.*

is about the same, though the next layer above or below may be much finer or coarser. If we follow the line of one layer either way for some distance we may notice that in some cases the grains become coarser as we proceed, or they may become finer; and many times we see that a layer becomes thinner and thinner in one direction and finally ceases entirely.

Each of the grains of sand and gravel, however small, and every boulder and cobble, was once part of a larger rock. These tiny bits are what is left of huge rock-masses torn or broken from ledges somewhere, and brought here and left as we now find them. It is clear that these layers of sand and gravel were deposited by water. The water was that from the melting of the great ice sheets. The tiny grains are what remain of large boulders and fragments carried and broken by the ice.

Fig. 45a. Superior National Forest, Ely. Falls of Isabella River; Kawishiwi River; Gabro Lake.

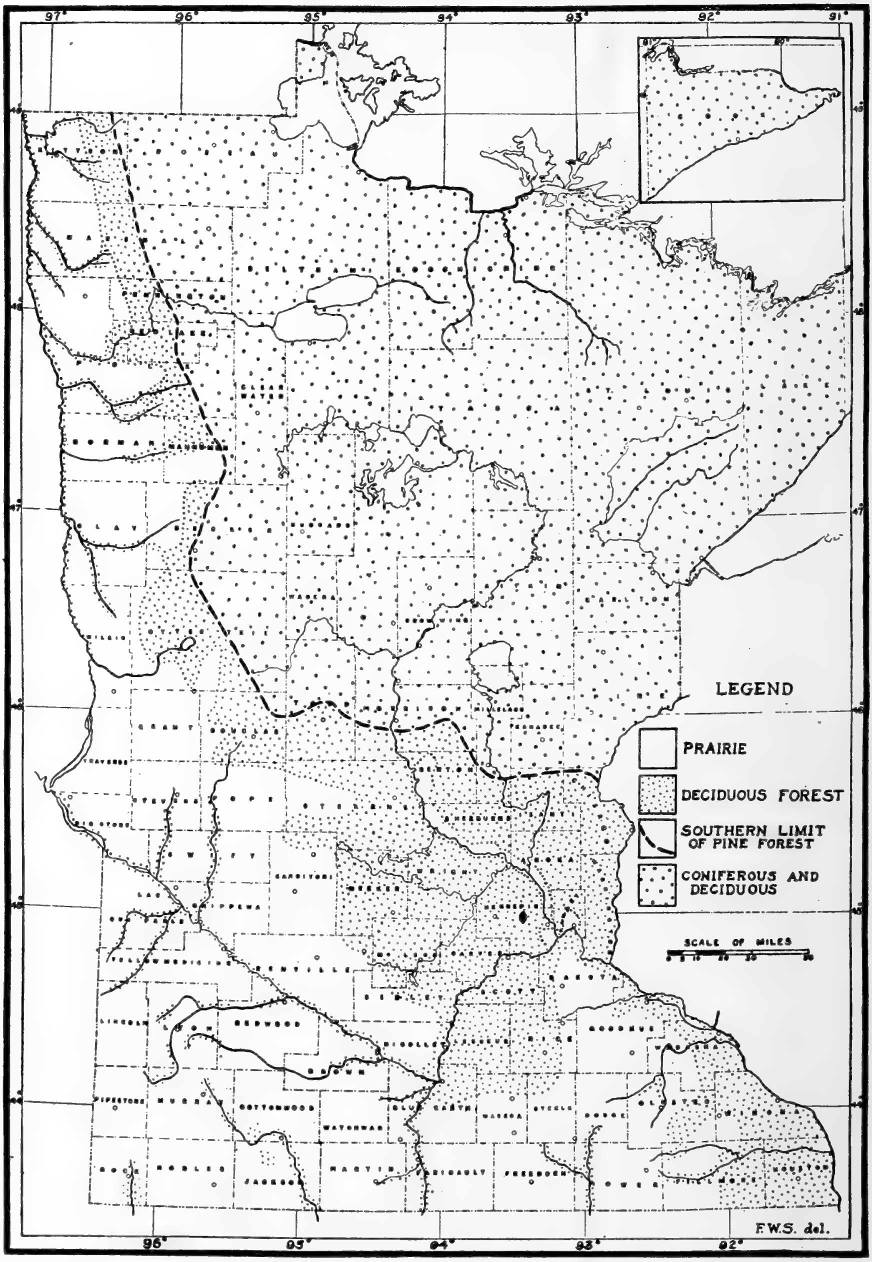


FIG. 46. Map of Minnesota Showing Distribution of Forest and Prairie. *After Warren Upham and Frederic K. Butters.*

CHAPTER VII

THE PRAIRIES AND THE FORESTS

Land and Plant Provinces. Why are the prairies prairie and the forests forest? Minnesota as a whole is a great, gently undulating plain. There are no rugged mountains within its borders. There are hills in the northeastern portion of the State that are old, worn-down remnants of mountain ranges, but nothing that compares with the rugged highlands of the western portion of the continent. The land surface of Minnesota possesses great diversity, and there are many extremely interesting landscape features, but no real mountains. There are about all the types of hills that exist anywhere, but they are all parts of the great general plain of the State. The land surface is flat, gently undulating, gently rolling, or roughly rolling.

In relation to vegetation, there are three great types of landscape. These are (a) prairie, (b) forest, (c) swamp, or wet lands. Just as there are reasons why every landscape has its particular form, so there are reasons for each plant province. In a general way the southern and western portions of the State are prairie, the northern and eastern portions are forest. Portions of northern and northeastern Minnesota are wet or swamp. Most of the swamp or wet lands are related to the forest province.

There are therefore really two great plant provinces of the State, the prairie and the forest. We may now ask, Why are the prairies prairie and the forests forest?

Climate the Controlling Factor. The plains that are prairie do not differ in their character as landscapes from the plains that are forest. They are the same plains. Climate has a controlling influence in the struggle that has been going on for ages between the prairie grasses and the forest trees.

We do find trees scattered here and there over the prairie region in Minnesota, and we do find prairie grasses in small patches nearly everywhere in the forested regions. The trees and grasses scatter their seeds. In one place young trees grow up and in another the grasses choke them out. How does this happen?

Take, for instance, a place where fire has burned so intensely as to kill out everything, both trees and grasses. The wind soon blows into that place seeds of the poplar, the cottonwood, and the willow, those pioneer trees in natural reforestation. The birds bring in seeds of fruit trees and bushes, the cherry, the huckleberry, the raspberry, and blackberry. The wind and the birds also bring in weed and grass seeds, "fire weed," golden rod, asters, and several kinds of grasses. Seeds drift in with the snow. In the spring they germinate and begin to grow. If there is plenty of moisture in the soil all the season through and moisture in the air, the young trees prosper. They soon grow up and spread their branches. They shade the ground and smother the weeds and grasses from under them.

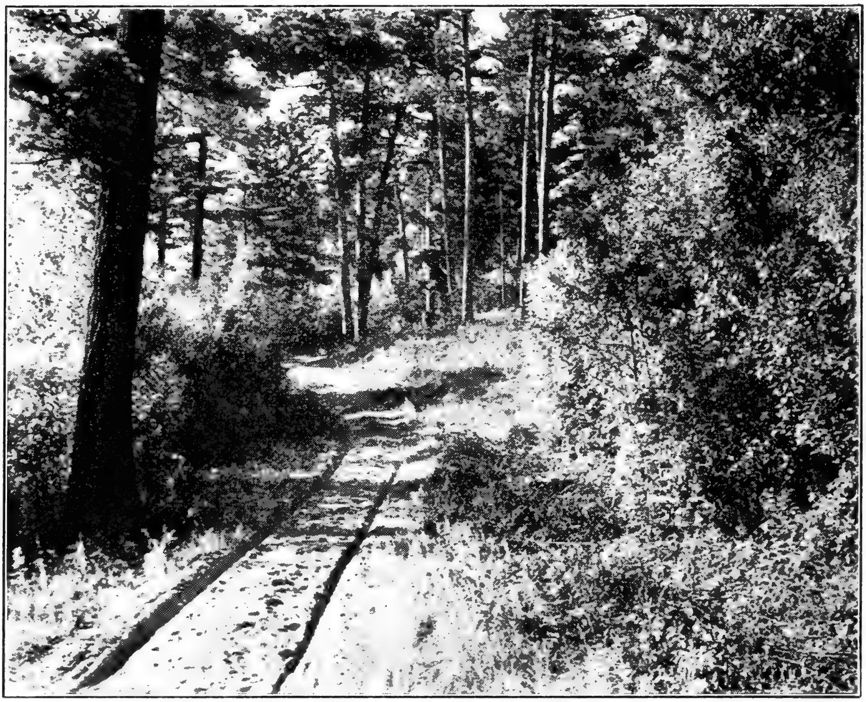


FIG. 47. Road in Itasca State Park Leading from Douglas Lodge to Forestry School. *Photograph by M. Heinzelman.*

If on the other hand there are dry spells in the growing season when dry winds sweep away the dews from the leaves and parch the ground, the grasses with their shallow growth on the ground have first chance to gather whatever moisture there is. The trees then are choked out and grasses survive. Thus is a prairie formed. It is as hard for a young tree to start in the prairie sod as it is for grass to grow in the shade of a forest. The trees that do grow here and there on the prairie are in ravines, on north slopes, on the leeward of lakes, on islands; in short, trees grow on the prairies where they are in some way favored and protected from the dry winds. A clump of trees may grow around a spring or along a permanent stream. The patches of prairie grasses in the forested regions are on sunburned south slopes, on coarse dry soils, or on the windswept spots where now and then the dry winds make the growth of trees very hard.

Trees can be grown almost anywhere, even on the Minnesota prairies, by cultivating the grass away from them and protecting them from fire, and cattle, and other stock until they are well started so that they shade the land. Cut away all the trees and brush in the forests of Minnesota, and grasses and weeds grow up in their place for a time. If, however, this land is left uncultivated, young trees and

FIG. 48. Second Growth Hardwood on Lake-washed Till, South of International Falls.

bushes soon begin to appear and in time the land will be again covered with a forest.

The Struggle Between Prairie and Forest. The amount and distribution of rainfall agrees only in a general way with the distribution of prairie and forest. The western prairie extends into southeastern Minnesota, into the wettest area of the State. The eastern forest extends into nearly the driest area in northwestern Minnesota. Besides the amount of rainfall, there is another matter which is important—humidity, the amount of moisture in the air. The humidity affects vegetation.

The velocity or swiftness of the drying winds also affects vegetation, for the swift winds dry up the ground many times faster than a slow breeze does. The rule is that the drying power of the wind increases as the square (v^2) of its velocity, that is, if the velocity of the

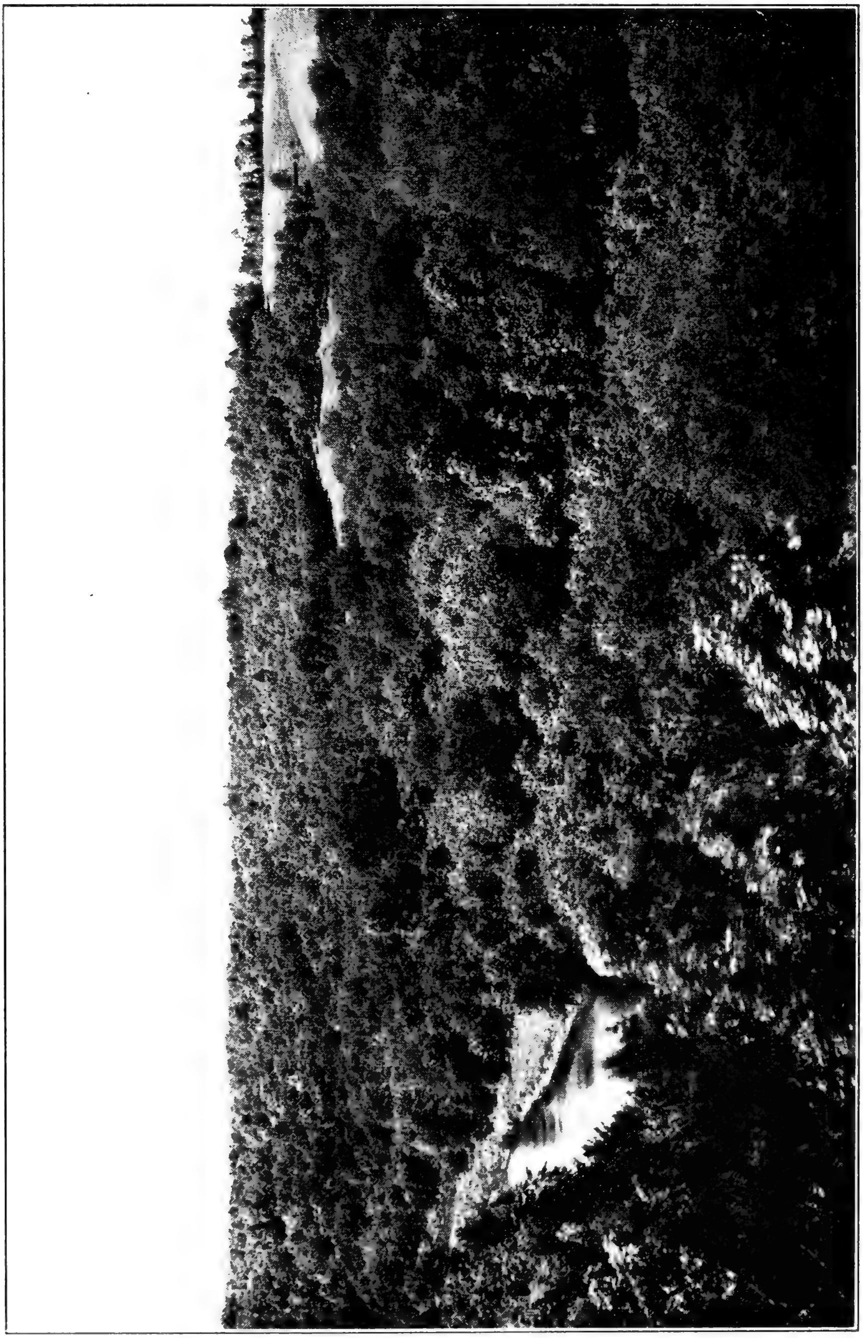


FIG 49. Hardwood Forest in Valley of Zumbro River, Southeastern Minnesota. *Photograph by J. P. Wentling.*

wind is doubled, the drying power becomes four times as great. If the velocity is increased threefold, the drying power becomes nine times as great. There are generally stronger winds in northwestern and southern Minnesota than in the northern and northeastern portions of the State.

The Hardwood Belt. The struggle for dominance between prairie and forest has been going on for centuries in Minnesota, between the westerly dry winds and the easterly moist winds. The belt of hardwood trees may be compared to a battle line between grass and tree. The solid prairie is on the west of it and the well-established forest is east of it. There are patches of hardwood forest and scattered hardwood trees also, all through the area of conifers or pine forest. The pines and other conifers, tamarack, spruce, balsam, fir, etc., are not pioneers in natural reforestation such as the poplar and willow are. These cone bearing trees bear winged seeds which the wind often carries long distances, but if these seeds fall in an open field or on a burned over area, they do not thrive. The young pines and spruce trees are what the botanist calls "tolerant," which is another way of saying they are neighborly to other trees, that is, they can grow in the shade of other trees. Indeed they do not thrive anywhere else than in the shade until they become rather tall trees.

When a pine forest is cut down and then burned over, as usually happens in Minnesota, that land does not grow up again to pine. Willows, poplar, cherry, birch, alder, and perhaps later also oaks, basswood, and maple, grow up. After a young forest with its shade has occupied the place of the late pine forest, then in case pine seeds are carried in by the wind, young pines grow up and in time these will overtop the other trees and make a dense pine forest again. The area marked on figure 46 as coniferous forest may be looked upon as an old, long-established forested region.

When a prairie is burned over or plowed up and then left uncultivated, it does not naturally grow up to forest. It goes back to prairie grasses again. When forest is cut off or burned up, it does not grow up to prairie naturally, but grows to forest again. This is because climatic conditions in nature determine in general whether prairie or forest shall occupy the region.

The Struggle on Wet Lands. In like manner as prairie and forest contend for supremacy, the sedges and swamp trees contend for possession of wet lands. The sedges resemble the grasses, but may be distinguished from them generally by the shape of their stems. Grass stems are round and those of sedges are generally square or three cornered. The sedges are often called slough grass.

FIG. 50. Norway Pine Forest, on Sandy Outwash Plain, near Cass Lake.

FIG. 51. Birch Thicket on Bear Point, Itasca State Park.

In the forested region in Minnesota there are many places where the ground is always wet. In such places the ground water stands close to the surface. Only certain trees that have shallow roots can grow there, such as tamarack and the swamp spruce. Such wet land areas which have grown up to trees are properly called swamp. In the swamps there are very often places where the ground water level is so near to the surface that not even swamp trees can thrive. Such a swamp is properly called a marsh. A marsh is like a swamp only that it is without trees and is grown over with sedges. Sedges thrive where neither trees nor grasses proper can grow.

FIG. 52. Hardwood Forest Bordering Small Stream, North of Jackson.
Photograph by J. P. Wentling.

When swamps and marshes in northern Minnesota are artificially drained so as to convert them into grassy meadow lands or pastures, willows, poplars, and other trees are kept out only by effort. In the prairie regions, on the other hand, when marshes are drained or dried up under natural conditions, grasses rather than trees tend to come in. The "crex" grass lands near McGregor and Ude and west of Backus are marshes which are mowed for their growth of sedge, out of which carpets and rugs are made.

Fig. 53. Mississippi River as it Leaves Itasca Lake. Pine and Hardwood Trees on the Upland Bordered by Water Loving Shrubs, and These in Turn give way to Swamp Sedges and Finally to Water Lilies and Reeds. *Photograph by Brown.*

Fig. 54. Draining a Muskeg Swamp in Roseau County.

Muskeg. When the swamp or marsh is grown up with peat moss, it is called muskeg, an Indian name. The moss makes a thick, spongy carpet covering the surface all about under the trees and under the tall sedges. This carpet is nearly always wringing wet because the moss has a peculiar structure by which it holds water until it is like

FIG. 55. Tamarack Swamp, Itasca County.

a very wet sponge. To appreciate a muskeg one should walk a mile through its thick yellowish-green wet carpet, sinking into it knee deep at every step or stumbling over roots and logs that are concealed under it. Because this moss helps to make peat bogs, it is often called peat moss. Small muskegs are found as far south as the Minnesota River near Minneapolis, but in the northern Minnesota forested region muskegs are more common and they are often miles in extent.

CHAPTER VIII

HISTORY OF A PEAT BOG

Bogs as generally thought of may seem very uninteresting. Land owners who have bogs on their lands are very likely to consider the only interesting question about them to be how to get rid of them, or how to change their character so that the land can be used for fields or meadows. In other words, how to get the bogginess out of them.

The bog lands of Minnesota, however, will probably some time come to have great value, both for their productive soil and for fuel. Like many other things which we do not know much about, peat bogs are likely to be better appreciated and valued when more is known of their history and character.

It may truthfully be said of a peat bog that there is very little that is hard to understand about it, and the understanding of it tends to lead to its use.

The Nature of Peat. Peat is the remains of plants submerged in water. The plants from which peat is formed are, generally speaking, such plants as grow in water. The fact that the plants grow in water means that the plant foods which are contained in the water are used up by the growing plants. These food substances, or salts, are known as nitrates. Without nitrates vegetable or plant remains cannot decompose or rot. All decay of organic substances, animal or vegetable matter, is related to a process which is associated with nitrate substances. As water loving plants continue to grow year after year in the ponds or lakes, and in swamps or marshes, more and more the nitrate substances in the water are used up for food, and less and less, therefore, the plants which grow and fall into the water decay. Thus an accumulation of vegetable matter gathers on the bottom of a pond or margin of a lake, and gradually develops into a peat bed.

Peat Bogs. A peat bog may be either a marsh or a swamp. How a pond or lake becomes a peat bog has been explained above. If, however, the bog contains the stumps and trunks of trees that have fallen into the bog and been submerged in the water, and imbedded in the remains of sedges, grasses, moss, and leaves, this would be called a swamp. The logs and stumps are not peat, but they are buried in a peat bed.

Peat consists of sedges, lilies, grasses, moss, and leaves, and the like, all more or less decomposed and packed together forming a "bed." Peat from Minnesota bogs may sometime be an important source of fuel as it is now in some parts of the world. So the swamp bogs of Minnesota may sometime be a source of timber supply from the logs which are entombed in them. A ton of wet solid peat contains 1,700 pounds of water and less than 300 pounds of vegetable or "fuel" matter. It will thus be seen that there are limits to the value of peat as fuel until it has been dried.

Peat in bogs may represent all degrees of decomposition or rotting, from almost perfectly preserved vegetable tissue of leaves and grasses to black muck which is the same material almost fully rotted or decomposed. The muck is black because of the carbon or charcoal that remains. The carbonaceous matter of plants is the most nearly indestructible of any of the elements or substances of which plants are composed.

There are different kinds of peat bogs, according to the kinds of plants from which the bed has been formed. The kind of plants in turn that grow in any bog is determined by the conditions. In some bogs sedges abound; in others water lilies; still again sphagnum moss; in some bogs there are logs and stumps of trees buried, such a bog being a swamp; in others there are no logs or stumps, the bog being a marsh. The resulting peat bed may, therefore, be made up of any one of these kinds of partly decayed plants, or of several of them mixed.

There are all degrees of decay in these bogs. In some the plant tissue is nearly as sound as when it was growing. In other bogs the bed is so far decayed that it is a nearly structureless black muck. Peat bogs are therefore classified according to the kind of vegetable matter of which they are made up and of the degree of decomposition that has taken place.

History of a Peat Bog. Just as there are different kinds of peat beds, so the length of time required for the peat bed to accumulate varies very much. If the history of a peat bed, as shown by a study of its structure, revealed that it began in a somewhat deep lake or pond, and plants having slender stems and leaves prevailed, it might have been many centuries forming. On the other hand, a peat bed that originated in a swamp where trees grew and contributed their stumps, roots and trunks, as well as twigs and leaves, might grow and accumulate more rapidly. There are peat beds in Minnesota that are 10, 20, and even 40 feet in thickness. Some of these show by their composition and structure that they accumulated very slowly. Probably some of Minnesota's bogs are more than 10,000 years old. If a peat bog is drained so that air gets into the peat, it will then at once begin to decay. A bed of peat that had been 10,000 years in forming might become black mucky soil in a single century or even less.

Cross Section of a Peat Bog. When a peat bed chances to be cut through by a railroad grade, a road, or a drainage ditch, so that a section of the bed is shown, it is often found possible to determine the history of the bed. At the bottom, under the peat bed, may be evidence to show what were the conditions before the peat bed began to form. In other words, it may be shown what was there before the bog began. Where now is bog may have once been the shore of a lake, as shown by a deposit or layer of sand and shells. It may have been at one time a lake bottom, as shown by shells in a deposit of mud. It may have been a shallow bay or slough, as shown by pond lily seeds and roots, or by seeds, stems, or roots of other slough vegetation. It may have been a marsh or swamp, and later developed into a peat bog; or it may have been dry land in the first place, as shown by stumps and roots of jack pine or of hardwood trees such as grow only on well-drained land. The peat bed itself may have begun from sedges, grasses, or moss, or any of the peat forming vegetable matter that has been referred to.

The successive layers of the peat bed may show the changes that have taken place in the history of the bog. It may have been at first a marsh. Conditions may have changed so that later trees grew and the bog became a swamp. Sedges, grasses, sphagnum moss, and other plants may also be found in successive layers, showing the history of the series of changes in the character of the bog.

Peat Beds, Past and Present. Peat bogs have played an important role in the history of the past. Many coal beds are beds of peat that have been changed into coal. Peat beds are now forming in Minnesota, the same as they have been forming during the centuries of the past. The story of the formation of the peat beds can be seen in the beds that are forming in the bogs of the marshes and swamps, lakes and sloughs that form a feature of the landscape today.

From Lake to Peat Bog. In many places swamps and marshes are found with the marks of a lake around them. With the banks and beaches of a lake shore all around the edge of a swamp, and a peat deposit from one foot thick at the margin to ten feet or more at the center,

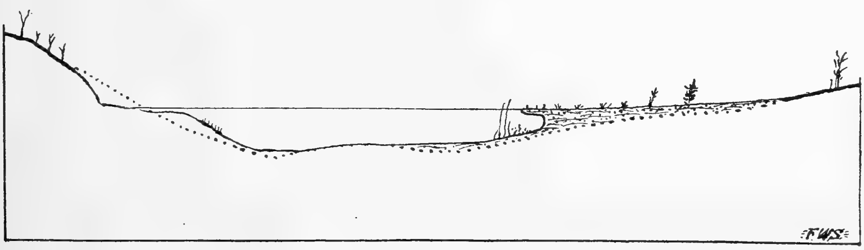


FIG. 56. Cross Section of a Lake Showing Wave-cut Shore (left) and Bog Filling (right).

no further evidence need be considered necessary to prove that a lake has been transformed into a peat bog and is slowly accumulating a peat bed. But there are also many such swamps with open marshes or with sloughs, or even clear lakes or ponds at their centers. In fact, every degree of bog growth can be seen in Minnesota from clear lakes or ponds to those overgrown by vegetation until they have become swamps and marshes (Fig. 56), showing how some lakes have been and are being filled up by growth of bogs around their outside borders, and gradually encroaching toward the center. Thousands of what were once shallow lakes in Minnesota have become marshes and swamps in this way.

From Forest to Marsh. Peat moss, called sphagnum, thrives in moist places, and this moss acts as a sponge, holding water to keep itself and the place where it grows wet. In the dense shade of a forest, this moss will thrive where it could not grow at all if the trees did not shade the ground. A growth of such moss a foot or more deep clogs drainage of the land and makes it swampy where there would be well-drained ground if the moss were not there. Groves of large spruce, of large tamarack, or of cedar, with some other varieties of trees scattered among these, and all standing surrounded by a foot or more of peat moss, make the beginning of a muskeg. As the peat deposit becomes deeper and deeper under the growing moss, the swamp becomes more and more wet. The trees that now survive are smaller. Gradually the larger trees are drowned out. This is the second stage of a muskeg. Such swamps are often on gently sloping land surfaces that would be dry except for the peat bog vegetation which holds the water from draining away.

With the wider spreading of the muskeg condition and with the deeper depositing of peat at the center or where the muskeg began to form, an open marsh is formed. This is surrounded by a stunted growth of small spruce or tamarack. Outside of the zone of stunted spruce and tamarack, there is a zone of trees of larger growth.

Muskegs of the North. In northern Minnesota marshes and swamps spread out one into another, uniting lake bog and forest bog over a wide area. For miles in extent covering whole townships, except for a few high places which stand as ''islands'' on the smooth muskeg landscape, what has been called the great Beltrami ''Swamp''—really the great Beltrami muskeg—spreads out from Red Lake and the Rainy River east to Vermilion Lake. On the Mississippi from Hill City to Palisade and McGregor at Island and Meadowlands in the St. Louis Basin, are other examples of muskeg.

Muskeg does not, of course, belong at all to the prairie region. The peat moss which has sometimes made shady forests over into peat swamp and peat marsh cannot grow at all out on the sunburned and windswept prairies. Peat beds of any kind are not extensive in the prairie regions, and those which do occur there are from sedges and grasses in overgrown sloughs and lakes. In the forested region, both the overgrown lakes and the mossy forest type of muskeg have grown up. Those two types of bog are not only found side by side, but also in succession. The muskeg or mossy swamp has followed upon the overgrown lake frequently, and, again, the growth of muskeg has sometimes blocked the streams so that lakes or open marshes have resulted where

FIG. 57. Cross River Meandering Through a Spruce Swamp, Cook County. *Photograph by F. J. Always.*

had once been dry, forested lands. The great muskegs which are miles in extent in the North are just like the smooth prairie lands in every way as to subsoil and landscape features, except that they are overgrown with peat moss with peat beds underlying the moss for the greater part from 1 to 20 and even 40 feet thick.

Hillside Bogs. From Mendota to Savage along the Minnesota Valley a sloping bog can be seen from the car window of the Omaha Railway. There is also a notable one just east of the State Fish Hatchery near Mounds Park in St. Paul, which can be seen from the railway or from the wagon road. There is always spring water seeping or flowing out of the upper side of hill bogs, and a growth of sedges, grasses, or moss with willows and other vegetation choking the drainage of what would otherwise be streams flowing from the spring. The bog becomes a peat or a muck deposit. At Chaska and at Jordan there are such peat or muck beds which are used for "mud" baths.

Hill bogs usually build up a terrace on the hillside from which the springs break out. Occasionally such a bog is built up on a flat plain or meadow. In this case a low, broad mound is built up with a spring

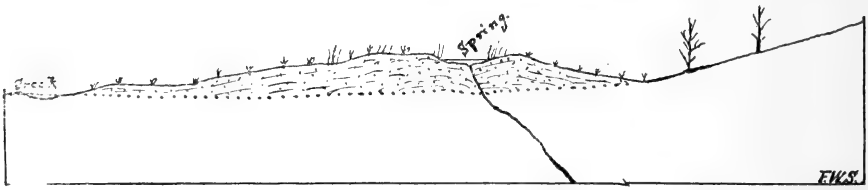


Fig. 58. Raised Bog. The Dotted Line Shows the Original Land Surface. The Bog has Grown Up Around the Spring.

issuing at the top. (Figure 58.) In attempting to walk toward the top of such a mound, one gets into worse bog when he may be endeavoring to get out of it.

CHAPTER IX

MINNESOTA, THE OLD AND THE NEW

The Landscape Before the Ice Came. What was Old Minnesota? What was the landscape of Minnesota before any glaciers had ever crossed it, before its valleys were filled, and its hills were planed off by the ice?

One little corner of the State, that of the extreme southeastern part, in Houston and Winona Counties, remains to tell of what was before the invasion of ice occurred. Here is a fragment of landscape that was not covered by the ice at any time during the glacial period. It is a part of Old Minnesota. We may imagine that the old landscape extends away under the drift, but its face has been much marred by the ice, and if we imagine the drift to be all lifted off from the landscape, the old landscape would appear much changed from that which was there before the ice came.

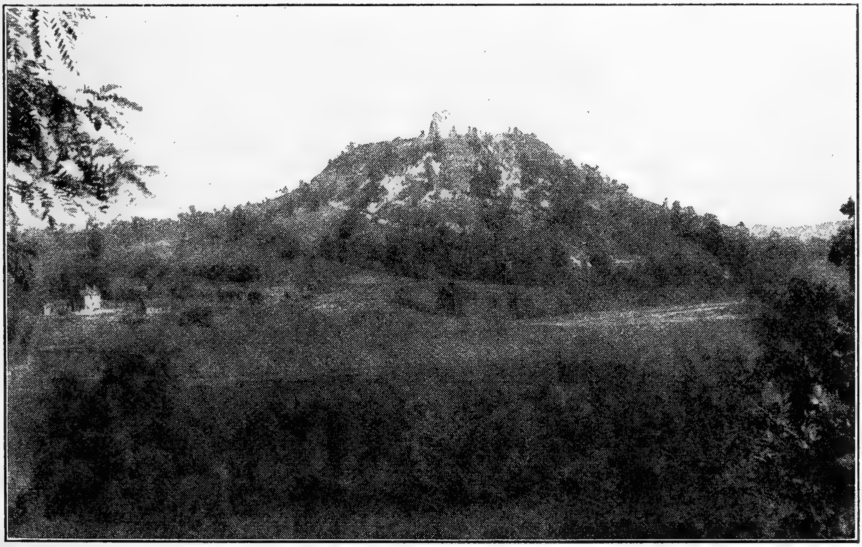


FIG. 59. Sugar Loaf. Near Winona. A Hill of Erosion.

In the main, the great valleys and highlands of the State remain today much as they were, because the ice of the great ice sheets followed the lines of least resistance in moving over the landscape, filling and flowing down the large valleys and turning aside and going around the greater highlands. However, the smaller valleys were filled and many hills were worn off, and in addition morainic hills and other deposits were thrown down when the great ice sheets melted. The little corner in Houston and Winona Counties remains as in preglacial time, except that the work of weathering and erosion has been going on through the long centuries of the glacial period and the time since.

The Old Landscape Becomes New. When the glaciers moved from Canada during the glacial period they put a new face on Minnesota. They put the same kind of face on Wisconsin and other States at the same time. This new face of the land in Minnesota has, of course, some features of the old face which it replaced. The higher parts of the State on the old landscape are in general the higher places of the new, and where the lower land was then is the lower land still. On the old surface there were no lakes excepting some bayous along the larger rivers. On the new landscape there are thousands of lakes of all sizes and depths,—lakes many miles in area down to frog-ponds and sloughs. On the old landscape there were many streams and all of them had regular valleys of erosion, while on the new surface there are some streams with valleys, some valleys without streams, some streams without valleys, and in some places there are neither streams nor valleys, only lakes and sloughs.

The drift which the glaciers brought and dumped unevenly over the land blocked the valleys, and as the glaciers melted away, the water from the melting ice helped to make new rivers either over the old valleys or along new lines. Since that time for thousands of years the streams have been working at valley making again, but it will be many thousands of years yet before the valleys are "old" again—before all the lakes will be gone, their basins cut across by valleys and ravines; and the hills rounded by erosion; and deep valleys carved in this young glacial landscape.

Meaning of Old Landscape. The land surface over which the first of the glaciers passed in its descent across Minnesota was, as has been said, an old landscape. It had deep valleys. In fact, if all the glacial drift were removed from the face of the land there would be deeper valleys than any that are now seen. The Mississippi Valley below St. Paul would be 200 feet deeper than the present valley. Beneath where Lake Minnetonka now lies, 400 feet below the present lake, would be the Mississippi River valley. Delano would be on the Mississippi River instead of on the Crow. The St. Croix would join the Mississippi at Delano instead of jumping across to the old Apple River valley above Stillwater. Benson, Hancock, and Elbow Lake would be on the Minnesota, and they would be more than 400 feet lower than they now are. This old face of

Fig. 60. Valley of Rollingstone River near Minnesota City.

Minnesota with its deep valleys was eroded and developed from the smooth young landscape that was lifted above sea level long ages ago,—long, long before the glacial period.

How the Landscape was "Born." It is spoken of as "young," this land that had recently been sea bottom, because when it first appeared as dry land it was "without form and void," that is, it was a broad low land surface on which there were no streams or hills. In fact, there were no landscape features. It was young, because it had, so to speak, just been born or just emerged from the sea. This new young face was formed on the bottom of the sea, being deposited as sediment or mud in what is called Cretaceous time.

The formations of which this part of the continent is made up were sediments deposited in the sea that had previously covered this part of the continent. This sea is spoken of as the Cretaceous Inland Sea. It covered the central portion of the North American continent from the Gulf of Mexico to the Arctic Ocean, during Cretaceous time. (See figure 61.)

Land Covered by the Sea. The changes that the North American continent has been through have been very profound. The whole story is too long to be told here. It may be stated here simply that during Cretaceous time the central portion of the continent, from the Gulf of Mexico northward to the Dakotas and Minnesota, and beyond in Canada to Hudson Bay and the Arctic Ocean, was sea bottom. This portion of the continent became lower relatively to sea level, so that the seas came in and covered the land. It must be understood that this change from land surface to sea was a slow one and the subsidence of the land and the creeping in of the sea upon the land was going on during a long time. The river valleys of that part of Minnesota that was covered by the sea were either "drowned," that is, swallowed up by the sea, or were brought so near to sea level that they began to fill up with sand and mud. It is probable that as long a time was required for the Cretaceous sea to creep in upon the subsiding land and for the valleys to be filled up as all four of the glacial stages occupied later. But the valleys were filled on the submerged landscape, and all land of Minnesota that remained above sea level was planed down and made flat by erosion.

Fig. 61. *After Dana.*

When later the Rocky Mountain region westward rising and folding the land which includes Minnesota lifted again above sea level, Minnesota thus came to have a new and young surface, and it was on this newly emerged surface or young landscape that rivers cut deep valleys, as already noted.

Remnants of the Ancient Sea Bottom. Some remnants of that ancient Cretaceous land surface still remain. At Coleraine a bank of oystershells over the ore bed of a mine is a part of the Cretaceous sea bottom. This ore bed belongs to a still more ancient sea bottom which will be described later. A bed of coal at Morton is what remains of a low swamp of that ancient Cretaceous time. Clay and sandstone containing leaf imprints at New Ulm and along the Cottonwood River are the filling of an estuary like Chesapeake Bay. Many such patches of the old Cretaceous lie hidden under the glacial drift of Minnesota.

In southeastern Minnesota, south and southeast of St. Paul, the remnants of the Cretaceous plain or near-plain (pene-plain) are found only near the tops of the highest hills. It is easy to conclude that there

FIG. 62. Valleys Bordered by Limestone Tablelands near Hampton.

was in Cretaceous time a pene-plain across where there are now hilltops, and that the Mississippi Valley and its tributary valleys were eroded into that plain after the Cretaceous Inland Sea had retired from the land and before the glacial period.

In the figure the relation of the Cretaceous plain to the present landscape is shown. Only the hilltop above the line AB is Cretaceous. Below the level of the line AB, the formations belong to a still more ancient time—Ordovician and Cambrian. The line AB is 400 feet above the Mississippi River at Red Wing, and low water level at this point is 664 feet above sea level. The remnant of the old Cretaceous landscape is therefore nearly 1,100 feet or more above sea level. The dotted line of the figure shows the position of the plain on which the ancient Cretaceous formations rested before these had been cut up by streams. At vv are shown the valleys as they are today, deeply carved not only through the old Cretaceous formation but also into the Ordovician and Cambrian below. (Figure 63.)

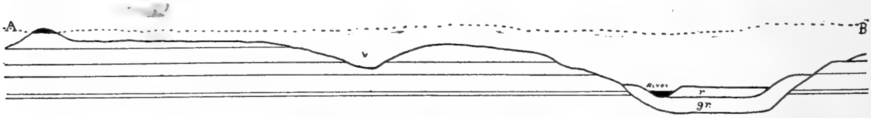


FIG. 63. Profile at Red Wing. Dotted line A--B, 11 miles. A—Southwest, B—Northeast.
A-B—Cretaceous plain before erosion.
V—Later eroded valleys.
gr—Glacial river gravel.
r—Recent river floodplain fillings (alluvial).
River—Mississippi River.

How the Ice Changed the Landscape. The evidence shows that when the first invasion of ice occurred glaciers overran an old forested landscape in Minnesota, a landscape on which were many valleys and hills, and on which drainage systems were well established. It ended leaving a new surface with lakes, ponds, and sloughs upon it and no established drainage systems, the former river valleys having been filled up. Then time changed that young face to an older one. In fact, that drift surface seems to have been eroded, furrowed, and gullied deeply before the Kansan or second drift covered it from sight and away from the weather.

The drift of this first glacial invasion in Minnesota is a gray drift, and very much like the gray drift of the second and of the fourth glacial stages, but it is darker colored and has as a rule considerable wood in it. The old drift at the sand pit of the Chicago, Milwaukee and St. Paul Railway south of Mendota is full of wood. The glacier of that time tore up trees, soil, and a deep clay subsoil, which it mixed with fresh rock flour and other debris brought down from the Northwest.

Now this poor old remnant of a once grand glacial deposit has been hard to give a name. It is variously called Nebraskan, Kansan, pre-Kansan, Jerseyan, and Older Gray drift by geologists. N. H. Winchell of Minnesota called it the Older Gray drift to distinguish it from the "Old" Gray drift of the second glacial stage, the Kansan, and the Keewatin of the fourth glacial stage.

Thus the landscape of Old Minnesota was destroyed, so to speak, and a new young face was imposed upon it by a great glacier which overran this part of the continent. This new and young landscape at once began to grow "older" by the development of drainage streams and the weathering of the surface deposits. Four great stages of ice invasion have occurred in Minnesota, that is, there have been four great climatic periods when arctic or semi-arctic conditions prevailed. Each one of these cold periods was followed by a comparatively temperate period or stage, spoken of as an interglacial stage. Indeed we are now living in the fourth interglacial stage, and for anything we know there may be another invasion of ice or another glacial stage, about which, however, we need not be worried. While each of the four glacial stages was very much like Greenland of today and not like Minnesota of today, the interglacial stages had a climate much like our climate now. The trees, moss, and animals, as shown by the buried or interglacial peat and soil beds, were mostly the same as now live in the region. With the advance of the glaciers the muskox and reindeer came south to the Missouri, and went again when the glaciers were gone.

There are peat and soil beds found under the drift of the Kansan or second period and on the first or oldest drift in southern Minnesota. Occurrences of that kind in Mower and Fillmore Counties were described long ago by Prof. N. H. Winchell.* Those peat and soil deposits seen at New Ulm and other places contain moss, pieces of trees, bones of animals, shells and other evidence which suggest muskegs such as now occur in northern Minnesota.

In the iron mines at Hibbing where there are three sheets of glacial drift above the ore deposit, two gray drifts from the Keewatin ice cap with the red Patrician drift between them, the lowest gray sheet is Kansan, or drift of the second stage, and the other two are drifts of the Wisconsin or fourth stage. On top of the Kansan is a buried peat bed. Such peat beds on the old gray drift were probably hillside bogs or iron springs. In the digging or boring of wells in Minnesota peat and mucky black soil are often reported struck between the Kansan and Wisconsin drifts. Wherever the original surface of the Kansan was not destroyed the old soil is found buried under the later drift deposit.

*Vol. 1, G & N H Surveys, Minnesota.

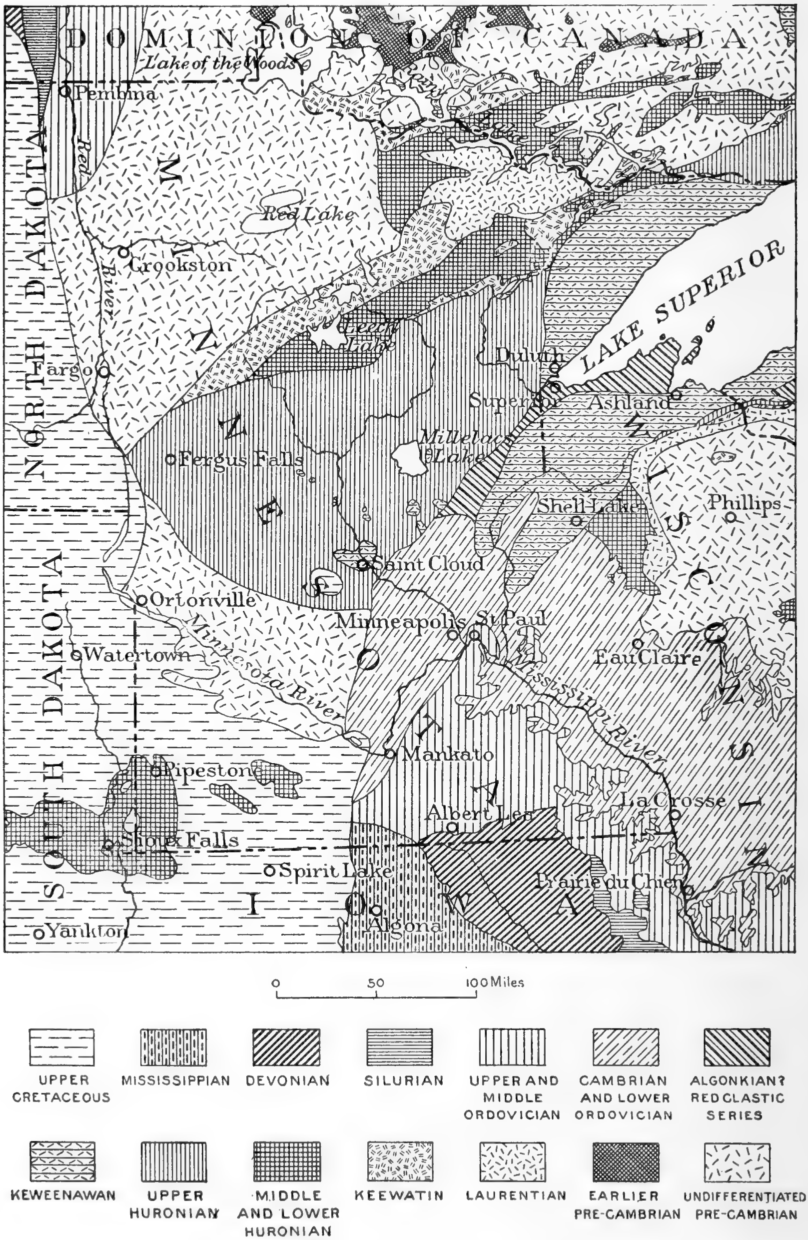


FIG. 64. Geologic Map of Minnesota and Adjacent Region Showing Distribution of the Rock Formations at the Surface.
In much of the area the bedrock is deeply covered with glacial drift. *From the Geologic Map of North America in U. S. Geol. Survey Prof. Paper* 71, 1912.

CHAPTER X

THE ROCK FOUNDATIONS

Earth's Interior. It is interesting to inquire into the character of the interior of the earth, though it is possible for us to know only its superficial character. An ideal section, showing all the geologic formations in order from the most recent down to the granite "foundation," is shown in figure 67. No such section exists at any one place in the world, but all the formations represented in this column occur somewhere at or near the surface. This column shows what would be the order of the formations if they all occurred at any one place.

The "bottom" or foundation in Minnesota is granite, so also it is granite everywhere where the "bottom" has been reached. The formation that rests upon this ancient granite floor is not the same in all cases. The younger or later formations lie upon or over those that are older, and the higher in the geological column the younger or more recent is the formation. Generally speaking, all the stratified rocks were formed on the sea bottom, being made up of sediments derived from the erosion of other rocks.

The oldest known rocks are granite and from these original granite formations, which it is supposed have appeared above sea level by upheaval from forces resident deep in the earth, the oldest known stratified formations were derived. The sediments in turn from which these oldest stratified rocks were formed, were themselves derived from previously existing rocks, and so the story goes back to that remote and unknown time when first the rocky crust began to be formed over the surface of a molten globe.

In the Beginning. What was the primitive condition of the earth when geology first began to be? We do not know, but the consensus of opinion among geologists is that in very early geologic time the globe was covered by water. In Genesis we read that the Spirit of God moved upon the waters and that the seas gathered themselves together and dry land appeared. The writer of the Mosaic books probably did not intend to write a geological history. Those majestic writings, however, gave to the children of Israel a conception of the beginning of things, when the earth was, so to speak, young. The dry land appeared. This so far as present day knowledge goes, is in accord with the facts as to the geologic beginning.

The crust of the earth it is known, is not rigid, but bulges out in one place and subsides in another. The "beginning" of land upon the earth so far as geologic history shows, was the expression of such a bulging or elevation whereby a portion of the rocky floor appeared above the surface of the ocean. As soon as such a land surface appeared, immediately erosion began, and the work of destroying the earliest continent began. The sediment from this primitive erosion became the early stratified deposits or formations.

A portion of the primitive North American continent, the oldest land in the world, is now embraced within the State of Minnesota. This

FIG. 65. Granite Exposures at Upper Falls on Snake River, Kanabec County.

ancient formation is in places concealed by glacial drift. It appears, however, at the surface over considerable areas.

Formation Beneath the Surface. It is much easier to look at the landscape than it is to see into it! We can look up at the stars at night, but when we look down, we see only the surface of the ground. When we wish to know what is under the surface, it is necessary to dig down to find out, and at that, we cannot dig very far. The deepest mines extend down only a mile or so beneath the surface, whereupon, it is 4,000 miles to the center of the earth.

What then is the rock foundation under Minnesota. There is a well on nearly every farm and wells in every village. Someone found out by digging or boring at each place, what kind of rock there is, down to well-water level, at least. The rock or earth at the surface is not in every place the same. The kinds of rock struck in making a boring or digging for a well, is not everywhere the same. A well may be begun in a limestone formation, then at some depth it may be clay or shale, and then in turn a sandstone formation, but however many different kinds of rock formation may be encountered in digging or boring a well, and however different any of these may be from the formation at the surface in any particular locality, these formations do not differ in kind from those which may be found in some other places at the surface.

That which is found in wells is not different from what may be found at the surface somewhere in ledges, bluffs, cliffs, sinks, or other rock outcropping. As far as wells and mines are concerned, they appear to be in what is only the upper part or surface crust of the earth. This is true in Minnesota and in all other places.

FIG. 66. Granite Exposures on Rum River, South of Onamia, Mille Lacs County.

The Granite Foundation. What then is the rock foundation under the surface formation in Minnesota? The spot at the center of the earth is, of course, the same under Minnesota as under any other place. A thousand miles around outside the exact center of the earth, too, may be assumed to be all the same, no matter what kind of rocks occur in any place at the surface. It may be that all the earth within 50, 20, or 10 miles from the surface, is the same everywhere in the earth and the same under all parts of Minnesota. That is to say, if wells were bored deep enough,—10, 20, or 50 miles,—it may be that the same kind of rock would be struck everywhere at these depths. The rock at that

G E O L O G I C T A B L E for Minnesota.

CENOZOIC.	Quaternary	Pleistocene	Wisconsin drift Illinoian drift — Upper Loess Kansan drift — Lower Loess Pre-Kansan drift
	Tertiary		(weathered rock surface, clays)
MESOZOIC	Cretaceous	Upper	Niobrara shales Benton shales Dakota sandstone
		Lower	Lakota sands and gravels
	Jurassic		
	Triassic		
PALEOZOIC	Carboniferous		? ? ? ? ?
	Devonian	Hamilton	Wapsipinicon limestones
	Silurian		Niagara limestone ? ?
	Ordovician		Maquoketa shales Galena, Decorah, Platteville Saint Peter sandstone Shakopee & Oneota dolomites
	Cambrian	Upper Middle Lowe	Jordan & St. Lawrence sands Franconia sandstone Dresbach sandstone Red Clastic series Keweenawan volcanics
PROTEROZOIC	Animican		Iron
	Huronian		Courtland quartzite &c. Range
	Keewatin		
	Archean		

F.W.S.

FIG. 67. The Two Columns at the Left Show the General Geologic Scale. The Two at the Right Show Formations that Occur in Minnesota.

depth would, no doubt, be found as hard as granite rocks that we know at the surface. It would be found to be crystalline rock or maybe of crystalline minerals, just as granite is a crystalline rock. In other words, the rock deep under the surface everywhere may be supposed to be granitic or like granite in character.

There are some granitic rocks cropping out at the surface at Ortonville, at Morton, and at Granite Falls, at New Ulm, and in the hills north of the Vermilion Range. These granitic out-croppings are either projecting ridges of the earth's central mass or they are what we may suppose the interior of the earth to be made of. There appears to be, at least, nothing else under them but just more of the granitic rocks. We may safely speak of them as the rock foundation of Minnesota. These rocks are known geologically as the Archæan group of rocks.

Besides these places where exposures of granitic rock occur at the surface of the ground, there are large areas where wells that go down through the glacial drift come at once upon the granitic rock. Figure 64 is a sketch map of Minnesota and shows what kinds of rock are found either at the surface where there is no glacial drift or immediately under it, where there is glacial drift. On this map the drift is ignored. Imagining that the drift has been removed, the map of Minnesota may be divided into two kinds of rock-surface areas: the areas where the Archæan granitic rock occurs at the surface and areas where some other group of rocks occurs at the surface with the Archæan at the bottom beneath the surface.

The Geologic Formations in Minnesota. There are four groups of rock-formation as shown on the map which lie over or above the Archæan granitic rock and under the glacial drift. These are called:—

(1) Mesozoic (Cretaceous). (2) Paleozoic. (3) Keweenawan. (4) Huronian. (5) Archæan.

The Cretaceous. The name Cretaceous includes all the rocks there are which belong to the Mesozoic group in Minnesota. This Cretaceous has been mentioned in a previous chapter, "The Old and The New," as a deposit made by a sea which extended into Minnesota from the south and west. It lies in some places on Paleozoic rocks, in some on Keweenawan, and still again on Huronian or Archæan.

Wells that have been bored through Cretaceous to its bottom strike one of these other rock groups. Near Morton Cretaceous clay beds are found lying on Archæan; near New Ulm Cretaceous sand and clay lie on granitic rocks of the Archæan in one place and in another they lie upon Huronian rocks, and in still another the Cretaceous formation rests upon Paleozoic rock. Near Goodhue and Austin, Cretaceous formations lie upon rocks of the Paleozoic age. The map, figure 64, shows in the southwestern part of the State, some high ridges of Huronian rock and the Cretaceous lies around them. These Huronian rocks were islands in the sea in which the Cretaceous formations were deposited.

The Paleozoic. The Paleozoic rocks occur in southeastern Minnesota and also in the northwestern corner. The Paleozoic formations include sandstone, shales or hard clays, and limestones, all these lying one above the other in successive deposits. The valleys in southeastern Minnesota have been cut by erosion of streams into this group of rocks. Valley erosion is still going on. Most of the cutting of these valleys was done before the glacial drift was deposited, that is, during the time preceding the glacial period. Some erosion of the top formation of

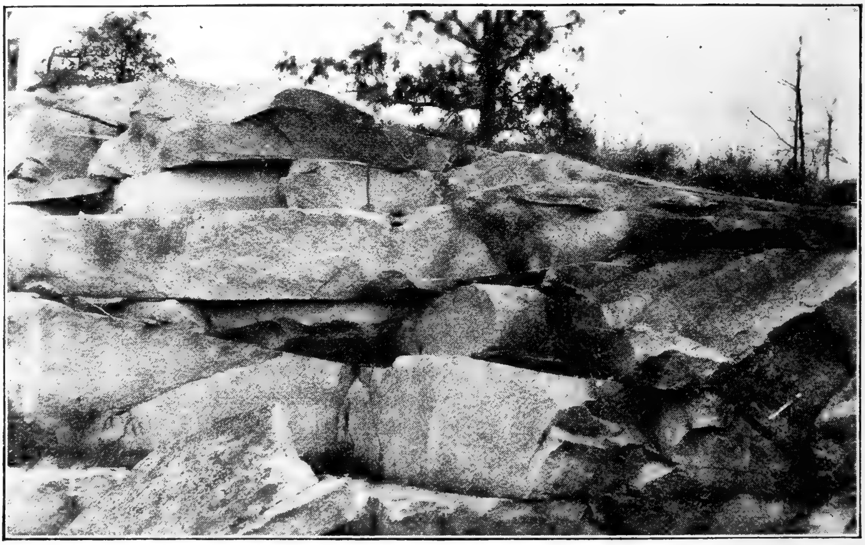


FIG. 68. Granite Outcrop at Meyers Quarry near Pierz, Morrison County, Showing Horizontal Jointing. *Photograph by Carl Zappfe.*

this group had occurred before the Cretaceous formations were laid down. This is evident from beds of these rocks which are found lying in what had been ravines and valleys in the Paleozoic group or formation.

At Minneapolis, a well was bored 2,135 feet deep before striking granitic rocks. Of the thickness of formations passed through by this well, 256 feet is drift, 754 feet is Paleozoic rock, and 1,125 feet is red sandstone of the Keweenawan group. The top of that well is at about 900 feet above sea level and Paleozoic rocks occur along the Mississippi from the Falls of St. Anthony to Fort Snelling at 800 feet above sea level. The well, which is near Lake Calhoun 4 miles from the river, is bored evidently where there was once a valley or ravine that is filled now 256 feet deep with drift. Its bottom is lower than the surface of the Mississippi at Fort Snelling, which is 700 feet above sea level. The bottom of the Paleozoic rocks at Minneapolis lies below sea level.

The Paleozoic formations are of lime, sand, and clay that were laid down by the sea. There are sea shells in these formations now. The sea that made them extended over this region from the south, evidently. In fact, the sea shore can be seen now by the boulders with sand and sea shells between them at Taylor's Falls. At Taylor's Falls rocks of the Keweenawan group stand higher than the Paleozoic and the sea shore lies against them.

The Keweenawan. The Keweenawan group includes volcanic rock and red sandstone which in some places, as near Duluth and Fond du Lac,

Fig. 69. Slate Outcrops on Mill Island at Little Falls, Morrison County.

have been found in wells in layers, one above another. The red sandstones are like the sands of the desert in color, but the sand grains and pebbles are assorted and arranged in beds in the way in which water deposits are generally laid down. The hills of Duluth are Keweenawan volcanic rock and also those at Taylor's Falls and Watab.

The sandstone rock at Sandstone, and that of Fond du Lac, belongs to the Keweenawan red sandstone, the same as that in the deep well at Minneapolis.

The Huronian. Lying under the Keweenawan, Paleozoic, and Mesozoic or Cretaceous rocks, but also occurring at the surface in places such as the Mesabi Iron Range, there is a large group of rocks, slate, schist, and other rocks of similar character which are called Huronian (the Lake Huron rocks). The Huronian rocks are folded, arched, and broken in the same way as rocks are folded and broken in mountain regions. These rocks appear to have been made in the same way as the Paleozoic and Keweenawan rocks were made. Some were sands, clays, and even limestones, and others were volcanic lavas that flowed either out upon the surface or were thrust into cracks between the other rocks and cooled and hardened there.

FIG. 70. Outcrop of Slate along the Railway Northeast of Denham, Pine County, Showing Parallel Jointing.

In the folding and twisting of them all into mountain ranges, they became hard like the Archæan granitics. The Huronian folded rocks and the Archæan between them in Minnesota are what remains of a very ancient mountain system that was thrust together and then eroded down at the top even before the other groups of rocks began to be laid down upon them.

The Huronian quartzite hills near New Ulm, at Pipestone, and Luverne are old mountains which are nearly but not quite worn down to their bases.

CHAPTER XI

OLD REDSTONE

In the valley of the Minnesota River in southwestern Nicollet County stands Old Redstone, a rock which has endured through all the changes since the early stages of geologic history on this continent. This rock is located near the village of Redstone, between New Ulm and Courtland, projecting into the valley from the northeast side. This monument of hard quartzite rock has stood there since the time when the North American continent was in its infancy.

A Remnant of the Ancient Continent. Quartzite, it has been explained before, is one of the hardest and most enduring of the common rocks of the earth, surpassing in this respect the hardest known granite. In fact, granite rocks that lie near Old Redstone and which probably at one time lay higher than its top, have yielded to the destructive agencies of time, and have become rotted and in places removed by erosion, while this hill of quartzite stands through all.

Old Redstone is a conspicuous hill standing out into the big valley in which the Minnesota River now flows and which was the valley in which the great glacial River Warren flowed during the time the waters of Lake Agassiz were drained southward. This hard old rock thrusts its head out, embracing an area of about 2 square miles. Of course it extends away into the earth, under or through other formations, to what extent we do not know. We are concerned now about the part that comes to or near to the surface.

It is a conspicuous feature in the valley, this rugged quartzite hill, rising 175 feet above the river and extending out from the northeastern side of the valley and turning the river from a direct course. This quartzite does not outcrop at any other point along the valley in this vicinity, so that Old Redstone stands out with the appearance of an isolated block.

Old Redstone gets its name fittingly from the fact that it is red (bright pinkish or strawberry) in color, and its color is so striking as easily to suggest the name. It is properly called ''old'' because it probably dates back to the earliest ages of Minnesota, and it has been stated before that the rocks in portions of Minnesota are among the oldest in the world. If it is true, as seems to be the case, that the outcrops of granitic rocks in the Minnesota and Cottonwood Valleys nearby represent granitic formations of Archæan age that once occupied these valleys and which have yielded to Nature's processes of destruction, then Old Redstone truly stands as a doorkeeper, keeping tally as it were on all the records of the geologic past. If Old Redstone could talk, what a story it might narrate! Let us commune with Old Redstone, and perhaps we may hear even his voice of stone, for written on his face

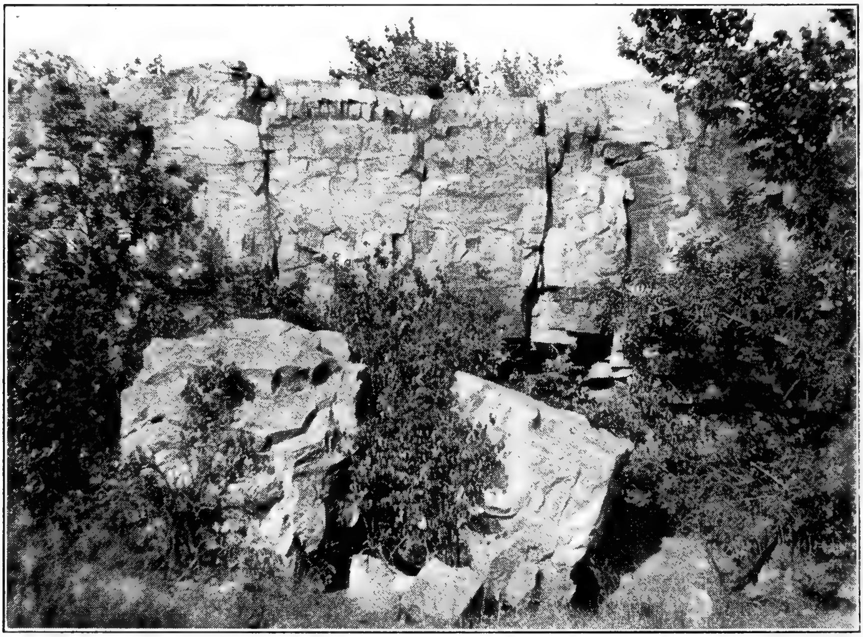


FIG. 71. Sioux Quartzite Outcrop at Pipestone. *Photograph by J. P. Wentling.*

and about his base and sides are indeed records of much that has gone before.

About the base of this ancient rock occurs a deposit of gravel of Cambrian Age, showing that in Cambrian time a sea surrounded this island or peninsula of hard rock. Instead of wearing it down and burying its base in sediments, it withstood the waves of the sea and the wearing of the wind and of weather. During the long ages between Cambrian and Cretaceous time, Old Redstone stood as a great rock sentinel above a surrounding plain or neighboring valley. During Cretaceous time, a valley which lay to the south of the rock was filled with delta deposits. But the top of this rock appears to have stood above the level of these deposits. During Tertiary time, a valley 200 feet deep was eroded, cutting into the granitic rocks to the north of Old Redstone. When the great ice invasions occurred during the Glacial Period, this hard old rock was twice buried and covered by great glaciers. The glaciers cut slight grooves in the hard rock and striæ which are still clearly visible were marked on the surface. The striæ show by their direction (S 33° E) the direction of the movement of the ice. It is probable that the sheets of drift deposited by the glaciers extended over the top of this rock, but these have been removed by erosion, either during interglacial or in postglacial time.

Relation to Glacial Valley. The valley of the Minnesota River and that of Big Cottonwood River, which enters the Minnesota opposite to this rock, are very interesting, and the rock itself has played an active part in determining the features of the valley at this point. This valley, through which the waters of the River Warren flowed, is here 200 feet deep and is marked by well-defined terraces. The fact that these terraces extend several miles up the valley from Old Redstone hill suggests that this rock may have been the cause of the formation of the terraces.

The old rock is thought to have been buried under the drift to a depth of 50 feet during the second glacial invasion. The rock was in the path of the River Warren, and the waters of this great glacial stream passed above the rock until its swift current removed the drift which lay over the rock. Then the river turned aside and went around the rock, as it was too hard to be worn away by the stream. The valley was gradually cut down deeper and the river continued to swerve around the rock to the westward.

Terraces Formed by Glacial River. This rock now projects for half a mile from the left or east bank into the valley. The city of New Ulm stands on what was an island in the River Warren about 4 miles up the valley from the northwest end of Old Redstone. The cemeteries at New Ulm are located west of the city on the highest terrace of the glacial Minnesota River. This terrace is about 60 feet below the general prairie level of that vicinity and was formed by the River Warren before this stream eroded its channel below the drift of the last, or Wisconsin, ice invasion. This terrace plain was the bottom of the channel of the River Warren, and it extended all the way across the valley excepting for a small island within the present limits of the city of New Ulm which stood higher than the flood waters of the river. The River Warren was fully 2 miles in width at this time. At this stage it flowed over the top of Old Redstone, and eroded away the drift that had been deposited upon it. This high terrace extends on the east or left side of the valley from a mile above Old Redstone to 4 miles below it.

A second terrace lies 30 feet below this high terrace, and on this second terrace the highest part of the city of New Ulm is built. This terrace is in the older (Kansan) drift. Old Redstone raises its bald

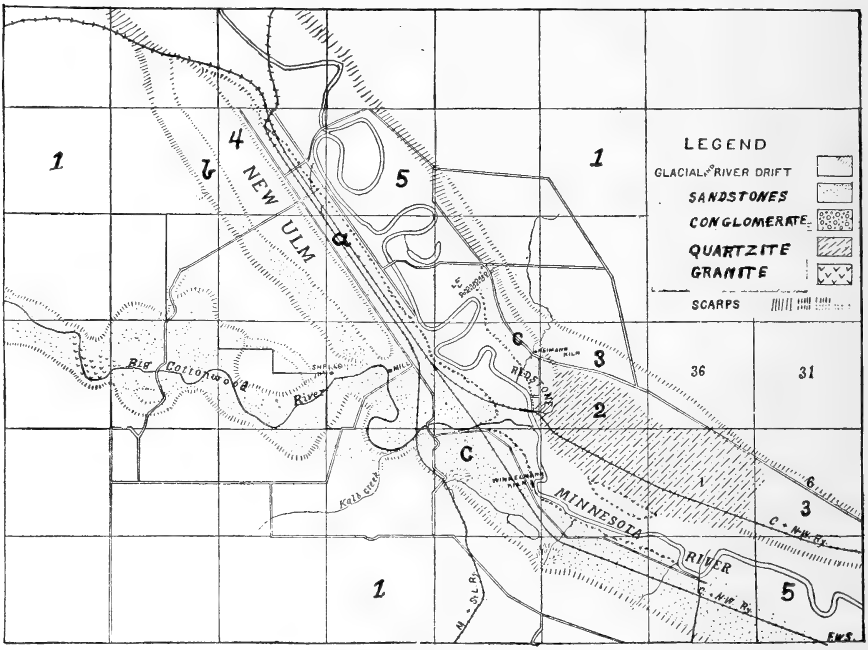


FIG. 72. Minnesota Valley at New Ulm.
1. Prairie level and drift surface.
2. Redstone quartzite hill in the valley below prairie level.
3. Old river terrace around Redstone hill.
4. Old island above the Redstone hill.
a. Lower terrace in front of the island.
b. Channel made behind the island.
c. Terraces of same level as a & b.
5. Minnesota River bottom land, and river meandering in it.

and polished head a few feet above the level of this terrace, showing that at the time the River Warren was at this stage, it turned out and went around this hard old rock. This terrace extends for a mile on the opposite side of the valley.

A third terrace lies 40 feet below that just described. This terrace rests upon the top of the Big Cottonwood formation, showing that the River Warren at this stage had eroded entirely through the drift sheets at this point. At the time when the river had eroded to this depth all the higher part of the present city of New Ulm was an island. One part of the river flowed up the old channel to the west of the city. The bottom of this old channel forms a part of this terrace plain. On the flood plain of the river to the east of the present city the business section of New Ulm is built. The Minneapolis & St. Louis Railway south of the Cottonwood River crosses a triangular tract of this terrace.

The glacial River Warren during the time it was carrying the waters of Lake Agassiz southward eroded this great valley 40 feet below the level of the flood plain represented by the terrace last described. The depots and railway tracks at New Ulm are located on this lowest terrace plain. It extends down the valley for 3 miles beyond the Cottonwood River, occupying a great part of the valley opposite Old Redstone hill.

Glacial River Obstructed. These terraces in the valley in the vicinity of Old Redstone are in marked contrast with the valley above New Ulm where the valley is a great simple trough or ditch cut into the gently rolling prairie. When the River Warren encountered the obstruction offered by Old Redstone, its waters were compelled to cut around the rock. This served to pond back the waters above the rock and to cause a rapids opposite to the rock. The river first formed its channel in the younger (Wisconsin) drift, later cutting into and through the older (Kansan) drift, and before the waters of Lake Agassiz finally were drained away by another outlet this great river eroded deeply into the Cretaceous (Big Cottonwood formation). The boulder clay of the younger or Wisconsin drift is a tough clay not easily eroded. Below this is a loose gravel bed. The top of the older or Kansan drift is also a tough boulder clay, and again below this is loose gravel. The top of the Big Cottonwood formation consists of beds of tough clay and below this is loose coarse sand.

As the River Warren flowed through the rapids opposite Old Redstone, the swift current eroded more rapidly because a rapid current erodes more vigorously. So when the river cut through a more tough and resistant formation at some point, the deeper channel thus formed would tend to be widened by the rapid crumbling of the looser formation underneath and the undermining of the overlying tough formation so that the channel would tend to grow rapidly wider. In this manner as the successive tougher and looser formations were reached, the terraces were formed.

An Ancient Landmark. Old Redstone thus because of its great hardness and natural resistance to weathering and erosion has stood through the long ages since Archæan time, and the first shaping of the North American continent. The encroachment of the sea during the Cambrian time threatened the hard old rock with destruction by waves, but the deposits of sea gravels at its base show that it stood unscathed. During the long Paleozoic ages while that part of the continent which includes Minnesota was land and subject to erosion of streams and the weathering agencies of heat and frost, air and water, Old Redstone stood bravely out on the landscape. And when ages later in Cretaceous time the sea again threatened to submerge it and bury it beneath a deposit of wave-washed sediments, still its head remained uncovered bared to attacks of wind and weather. Finally, after the lapse of yet more ages of geologic time, twice great glaciers plowed over its head and combed and rasped its hard face, leaving grooves and scratches to show how hard this great mass of ice had attacked, polishing the bald pate of Old Redstone, and as a last mad effort throwing handfuls of drift over this grand old monument. But this covering of drift was allowed to remain for but a short time, for it was swept away in the early stages of the River Warren and Old Redstone again stood out and defied the swift currents of the river to destroy him. And as the river continued to pass by, it was compelled to pay its respects by bowing its way in a wide curve around the old rock, kissing its sides as it passed, and further doing the bidding of the sturdy old master as it compelled the stream to build broad terraces to its memory.

CHAPTER XII

TRAVERSE GAP

A Gap Across the Continental Divide. On the western border of Minnesota near where the three States of North Dakota, South Dakota, and Minnesota meet, two great valleys meet, one the Red River Valley, extending away to the north and discharging its waters into Hudson Bay; the other the Minnesota Valley, extending south and east and discharging its waters into the Gulf of Mexico.

These two great valleys come together, or rather separate, at the "divide" which is itself, really a valley bottom,—a gap eroded in the earth by running water. This gap is a great valley more than 100 feet deep and more than a mile in width,—Traverse Gap. In this gap, or valley, two great river systems take their beginning or "rise." The two valleys extend away in opposite directions like two bottles placed with their necks together end to end.

The Red River Valley is a vast plain and embraces northwestern Minnesota and the eastern portion of North Dakota and extends far into Canada. Its floor is almost as level as the sea itself. The valley of the Minnesota is an old, comparatively narrow channel cut deeply into the landscape and having no very well-defined relation to present drainage of the territory through which it passes. Its flat bottom and terraced sides show that a vast stream has at some time passed down its course.

Traverse Gap and Its Lake. Let us look at this Traverse Gap. It is a most interesting landscape feature. Its history is also as interesting as a story. Let us look first at the lake which lies in this gap, Lake Traverse. "Traverse" is a French word meaning "through,—crossing,—crosswise or contrary." The lake was named by early French traders, but whether it was the "traverse" or "crossing" for canoes from the Minnesota to the Bois des Sioux and the Red, or because the lake lies crosswise on the map (Upham) or because it crosses the divide between valleys, or for all these reasons together, no one appears to know. It is a contrary lake any way and it drains in the wrong direction. At extreme low water the lake has no outlet, but at the average, or normal stage, 973 feet above sea level, it discharges northward by Whiterock, S. D. In flood stage, it flows on both sides of Whiterock and floods northward. The highest stage known is 976.6 feet above sea level, at which stage it lacked less than 5 feet of rising high enough to flow

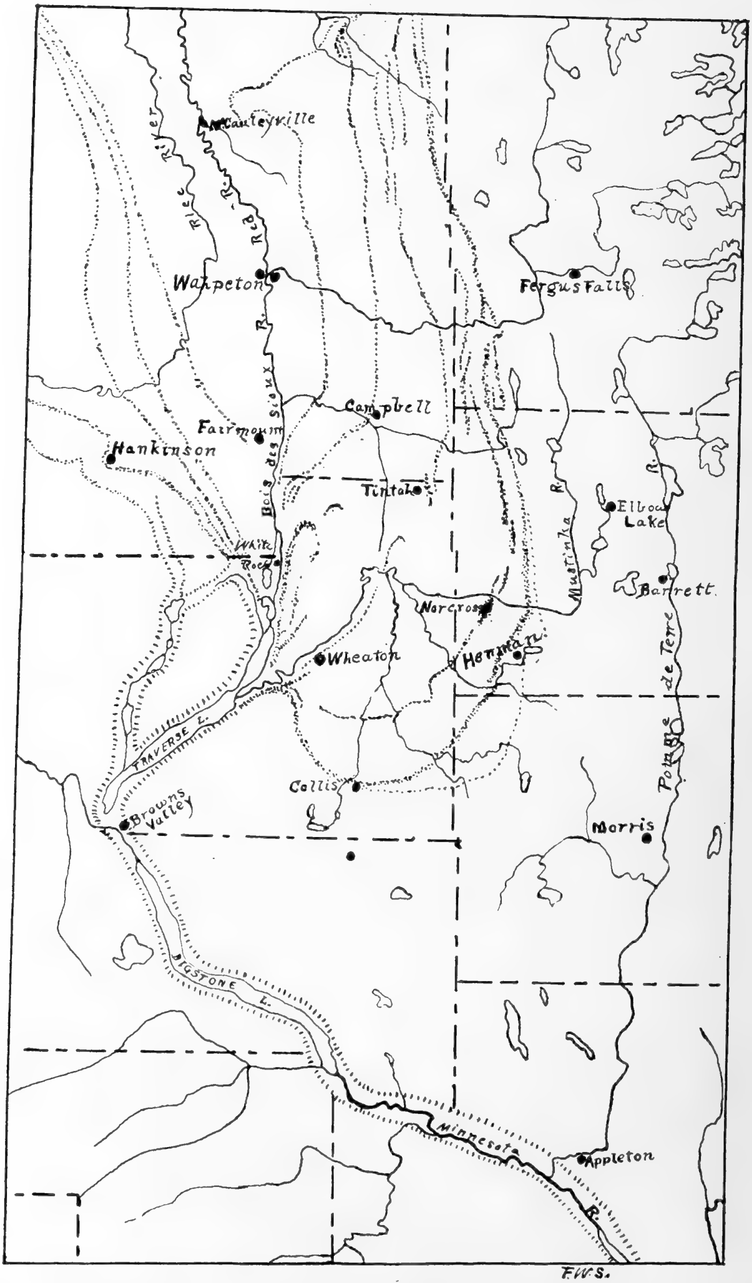


Fig. 73. Map Showing Part of Glacial Lake Agassiz, its Outlet Through Minnesota Valley, and Beaches.

south through Brown's Valley (981 feet above sea level) to the Minnesota.

Stories told by old timers that Traverse Lake has been seen to overflow south to the Minnesota, through Big Stone Lake, and that Big Stone Lake overflowed north to Traverse, are only a few feet from the truth at least.

It would not be very hard to cut a channel across from Traverse Lake to Big Stone Lake and change the drainage that way. In fact, the town of Brown's Valley is built on the sandy filling which the Little Minnesota has carried from the prairie to the west into the gap, or valley. It is the Brown's Valley filling that separates Lake Traverse from Lake Big Stone and holds the former up until it drains to the north. At Browns Valley it is easily seen how the Minnesota Creek or Little Minnesota River, which tumbles down from the prairie on the west into the gap, has brought down and spread out sand and mud between Lakes Traverse and Big Stone. In fact, before that flat townsite had been made by the stream, Lake Traverse was only the upper end of Lake Big Stone. The true head of the Minnesota River then was Mustinka River, which flowed over near Elbow Lake, Minnesota, by Herman and Wheaton to the gap and then south through Big Stone. Of course, Elbow Lake, Herman, and Wheaton had not been thought of then for this was in the early stages, soon after the ice of the "Ice Age" had melted off from the continent.

The Bois des Sioux River headed at this time near Whiterock, flowing north to Hudson Bay, when indeed there was enough water to form a current at all, but it did not at this time take its beginning in Lake Traverse. If now, we go south along this gap to Ortonville, or we might say, if we should follow this ancient valley across the present "divide" between the Red River Valley and the valley of the Minnesota to Ortonville, it will be easily seen that at a little earlier geologic moment, Big Stone Lake was not there as a lake at all, in fact, there was a time when there were no lakes in the Traverse Gap, but only a flat bottomed deep valley with steep sides, in which the Mustinka River and Jim Creek joined and flowed south through the present Minnesota Valley. At this time there was no Big Stone Lake. The Whetstone River made Big Stone Lake by carrying in sediment until it filled the valley. The process of filling the stream or gap is well seen at the mouth of the Mustinka in Traverse Lake. There, that river has a wide delta, extending nearly across the lake and it is building up this delta little by little, as floods come and go in the Mustinka River.

Now, let us look at this gap. It looks like a great valley or river gorge. Where does it begin and to what river does it belong? It is not the valley of the Bois des Sioux, for from Breckenridge up to Fairmount there is no such valley. The river here lies on a flat plain. The Mustinka and the Little Minnesota have not such valleys until they reach the gap. The valley at Traverse Gap is older than these streams. It was there before the streams.

Let us look at the gap as a whole. It has about the same relation to the Red River Valley that the neck has to a bottle. The valley is

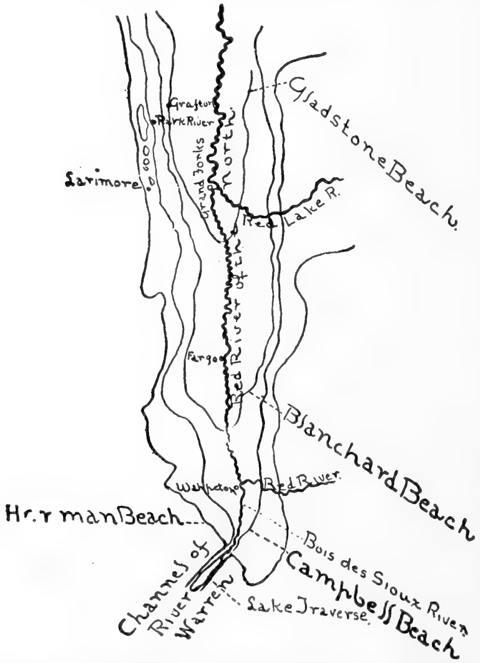


FIG. 74. During the Higher Stages the Lake Outflowed Southward. The Lower Beaches Cross the Red River of the North.

wide and open, but at its southern end it converges into the gap. The Red River Valley is an old lake bed and the gap is that lake's outlet.

How Lake Agassiz Began. A glance at the map, figure 74, shows the relation of this ancient channel to the lake that once discharged its waters southward through it. Better still, a glance over the country about Lake Traverse would reveal the record of interesting things that have transpired here. If we could go over the country in an aeroplane and look down upon the block of country that embraces the place where the two bottle-noses, so to speak, come together, the meaning of the landscape features would soon become apparent.

In Chapter III we saw how great glaciers had passed over the landscape and how many changes were wrought, valleys being filled, hills planed down, and stream courses changed. In this region some very marked changes were brought about. Big Stone, Ortonville, Brown's Valley, Tintah, Herman, Wheaton, and Graceville are "historic" towns as far as the story of the lands on which they are built is concerned.

Look again at the map, figure 74, the Herman Beach is a prominent landscape feature. It made the town of Herman famous! It will be observed that this beach extends west and north, and east and north from Traverse Gap. This beach has been traced by Mr. Warren Upham from Maple Lake, Minnesota, southward to Traverse Gap and thence northward to Duck Mountain in Manitoba, a distance of more than 700 miles. So, also, Norcross, Tintah, Campbell, and McCauleyville Beaches converge at the south into Traverse Gap. All these beaches mark stages or levels of Lake Agassiz. The fact that they all run into Traverse Gap shows that the lake discharged southward when these beaches were being formed.

Let us briefly note the changes that were wrought in this region by the Great Ice Sheet, and how the present landscape features came to be as they are today.

It has been stated before that Traverse Gap cuts across the divide between the Red River Valley and the Minnesota Valley. This divide runs from Donnelly, 1,126 feet above sea level, west to Graceville 1,111 feet above sea level, to the south end of Traverse Lake. West of Traverse Lake the divide runs northwesterly between Little Minnesota River and Jim Creek. This divide is everywhere more than 1,100 feet above sea level except in Traverse Gap, by which it is cut across.

During the Wisconsin stage of glaciation a great lobe or tongue of ice extended its way from far north in Canada southward across western Minnesota and eastern North Dakota, its southern extremity being near the present city of Des Moines, Iowa. The Coteau des Prairies in northeastern South Dakota is a prominent highland which offered serious resistance to the passage of the great glacier. The ice, however, did pass over this highland, but the highland served to separate the glacier into two lobes. The lobe which moved east of the highland and southward to Des Moines is known as the Minnesota Glacier. The lobe which moved to the westward of the highland is known as the Dakota Glacier.

During the retiring stages of this ice invasion, when the glacier was sometimes advancing more rapidly than it melted at the edge, and again, melting more rapidly than it advanced, or retreating, a series of moraines was formed.

When the ice of the Minnesota Glacier stood at the position indicated by the moraine which lies to the south of Ortonville and extends northwesterly to the west of Brown's Valley across South Dakota into Richland and Sargent Counties, North Dakota, there was no Traverse Gap, nor had the Herman Beach been formed, nor indeed had any part of Lake Agassiz. The whole country to the north and east was deeply buried under the ice. So also that part of southern Minnesota, which is now the Minnesota Valley, was beneath the great ice mass. This, however, was during the closing or receding stages of the Wisconsin glaciation, and the ice was in a general way "retiring" or melting off the landscape more rapidly than it advanced from the north.

After the formation of the moraine referred to, the ice front retreated or melted back to a position about Graceville and about five miles southeast of Wheaton, thence extending northwest across South Dakota, and northward to the west of Hankinson, North Dakota, and east of Milnor, North Dakota. Readjustments of drainage had to be made and new avenues for the escape of the ice waters from the melting glacier had to be found.

It will be borne in mind that the divide lies along a general line from Donnelly to Graceville, the south end of Traverse Lake, and then in a northwesterly direction into South Dakota between Little Minnesota River and Jim Creek. There was, therefore, land lying north of the divide off from which the ice had melted. This, in brief, was the beginning of the conditions which brought Lake Agassiz into existence and which marked the opening of the great glacial channel of the Minnesota Valley and the beginning of the River Warren.

Lake Milnor. At this time Lake Milnor came into existence,—a long, narrow body of ice water extending from about 10 miles northwest of Milnor, south and east, and discharging through Cottonwood Coulee and Jim Creek valley southward to Traverse Gap and the River Warren. Cottonwood Coulee is now a flat-bottomed slough from one-half to three-quarters of a mile in width. The southern portion of this old channel, occupied by Jim Creek, became part of an outlet of Lake Agassiz. Lake Milnor was an enlargement of the glacial Sheyenne River, a large glacial stream which carried southward the ice waters from along the edge of the glacier in North Dakota. A prominent beach marks the southern and western side of this lake, the eastern and northern shore being the edge of the glacier. This beach is about 25 feet higher than the Herman Beach,the highest beach of Lake Agassiz proper.

When the ice again retreated, a portion of the northward sloping plain to the north of the divide was cleared of ice, thus a basin having the continental divide for a southern curved side and the ice wall of the retreating glacier on the north was uncovered. There appears to be reason for thinking that the edge of the ice at one time lay along a line from a few miles south of Herman, north and west to Wheaton, near White Rock, South Dakota, and east of Hankinson, North Dakota, to Wyndmere, North Dakota. At this time the Herman Beach began to be formed. The development of a great lake, however, occurred when the ice had again further retreated and Lake Agassiz now became a body of water many hundreds of square miles in extent. The lake increased in size and depth with the retreat or melting away of the ice toward the north. At the time when the great moraine was formed, on which the city of Fergus Falls is located, and to which Mr. Warren Upham has given the name of the Fergus Falls moraine, Lake Agassiz was a sheet of water covering an area probably of approximately 5,000 square miles.

CHAPTER XIII

GLACIAL LAKE AGASSIZ

The Beginnings of the Lake. A northward draining valley existed in northwestern Minnesota and eastern North Dakota before the glacial period. This was the preglacial Red River Valley. The land both east and west of Lake Traverse is higher than the land to the north

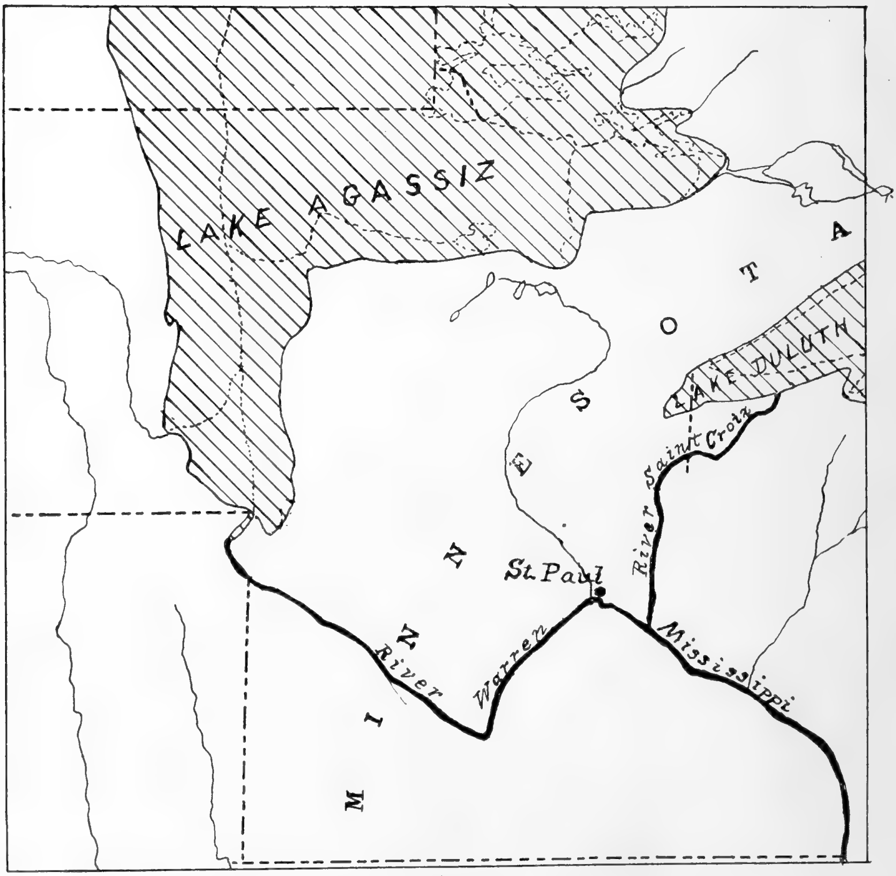


FIG. 75. Map Showing Southward Drainage of Lakes Agassiz and Duluth.

(this must be so since the Red River flows toward the north); a highland, the Manitoba Escarpment, extends from the Coteau des Prairies northward to Pembina Mountain in North Dakota and beyond in

Canada; the continental "Height of Land" lies to the east in Minnesota; the preglacial Red River Valley lies between these two highlands. It will thus be understood how glacial Lake Agassiz came into existence.

When the ice had melted back so that the regions about Wahpeton and Fargo were no longer covered by the ice sheet, the front of the ice being about where Hillsboro and Blanchard now are, the water from the melting ice filled this basin. The waters from the melting of the ice caused the basin to overflow, and the outlet was naturally formed at the lowest point of the rim. This outlet was by the old channel in which Lake Traverse now lies.

If we think of the great ice sheet retreating toward the north, that is, that it melted more rapidly at its southern edge than the mass moved southward, it will not be difficult to understand how it was that the lake became larger, until it finally spread over a great area the extent of which in Minnesota, North Dakota, and Canada has been determined by Mr. Warren Upham to have been as much as 110,000 square miles. Lakes Winnipeg, Manitoba, and Winnipegosis still occupy a part of the old lake bottom. These are remnants of Lake Agassiz that remain to tell of the glory which has been.

Relation of Fergus Falls Moraine to the Lake. At the time of the formation of the Fergus Falls moraine, Lake Agassiz embraced an area of about 5,000 square miles. The Herman Beach was being formed on the eastern, southern, and western shores; the ice wall of the great continental glacier formed the northern shore. The lake extended from the outlet at Traverse Gap to the wall of the ice front as far north as Ada, Minnesota, and Caledonia and Hillsboro, North Dakota. Its eastern shore in Minnesota was about 8 miles west of the city of Fergus Falls and 3 miles east of Barnesville. Its western shore in North Dakota was near Wyndemere, at Sheldon, and about 5 miles east of Buffalo. Its depth at Breckenridge and Wahpeton was about 100 feet; at Moorhead and Fargo about 200 feet, and about 275 feet at Caledonia.

The Fergus Falls moraine is easily recognized east of the lake bottom in Minnesota by high, rounded, and irregular hills and hollows. It appears again on the west side of Lake Agassiz in North Dakota as rolling hills or undulating prairies near Galesburg. Upon the area of the Red River Valley, however, the materials which were dumped at the edge of the melting ice sheet where the ice front was bathed by the waters of the lake were washed away and leveled down by the action of the waves and currents of the lake and finally the materials distributed over the bottom.

The course of the moraine across the bottom of Lake Agassiz is marked by the slightly undulating character of the prairie. The morainic materials were not entirely leveled by the action of the lake waters so that the bottom became slightly uneven. This belt of slightly undulating prairie extends across the Red River Valley from Ada and Rolette, Minnesota, in a westerly and northerly direction to Caledonia, Reynolds, and Buxton, North Dakota, and thence southwesterly to Blanchard, varying in width from 3 to 6 or 7 miles.

The undulations in the prairie surface upon the belt of this leveled moraine vary from 3 to 5 feet, though sometimes 8 or 10 feet above adjacent hollows. Over this belt, many boulders are strewn and gravel is more common than elsewhere on the lake bottom. Boulders sometimes occur in chains or elongated patches upon the beach ridges, having been carried or shoved up on the shore by ice during the winters.

Where the Fergus Falls moraine is crossed by the Red River between Caledonia and Belmont, occurs what are called the Goose Rapids. These rapids are caused by the dam made across the river's course by the materials of the moraine. Boulders are so numerous along the river channel here that boats cannot pass in time of low water.

Increase in Size of the Lake. The area of Lake Agassiz increased by a somewhat sudden or rapid melting back or retreat of the ice front; it would seem that the climate must have become warmer from some cause, for the edge of the ice sheet moved back or receded towards the north near to where the city of Winnipeg now stands. Thus, a great part of Minnesota, which was covered by Lake Agassiz, was now relieved of its burden of ice and was covered by the waters of the lake. The Dakota lobe of the Keewatin glacier had not yet melted entirely from off North Dakota. The Minnesota lobe extended as far south as Lake Itasca and formed the hills of the conspicuous moraine of that part of the State.

Still another period occurred when the forward movement of the ice sheet was not as rapid as the melting and Lake Agassiz extended still further northward to the southern ends of Lakes Winnipeg and Manitoba and eastward nearly to the Lake of the Woods. The hills forming the moraine which marked the position of the ice at this stage of the development of Lake Agassiz, have been named by Mr. Warren Upham, the Mesabi Moraine.

Finally another recession of the ice caused the areas now occupied by Lakes Winnipeg and Manitoba to be uncovered, a moraine being formed along what is now the eastern shore of Lake Winnipeg. The moraine forms a dam which still prevents the drawing off of the waters of this lake. Some of these morainic hills which are partly covered by the waters of this lake now form islands along its eastern side.

Depth of the Water in the Lake. Along the great ice wall which formed the northern shore of Lake Agassiz the waters were probably the deepest that they were anywhere in the entire lake. The slope of the Red River Valley, which is the old lake bottom, descends from Lake Traverse towards the north to the Nelson River outlet of Lake Winnipeg, a distance in a straight line of about 700 miles. It will be recalled that when the northern ice-shore of Lake Agassiz was at Caledonia the water was there about 275 feet deep and 200 feet at Fargo, and about 100 feet at Breckenridge and Wahpeton, and flowed over the rim of the basin at Lake Traverse. When the lake had extended as far north as the present mouth of the Red River at Lake Winnipeg, its depth there was 650 feet; over the northern end of Lake Manitoba about 525 feet; and when the morainic hills which hem in the waters of Lake Winnipeg on the east were dumped from the melting ice they were left in water from 600 to 700 feet deep.

The great depth of the water of Lake Agassiz at the ice front on this far north shore, and the great amount of material deposited as a moraine, may help to explain why Lake Winnipeg has not disappeared along with the rest of Lake Agassiz. Deep bodies of water are less readily affected by storms and their waves are less active in eroding the bottom and shores. The moraine which was deposited at the edge of the ice therefore remained as hills below the surface of the water, and they were not leveled down when the waters of the lake were finally lowered by the melting of the ice farther north. This range of morainic hills therefore remains as a dam holding back the waters of Lake Winnipeg and the sister lakes, Manitoba and Winnipegosis, this group of lakes being the last vestige of the great Lake Agassiz.

The Southern and Eastern Outlets. During all the time in which Lake Agassiz was extending its area the waters were unable to flow to the north by the present Nelson River outlet to Hudson Bay because of the great ice sheet which barred the way. This still lay upon the land between the present Lake Winnipeg and Hudson Bay and probably still filled the basin of Hudson Bay.

That the outlet of Lake Agassiz was southward by Traverse Gap and the River Warren, is shown by the fact that the Herman Beach extends along the eastern and western sides respectively and along the Traverse Gap. Not only does the Herman Beach converge into this gap, but also the Norcross, Tintah, Campbell, and McCauleyville Beaches converge to this outlet.

During the later stages of Lake Agassiz and before the opening of the Nelson River outlet to Hudson Bay, the waters of the lake were discharged by an easterly outlet. This is shown by the fact that the

Blanchard, Gladstone, Emerado, and other beaches loop southward into the Red River Valley and across the axis of the valley at the south end of the loop in marked contrast to those beaches that extend into Traverse Gap (figure 74).

The length of Lake Agassiz from south to north was now about 550 miles, and its width from Red Lake in Minnesota to Larimore in North Dakota was about 130 miles. Its area embraced about 65,000 square miles in Canada, about 15,000 square miles in Minnesota, and about 6,500 square miles in North Dakota.

Into this vast sheet of water many large rivers poured their waters, and to these were added the waters from the melting ice sheet which poured directly into the lake.

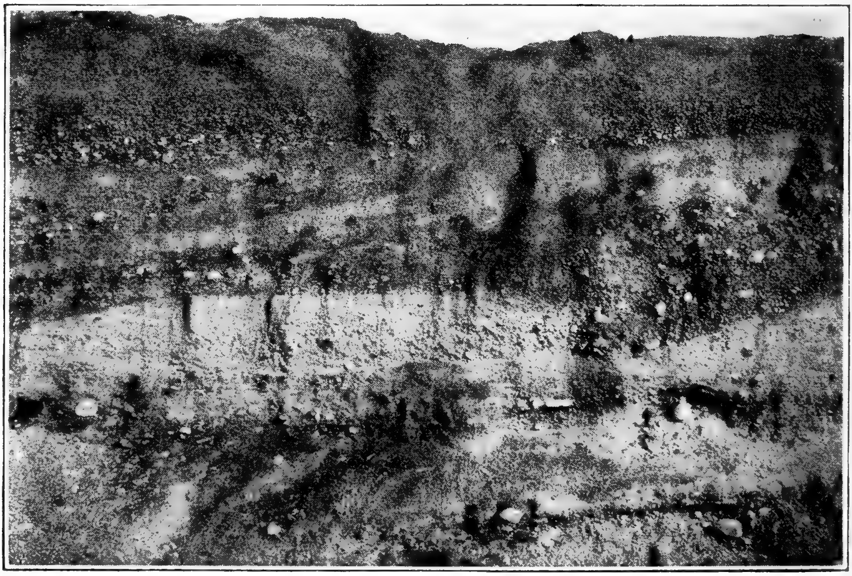


FIG. 76. Gravel in Beach of Lake Agassiz. *Photograph by D. W. Johnson.*

Earth Materials Deposited in the Lake. The melting along the edge of the ice sheet, which was the north shore of the lake, caused the dumping of a great amount of rock, boulders, gravel, sand, and fine silt into the lake, much of which was washed away and spread over the bottom of the lake. The rivers also brought in gravel, sand, and fine silt in great quantity which also was added to the floor materials of the bottom. Some of these streams formed deltas at their mouths. All did not form deltas, for there was much more gravel, sand, and silt from the melting ice sheet delivered to some of these streams than to others. Those which carried the greatest loads of earth materials when they reached the lake shore and their currents were slackened, dropped their burdens and so formed deltas.

There were three large deltas formed on the west side of Lake Agassiz in North Dakota, and one in Manitoba. Two smaller sand-plains were formed on the east side in Minnesota. Those in North Dakota were formed by the Sheyenne, Elk, and Pembina Rivers, and the one in Manitoba by the Assiniboine River. The two in Minnesota were formed by the Buffalo and Sand Hill Rivers. These deltas all bear the names of the streams by which they were formed. There is no Elk River now, for this was a glacial river only, that is, its waters came entirely from the melting ice and when the ice had all melted it ceased to be. However, its old valley is left, and the delta which it formed.

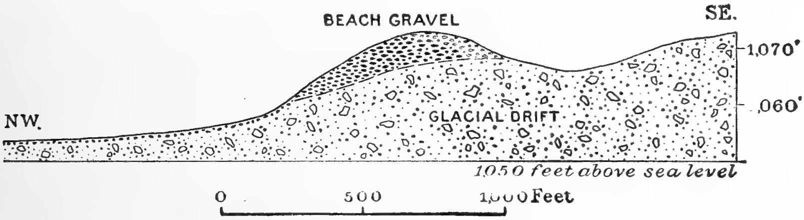


FIG. 77. Section Through Herman Beach near Herman. The Beach Gravel here Surmounts a Hill of Till.

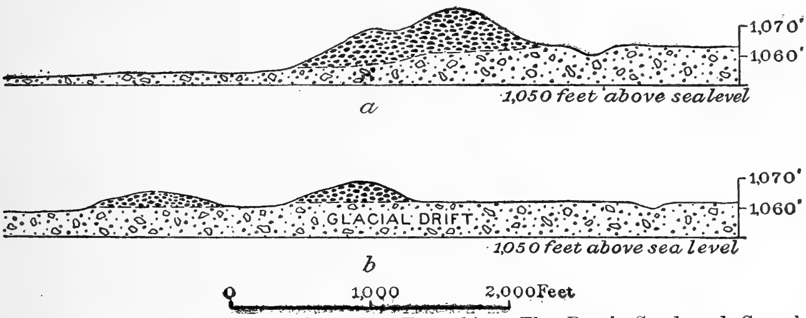


FIG. 78. Sections of Herman Beach, Logan Township. The Beach Sand and Gravel Rest on Glacial Drift.

Beach Ridges or Shore-lines of the Ancient Lake. Ridges of sand and gravel extend for great distances along the east and west sides of the ancient lake bottom. These are beach-ridges or off-shore sand-bars piled up by the waves of the lake. The shore did not, however, always remain at the same place, as the lake level was lowered by cutting down the gap that formed the outlet, and a margin or belt of land was left along the edge which was not covered by water. What had been lake bottom became land. Where the waves had once beaten upon the shore and built up long ridges of sand and gravel the waters ceased to reach. The level of the lake became lower and the shore line moved in toward the center or axis of the lake. The waves, therefore, beat upon the shore at a lower level and a beach ridge was built by the waves marking the new shore line. The successive levels or stages of the lake are marked by these shore lines or beach ridges, so that the old lake bottom, as we see it, is not quite level. Each of these ridges is a little higher from the center or axis of the lake toward the shore, a series of ridges forming a succession of benches or steps, each one toward the shore being higher than the preceding.

Lakes build up off-shore sand-bars, because when the waves roll in upon the shore carrying and rolling on the bottom sand, earth, and gravel, these materials are dropped where the waves "break" upon the bottom. Along the off-shore line where the breakers are formed the water loses a good deal of its force, the sand and gravel which were

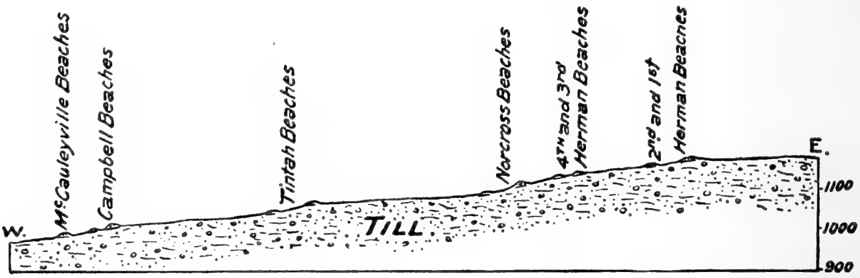


FIG. 79. Profile of Beaches. West of Maple Lake.

being carried are mostly thrown down, and a "bar" is thus built up. To this off-shore bar layer after layer is added till it is built up as high as the surface of the water, or even higher, for when the waves roll high during storms ridges of sand and gravel are piled up higher than the surface of the water, sometimes 15 or 20 feet. In these ridges gravel and sand pits are often opened, and the sand and gravel are often beautifully arranged and assorted in layers.

It is commonly the case that the land is not as high back of or on the shore side of these ridges. Here, when the waters were beating upon the shores and the waves were driven over the sand and gravel of the off-shore bars, was a lagoon, a place where the water which was driven over the ridge formed a shallow pool. Such lagoons are often seen on the prairies of the Red River Valley, and the soil in such low places is often more "heavy" or clayey, and not infrequently marshy, while the crest of the ridge is sandy or gravelly only a few rods or even feet distant. This is because the coarser material carried by the waves was thrown down when the waves "broke" upon the bar, and only the finer sediment, such as forms the heavier clayey soil, was carried over the ridge and deposited in the lagoon.

Stages in the lowering and retirement of the lake are shown by the succession of beaches from the highest or Herman down to the McCauleyville. Figure 79 shows a section across several beaches on the north line of Onstead and Godfrey Townships west of Maple Lake. In some places beach ridges were formed. In other places the waves eroded or cut away the bank. In still other parts of the shores no traces of the work of the waves remain. In such cases the location of the shore at any given stage can only be approximately arrived at.

Figures 77 and 78 show sections through the Herman Beach. The sands and gravels, assorted by the waves, are piled in ridges along the ancient lake shore on till or boulder clay. Back of the beach-ridges are shallow basins or "lagoons."

In figure 78a the beach is shown double-crested. In figure 78b the beach is divided into two distinct ridges. This is due to the fact that the shore was being slowly lifted during the Herman stage of the lake, and what is a single beach southward becomes two or more distinct beaches to the north. This is further explained in the next chapter.

CHAPTER XIV

CHANGES OF LEVEL OF LAKE AGASSIZ

Stages and Beaches. It has been previously explained how Lake Agassiz came into existence by the hemming in of the waters of the melting ice sheet by the higher lands which formed the sides of a great preglacial valley. These formed the shore boundaries of the lake on the east, west, and south, while the great wall of ice formed its northern shore. Since the lowest place in the rim of the surrounding highlands

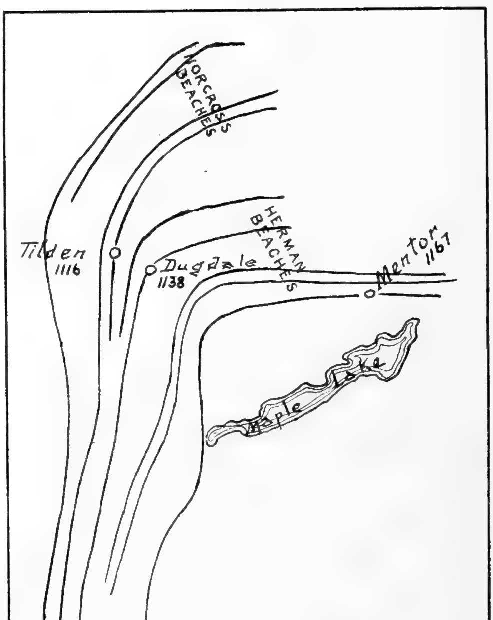


FIG. 80. Map of Portion of the Herman and Norcross Beaches, near Maple Lake, Minn., Showing the Multiple Character Northward. The Five Herman Beaches Become One Beach, and the Four Norcross Beaches One.

was at the south here was established the first outlet. And the waters must needs find escape to the sea to the south because the great ice sheet prevented any drainage toward the north. The first great stage of the lake was begun when the ice had melted back to the position of the Fergus Falls moraine. During this time the highest beach or shore line, the Herman Beach, began to be formed. As has been before explained the Sheyenne delta began to be built up as soon as the lake began, and its level had not changed much when the Elk Valley and Pembina deltas were formed. Lake Traverse now lies in the north end of the old outlet channel, near the southeast corner of North Dakota and on the boundary between the States of South Dakota and Minnesota. The lake grew larger by the melting of the ice sheet, or the "retreating" of the ice wall which formed the northern shore. The water remained at the same height during all the time the lake was increasing in size, the outlet channel being cut down during the time 5 or 10 feet.

The beach which marks the next lower stage or level of the lake is the Norcross. At the time this beach was formed the level of the lake was about 20 feet lower than during the time of the formation of the Herman Beach, the outlet having been cut down this amount. The lake stood at this level for quite a long time, as is shown by the well-defined shore lines or beaches. Then the outlet was cut down again

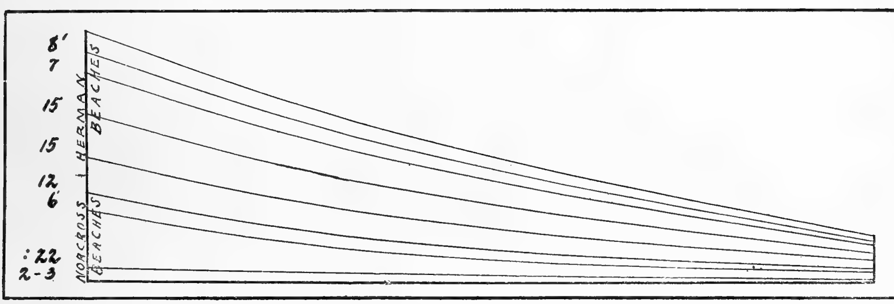


FIG. 81. Diagram Showing the Progressive Elevation of Beaches Northward in Vicinity of Maple Lake, Minn. Continue the Lines to the Right and the Upper Five Meet in One, and the Lower Four in One.

about 15 feet, causing a lowering of the lake this much below the Norcross stage. At this level the higher of two Tintah Beaches was formed, followed by another lowering of the water-level of about 15 feet and the forming of the lower Tintah Beach. Again the level of the water was lowered about 15 or 20 feet and the Campbell Beach was formed. And finally about the same amount of cutting down of the outlet brought the level to the lowest stage while yet the waters escaped to the south, the McCauleyville Beach being formed at this lowest level. Thus a beach was formed at each stage of the lake.

The names of these beaches are a little awkward, and have no meaning except that they are names. They were applied to the beaches from towns which are built upon the beaches or which are near to them. The five names applied to the higher beaches of the lake are the names of towns in Minnesota. Other and lower beaches were named from towns in North Dakota and Manitoba, as the Blanchard, the Hillsboro, Emerado, etc., in North Dakota, and Gladstone, Burnside, etc., in Manitoba.

The next lower stage than the McCauleyville was about 20 feet below the bottom of the southern outlet channel, and the melting of the ice at the north had allowed the waters to find escape by another outlet. At this time were formed the Blanchard Beaches, and it is known as the Blanchard stage of the lake. The outlet was probably into Lake Superior, thence to Lake Ontario, and by way of the Mohawk Valley and the Hudson River to the Atlantic Ocean. The ice had not yet melted off from the valley of the St. Lawrence and hence escape of the waters by that course was impossible.

It was noted above that during the time of the forming of the Herman Beach the outlet channel was cut down only 5 or 10 feet, although the water stood for a considerable time at this level. Then while the outlet was being cut down 15 or 20 feet no shore line whatever was formed. While the water stood at this second level, the Norcross stage, another beach was formed. Again the outlet cut down rapidly, leaving no beach ridges on the shores because the water did not stand at any one level long enough for the waves to pile up a shore ridge. This is the upper beach of the Tintah stage. Again the outlet deepens suddenly while no shore lines are formed, and then the water stands at the second level of the Tintah stage while the lower Tintah Beach is forming. Then, still again is the outlet cut down rapidly to the Campbell stage, and the Campbell Beach. And finally another lowering of the outlet to the McCauleyville stage, when the last beach was formed while the waters discharged by the southern outlet.

But the next level of the lake is below the bottom of the outlet. It was not, then, the cutting down of the outlet channel which caused these changes of level of the lake, for this outlet could not drain the lake below its own bottom. It is evident, therefore, that some other outlet had been found for the waters at a lower point in the rim of the lake. This occurred when the ice melted back at the north so as to uncover a lower place in the surrounding highlands which kept the waters hemmed in. This, however, does not explain why the lake stood at certain levels long enough for the waves to build up distinct beach ridges while the outlet was cut down but little, and then the outlet cut down so rapidly that the waves left no shore marks at all.

The outlet was changed and the old River Warren became an abandoned channel. This is shown by the fact that those beaches which were formed after the McCauleyville stage, the lowest stage while the waters were drained to the south by the River Warren, run across the axis or central part of the old lake bottom (where is now the Red River of the North) instead of running down along either side of the old channel, as do the McCauleyville and the higher beaches.

Figure 74 shows the relation of the higher beaches formed while the lake discharged toward the south and the first two (Blanchard) beaches formed after the lake had ceased to overflow southward and had formed a lower outlet into Lake Superior.

The explanation of these rather remarkable things is somewhat difficult, and those who do not care to attempt to follow it may omit the next few pages.

Causes of These Changes. The cause of these changes of level of the lake is a somewhat difficult one to understand. It is no less a matter than changes in the form of the earth's crust, changes in the altitude or level of the surface of the earth itself. It has been observed that in following the beach lines from south to north that they are not simple or single ridges at the north as they are in their southern parts, but they become double and multiple as they are followed northward. The Herman Beach, for instance, which is a single ridge in its southern portion, becomes five distinct beaches near Maple Lake in Minnesota, and still farther north in Manitoba becomes seven distinct beaches. And similar facts are observed on the west side of the lake. The five beaches near Maple Lake are separated from each other by vertical distances of 8, 15, 30, and 45 feet; that is, the highest Herman Beach is there 8 feet higher than the next lower, that is, 15 feet higher than the next lower than this, making the highest 23 feet above the third one, and this third one in turn is 30 feet higher than the fourth, making 53 feet from the highest to the fourth lower, and the fourth is 45 feet higher than the fifth, so that the first or highest is 98 feet higher than the fifth or lowest. And all these merge into the one single Herman Beach in the southern portion of the lake. Similarly the Norcross Beach, which is a single beach ridge in the southern portion, becomes double at the north, as does also the Tintah, while the Campbell and McCauleyville Beaches each become separated into three distinct ridges at the north.

The five stages of the lake, while it discharged its waters by the southern outlet, are represented in the southern portion by the five beaches named, the Herman, Norcross, Tintah, Campbell, and McCauleyville. These five beaches in the south are represented by seventeen beaches in the north. The highest, or Herman Beach, near the old outlet at Lake Traverse, is about 90 feet higher than the lowest or McCauleyville Beach, while the vertical distance between the highest of the Herman Beaches, 300 miles to the north, and the lowest McCauleyville Beach is nearly 300 feet. In traversing these beaches from south toward the north it is observed that they rise gradually northward. They were formed at the water's edge and were therefore in the first place level.* The ascent or rise is more gradual toward the south and more rapid toward the north. The uplift of the crust of the earth was, therefore, going on at the time Lake Agassiz was here and forming the beaches, and the uplift, was greater toward the north.

The movement of elevation of the country at Lake Traverse during the time of formation of the five beaches while Lake Agassiz outflowed to the south was about 90 feet. On the international boundary at Pembina Mountain it was 265 feet. At Gladstone, in Manitoba, about 350 feet, and 200 miles north of the international boundary on the east side of Duck Mountain, nearly 500 feet.

To explain these remarkable changes of level it is necessary to consider a somewhat difficult geological problem, that of the changes of level of the earth's crust before referred to. This is the rising in one place and sinking in another, over large areas, or regional elevation and subsidence, called "epeirogenic movements," of the crust of the earth.

That the form of the earth's outer layers or "crust" is not fixed or "solid" is a well-established fact. The sea creeps upon the land, or withdraws from the shore as the land rises or sinks, very slowly, to be sure, but none the less truly. The movement is more easily recognized at the seashore because the sea level forms a convenient base-line for making comparisons. It is thought that the great basin in which Hudson Bay lies is being uplifted at the present time, probably a continuation of the same great movement by which the beaches of Lake Agassiz were lifted out of their level positions. This uplift of the basin of Hudson Bay has been estimated to be from 5 to 10 feet in a century.†

If the great weight of the vast ice sheet caused the crust of the earth to bend down or sink, then the melting of the ice and the flowing away of the water would relieve the pressure and so allow it to rise again. The ice was deeper at the north and the rise of the land, as we have seen, was much greater at the north.

The Herman stage of Lake Agassiz represents that period of the lake during which all the beaches at the north which unite into the one Herman Beach near the outlet at Lake Traverse were formed. But during all this time the water was pouring out at the Lake Traverse outlet without cutting the channel down very much, which means that the current was not very swift at the outlet. The elevation at the north

*The surface of the lake was not perfectly level, for the waters were drawn by the attraction of the great mass of ice toward the north, making the water "pile up" toward the north, and hence the shore lines would rise a little in going north, but for our study they may be considered as horizontal.

†Dr. Robert Bell.

may be likened to the slow tipping of a broad pan or dish filled with water so as to just keep the water steadily flowing out at the side. But then there followed a more sudden and widespread elevation which affected the whole area of the lake. The whole basin was lifted up, which had the effect to increase the rate of flow of water at the outlet, and so the channel was cut down rapidly to the level of the next stage of the lake, the Norcross stage.

Here the same process was repeated, the outlet staying just about the same during the time that the several Norcross Beaches were being formed at the north. These beaches, like those of the Herman stage, unite into one in the southern portion of the lake, showing that the uplift during this stage did not extend to the southern end of the lake. The close of the Norcross stage is marked by another comparatively sudden uplift of the whole lake bottom, followed again by the rapid cutting down of the outlet channel.

This series of changes, viz., the uplifting of the northern portion of the lake area during the time of each stage while the outlet remained at just about the same depth, followed by a somewhat sudden uplifting of the whole region of the lake so that the water passing through the outlet channel increased in speed so as to cut down its depth a considerable amount, to the level marking the next lower stage, continued during the five great stages while the outlet remained at the south. The two Tintah Beaches at the southern outlet mark substages, there being a lowering of the outlet between the two periods of the Tintah stage when the two beaches were formed.

Finally, at the close of the McCauleyville or lowest stage of the lake while the outlet remained at the south the uplifting of the bottom coincided with the uncovering of a place in the rim of the lake lower than the bottom of the Lake Traverse outlet, and so the outlet was changed to the northeast.

The several beaches at the north which belong to one stage and which unite to form one at the south, mark intervals of quiet or pauses in the uplifting which affected the more northern region only and not the whole area of the lake. This means that the uplifting was progressively greater toward the north.

The succeeding beaches, which mark the stages of the lake after the water had ceased to be discharged by the southern outlet, are three Blanchard Beaches, representing three stages of the lake, each being lower than the preceding, the first being 15 feet lower than the McCauleyville Beach, the second 20 feet lower than the first, the third 15 feet lower than the second, the Hillsboro 12 or 15 feet lower still, the

Emerado 30 feet, the Ojata 25 feet, the Gladstone 20 feet, the Burnside 20 feet, the Ossawa 15 feet, the Stonewall 20 feet, the Niverville 45 feet, and from the Niverville Beach still another fall of 45 feet reaches the earliest level of Lake Winnipeg, and the cutting down of the Nelson River outlet has lowered Lake Winnipeg still further 20 feet.

Let us now briefly review the history of Lake Agassiz. The lake first began as a body of water from 1 to 3 miles wide and about 30 miles long, and was little more than a broadening of the Sheyenne River. The melting back of the ice sheet to the position of the Fergus Falls moraine increased the size of the lake and the first and highest Herman stage of the lake was ushered in. When the ice melted back to the position of the Leaf Hills moraine it became still larger; and again the rapid recession of the ice to the Itasca moraine increased its area still further. And when the Mesabi moraine was formed the lake extended to the southern ends of Lakes Winnipeg and Manitoba, and still later embraced all the vast territory adjacent to these lakes. Most of the melting away of the ice occurred during the time of the formation of the Herman and Norcross Beaches, as these beaches have been traced from Maple Lake, Minnesota, south to Lake Traverse, and north through North Dakota to Duck Mountain in Manitoba, a distance of more than 700 miles.

The deltas which have been described, the Sheyenne, Elk Valley, and Pembina, and also the Buffalo and Sand Hill deltas in Minnesota, and the great Assiniboine delta in Manitoba, were formed mostly during this earlier time of the lake, as they are crossed by the Herman and Norcross Beaches, whereas the others which mark lower levels of the lake mostly pass around them, leaving them to the landward.

The changes in level of the lake were caused by changes in the form of the earth's crust, an uplifting of the floor of the lake causing more rapid cutting down of the outlet and draining away of the water, the successive stages or levels of the lake being marked by shore lines or beach ridges. The northern portion was uplifted more than the southern portion, as is shown by the beaches which become double and multiple at the north. Finally the floor of the lake was uplifted so that escape of the waters by the southern outlet was cut off and the waters overflowed to the east, the ice melting at the north so as to allow the waters to escape by a new outlet at the same time the outlet to the south was elevated. Successive stages in the level of the lake are marked by beaches.

At the time of formation of the Gladstone Beach the southern point of the lake was about as far south as Buxton, the Red River of the North flowing into the lake there. The western shore of the lake in North Dakota is marked by the Gladstone Beach west of Grafton and

Minto. At the time of the formation of the Niverville Beach the lake did not extend south of the international boundary, and the Red River of the North flowed into the lake near Morris, Manitoba, 25 miles north of Neche and Pembina. The entire area covered by Lake Agassiz was about 110,000 square miles, or an area equal to more than that of the entire State of Minnesota, and the greater part of this vast expanse was covered during the highest or Herman stage of the lake. The depth of the waters of Lake Agassiz above the present surface of the south end of Lake Winnipeg during its higher Herman stages was about 600 feet. At the time the waters ceased to discharge by the southern outlet and began to overflow toward the northeast the depth at this point was about 300 feet. At the time of the Niverville stage, the last before the waters fell to the highest level of Lake Winnipeg, the depth was about 65 feet. Finally the ice disappeared, uncovering the present Nelson River outlet and the waters lowered to the highest level of Lake Winnipeg, and then by the cutting down of the Nelson River channel the waters were lowered to the present level of Lakes Winnipeg, Manitoba, and Winnipegosis, which remain as a last vestige of the once great Lake Agassiz.

CHAPTER XV

HISTORY OF MINNESOTA RIVER

It has been stated in the previous chapter that when Lake Agassiz began to be formed by the gathering of water from the melting of the ice sheet, the lake outflowed southward at the lowest point of the rim of its basin. It was stated that the valley of the Red River of the North and the valley of the Minnesota have their heads in Traverse Gap, like the necks of two bottles placed end to end.

FIG. 82a. Minnesota Valley Above Redwood Falls (west). *Photograph by J. P. Wentling.*

Retreat of the Minnesota Glacier. The outlet of Lake Agassiz was not made in a day. It grew; it grew as the water made it grow,—deeper and longer. Where did it begin and how did it grow? Strangely the outlet is older than the lake itself.

It will be recalled that the Minnesota glacier lay upon what is now northern Minnesota before Lake Agassiz had its beginning. At the time of its greatest extension southward this glacier or lobe of the great ice sheet reached as far south as Des Moines. At this time the eastern edge of the ice lobe lay between St. Paul and Minneapolis and was reforming the morainic hills that mark the campus of the Agricultural College and that part of St. Paul known as St. Anthony Park. It covered Mendota.

During the slow "retreat" or melting back of the front of this great glacier, vast torrents of ice water developed and flowed from in and off the glacier, bearing great loads of sand and gravel and finer earth material. Old drainage channels had been destroyed by the great ice sheets,—by the Patrician glacier in particular around St. Paul,—and new channels had to be formed. (See Chapter IV.) The old junc-

FIG. 82b. Minnesota Valley Above Redwood Falls (east). *Photograph by J. P. Wentling.*

tion of Minnesota River with the Mississippi above Shakopee had been destroyed and the valley from there to Pine Bend above Hastings was blocked by hills of drift materials,—boulders, clay, gravel, and sand. So as new torrents of water came a new channel had to be formed, and thus began to be formed the course of the river by way of St. Paul.

Outwash Plains Formed. Streams of water coming from the glacier and spreading out in front of it, washed out gravel and sand, making "outwash plains" in front of the ice. These plains remain as evidence showing where the border of the ice was when the streams came from it. One such stream emerged from the ice and formed the gravel plain where the fields of the State Agricultural College and the State Fair Grounds now are. Another came from the ice south of Mendota. The water gathered along the front of the ice and broke across at the lowest point to the Mississippi, where the river now runs through St. Paul. The ground over which it flowed at first was 100 feet higher than that of the present channel. Thus it is seen how a new river began through St. Paul to Hastings and how in these few miles a turbid stream of ice water laden with silt, sand, and gravel began excavating a new channel. It was a long time after that, in years, that the ice had melted so that Traverse Gap began to be formed. It was the bottom or body of the "bottle" forming at this time that was finally to have its nose in Traverse Gap.

As the glacier melted back a little way, one large stream came from the border of the ice just where Lake Calhoun now is, and another came from the ice at Shakopee. These streams combined at Mendota and rushed through the new channel by St. Paul. Later the glacier's border stood at Carver and then at Belle Plaine, and the streams of ice water which formed outwash plains at these places made the early glacial River Minnesota. By this time it had cut its channel down to the limestone bed or ledge on which Fort Snelling is located and the old Capitol at St. Paul now stands. "River Minnesota" is the glacial Minnesota River.

As the glacier melted back farther, so that its streams could make the outwash plains at Ottawa, St. Peter, and Mankato, successively, these gravel fans, facing down the valley, show where the source of River Minnesota was,—at the edge of the glacier, near its end. When the end of the tongue of ice stood at Courtland and at New Ulm, more outwash plains developed at those places, as may be seen today, and the River Minnesota headed at those points. As the ice retreated farther, and the river continued to head from it in large volume, a stream with a channel a mile wide was established before the outlet to Lake Agassiz at Lake Traverse was formed. The great valley which became the outlet of the lake was thus made before the lake came to be.

Terraces Formed. St. Paul, Mendota, Fort Snelling, Shakopee, Carver, Chaska, Merriam, Jordan, St. Lawrence, Belle Plaine, Le Sueur, Ottawa, Kasota, St. Peter, Mankato, Courtland, New Ulm, Morton, Granite Falls, and Ortonville all stand on terraces of the glacial river's making. The river seems to have prepared good townsites almost as if hired to do it.

The first stage of the valley was wide and flat, and no doubt the stream was overloaded with gravel, sand, and mud, which it was carrying towards the Mississippi and the Gulf. However, after Lake Agassiz became the head of the river and served to catch the gravel, sand, and mud by settling it on the lake's bottom, the Minnesota had less load to carry and the stream could then cut a deeper channel. In doing this terraces came to be left along the valley, incidentally.

Three Stages of Minnesota River. The glacial Minnesota River, called "River Minnesota," had two stages; the earlier stage, as already described, and a later stage, during which it was the outlet of Lake Agassiz. The second stage is called also the "River Warren." It was during the River Warren stage that the deep wide valley that we now see was cut, and in which, after the River Warren ceased to flow from Lake Agassiz, the modern river or Minnesota River proper began to flow and now meanders.

This relation of the modern Minnesota River to its valley, as the channel of a glacial river, was first noticed and described by General G. K. Warren in 1868. To honor him for his good understanding of the meaning of what he saw, Dr. Upham named the river after him, "River Warren," and the valley is the River Warren channel.

The River Warren had only the modern streams as its branches but the earlier River Minnesota had some notable glacial streams as branches. One stream came for a while from Madelia, down the Watonwan and Blue Earth. Another river came from above Benson, down the Chippewa. A large one came from near Morris, down the Pomme de Terre Valley. For a time a stream came from the glacial border at points near Marshall, Sanborn, and Springfield on the Cottonwood Rivers but went through Hanska Lake past Madelia. Then later a stream headed near Sleepy Eye and went down the Big Cottonwood, directly to the River Minnesota. All those branches headed in outwash plains.

History of the River at New Ulm. Let us now look at the record of glacial "River Minnesota," at New Ulm. The Minnesota Valley as we see it was the glacial river's channel. The valley from Morton to New Ulm, is a mile wide across the bottom and 200 feet deep, with steep sides. Such is the valley that the river made where it was not obstructed. What it did where it met obstruction is well shown at New Ulm where it is a mile and a half to two miles wide, including the terraces.

The struggle of the river against a buried hill of quartzite,—the hardest kind of rock formation,—resulted in its making the townsites of Redstone, New Ulm, and Courtland. (See Fig. 72.) An old hill of red quartzite, now called Redstone hill, standing in the valley below

New Ulm had been buried by the glacier's drift and the surface smoothed off over it. When the river began, the stream ran right over the place where this Redstone hill was buried. When the river had dug its channel about 50 feet deep or one-fourth its final depth, the top of the Redstone hill was uncovered in the bottom of the stream. It made a rapids in the stream and being a very hard rock and a solid ledge, the rapids might have remained until now before the Redstone hill had been worn down. Not being able to cut the quartzite ledge away fast enough in its bottom, the stream soon became shallow and wide by cutting away the soft drift materials in its banks to make room for the river to pass. This it did for several miles above and below the Redstone rapids in the river. It thus spread out on a wide gravelly bed over what is now New Ulm townsite.

In spreading out, the stream got beyond the rock ledge or what is now the top of Redstone hill and thus onto softer formations of sand and clay. There the stream began cutting down again and in time it made a channel south of Redstone hill. For a while at New Ulm, there was an island,—first a bar and then higher, longer, and wider. The channel or part of the stream west of the island was abandoned later and the stream,—now at the River Warren stage,—settled into a deepening channel on the east side of the New Ulm island.

When River Warren,—the outlet to Lake Agassiz,—ceased, the Minnesota River in about its present volume began. Since it is much smaller than the valley, it meanders within the high bluffs but has cut the bottom of the valley a little deeper, leaving parts of the River Warren's valley bottom as terraces (a. b. c. Fig. 72) in the valley.

CHAPTER XVI

THE "NEW" MISSISSIPPI RIVER.

In the last chapter an account is given of the "new" Minnesota River valley, a valley that was made by the glacial Minnesota River, the River Warren. During the time that Lake Agassiz discharged southward by the River Warren the Minnesota Valley carried the main stream rather than the Mississippi, and might have been called the real Mississippi if there had been any men here at that time to give it a name. When we speak of a "new" Minnesota Valley we mean to say

FIG. 83. Valley of Root River, Fillmore County.

that there was also an "old" Minnesota River and Valley. There had been such a valley, but the glacier had filled it with drift. The old Minnesota may have been and probably was the main branch of the old Mississippi. It might have been called the real "Father of Waters" if there had been any names then for those rivers. However there were, in all, three main branches or tributaries in Minnesota which met to form the greater Mississippi before the glaciers filled their valleys, and there are now three main rivers near where the old ones were. We may as well call the old rivers by the names of the new ones that have taken their places. Thus we have the "old" Minnesota and the "new" Minnesota; the "old" Mississippi and the "new" Mississippi; and the "old" St. Croix and the "new" St. Croix.

The Old Valley of the Mississippi. The new Mississippi runs in the same valley as the old river did from Hastings down past Red Wing, Lake City, Winona, and southward. This part of the valley was not reached by the last glacier at all, but was partially filled in by gravel and sand carried by the waters from the melting glaciers to the north. The valley is wide and deep, with deep valleys coming into it from both sides. The bluffs are 300 to 500 feet high, and are of solid rock. The bottom of the old valley is filled 100 to 200 feet

FIG. 84. Itasca Lake Post Office, Itasca State Park.

deep with gravel and sand that was carried in by glacial rivers from above Hastings. The cities of Wabasha, Lake City, and Winona stand on terraces built in the old valley by the flood waters that came from the united glacial rivers—Minnesota, Mississippi, and St. Croix. There would be plenty of room for cities in the valley even if there were no glacial terraces. The valley as we see it is the old valley yet, except that it is partly filled with gravel, sand, and silt.

The old valley is open for 10 miles in a northwesterly direction above Hastings, but is not occupied by the present or "new" river. At Pine Bend, or across the river from the large island known as Gray Cloud Island, the old valley is abruptly blocked. The drift of a glacial moraine is piled across the old valley, filling it to 250 feet above the present river's level. The new Mississippi, the present river, occupies a smaller valley which comes into the old valley from the east or north side.

In the moraine that crosses and blocks the old valley there are many deep holes or basins along the course of the old valley. Marcot Lakes are on the bottoms of such basins. Near those lakes at Westcott a deep well was bored and in it bed-rock—the bottom of the old valley,—was struck at 510 feet above sea level, or 180 feet below the surface of the river at St. Paul. It is thus clear that the old valley runs by Westcott, and that the course of the present river by Newport and St. Paul is that of the new Mississippi. From Westcott the course of the old

Fig. 85. The Father of Waters, as it Leaves Itasca Lake.

valley is northwestward across under the new Minnesota Valley and under Lake Minnetonka toward Delano and the North Crow Valley. The old valley is, of course, filled with drift. The drift is nearly 200 feet deep where the new Minnesota crosses the old valley, but the old northeast bluff is cut by the new valley between Fort Snelling and Mendota, and the old southwest bluff is uncovered at Shakopee. Shakopee stands, in part, on the old bluff. At Lake Minnetonka the old valley is completely buried. A well 400 feet deep at the lake failed to reach bed-rock below the drift which fills the old valley there.

The junction of the old Minnesota with the old Mississippi was about where Lake Minnetonka is now. It joined the Mississippi from the south, and for some distance occupied nearly the same position as that of the present Minnesota Valley. The site of the town of Carver was, however, on the right side of the old valley instead of the left as now. The old river ran under the sites of the towns of Belle Plaine and Le Sueur,—that is, these towns are built upon filled in material,—with Carver, Merriam, Jordan, Lawrence, and St. Peter on the east or right bank, and Blakely, Henderson, and Ottawa on the left or west bank of the old valley.

Formation of Falls and Rapids. The elbow of the present valley at Mankato is a result of the new river not following the old valley. East of New Ulm a moraine lies close upon the valley. This means

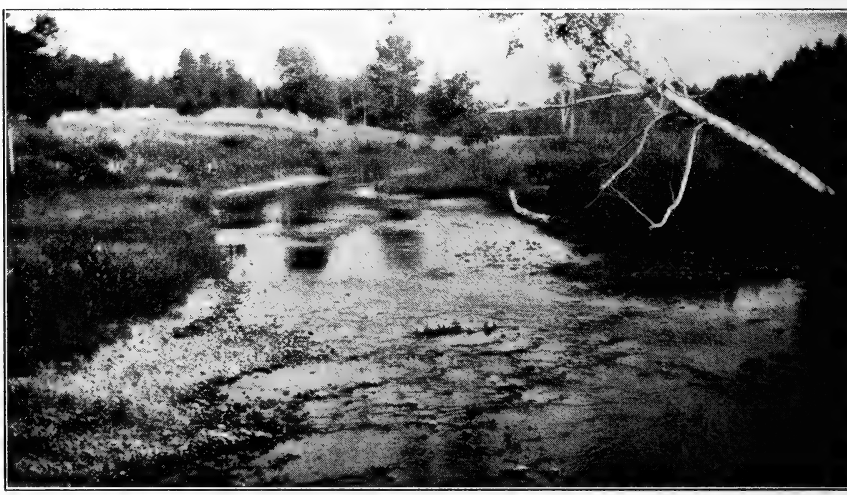


FIG. 86. The Mississippi a Few Rods Below the Outlet of Itasca Lake. *Photograph by Bernard Hilton.*

that the edge of the glacier was here. The ice blocked the old valley and forced the glacial river to seek a new course. The glacial stream swept across the divide from the main valley above New Ulm to a tributary valley at Mankato, and then followed this tributary back to the old valley. Thus the modern river goes by Mankato to this day. The old valley that is buried extended from north of New Ulm to the north of St. Peter.

The new Minnesota Valley breaks across divides in this way in several places from Big Stone Lake down. It crosses rock ledges of an old divide 970 feet above sea level at Ortonville, and one at 930 feet at Granite Falls, while the old valley at Elbow Lake, as shown by a deep well, is less than 800 feet above sea level, and near Benson and near New Ulm the old valley bottom was found to be still lower. The old Minnesota (branch of the old Mississippi) probably had its head near the present site of Detroit.

The Mississippi in New Course. The old Mississippi had its head or source near where Lake Itasca now is. Its valley extended directly south. The present drainage from the Itasca region is now far around

FIG. 87. The Mississippi One-half Mile Below the Outlet of Itasca Lake. Residence of M. Heinzelman.

by Grand Rapids, and then by a valley that was once a tributary of the old Mississippi. The old drainage from the Itasca region was south by Park Rapids through what is now Crow Wing Valley to Staples, and then through Long Prairie Valley to Sauk Centre, down the Sauk Valley to Richmond, through Eden Valley to the Crow Valley, down the Crow to Delano, and across Lake Minnetonka to Hastings, as has been before described. With this original course how did the Mississippi come to have the course it now occupies?

Looking at the map, figure 25, it is seen how two of the glaciers that moved southward into Minnesota from Canada at the time of the last glacial invasion flowed over and covered the original course of the river and turned it out of its valley. First came the Patrician glacier southward across eastern Minnesota. All the tributary valleys on the east side of the Mississippi and part of the main valley were buried under the ice. The Patrician glacier came from the hard-rock

FIG. 88. As It Was. Old Corduroy Road in Itasca State Park.

country of Canada, evidence of which is seen in the large and very stony moraines that it built. As the glacier advanced streams of water from its melting carried great quantities of red sand and gravel away from the ice-front and filled the valleys even before the ice reached them. As the ice advanced boulders and clay were deposited over the gravel and sand. Sometimes more gravel and sand were deposited over the surface as the glacier retreated or melted back. After this fashion the old valley was filled all the way from Sauk Centre to Hastings.

Slowly the Patrician glacier receded or melted back, i. e., the ice melted more rapidly along its southern edge than the mass of the glacier moved southward. As the glacier shrunk away streams flooded the valleys and to some extent cleared out the deposited materials. In this way the Mississippi regained its old course and flowed south by its old valley as far as Delano. From Delano, however, the waters found their way up the old (preglacial) valley of the Minnesota as far as about where Waconia is now. The Minnesota Valley was filled with drift between Belle Plaine and Merriam. The glacial flood waters thereupon found their way across the moraine to Shakopee, thence to

FIG. 89. As It Is. Auto Road in Itasca State Park.

Savage and south up the Credit Valley and east to the Vermilion. A valley or channel, a mile wide, a monument to the early efforts of the "Father of Waters" to find a place for itself, extends across Dakota County along the Vermilion River by Farmington down to Hastings, where it joins the old valley. The Mississippi, however, did not continue permanently in this valley because before the glacial floods from the Patrician glacier ceased the Keewatin glacier had begun to invade the territory and began blocking the valley again.

While the Patrician glacier was retreating from the east side of Minnesota the Keewatin glacier was advancing up the valley of the Red River of the North, and down the Minnesota Valley. This glacier crowded over onto the Mississippi also, covering up the old valley again from Staples south to Fort Snelling. This glacier also filled the valley of Rainy River, and pushed over the continental divide past Grand Rapids to Aitkin.

The Keewatin glacier came from the limestone regions of Canada, whereas the Patrician glacier came from the hard-rock region farther east. The Keewatin glacier because of this carried more clay than stones. However, there was considerable outwash of gravel and sand carried from it by glacial streams and deposited in the valleys below. The gravels and sands from this glacier are gray, while those deposited

FIG. 90. Douglas Lodge, Itasca State Park.

from the Patrician glacier are red, so that the deposits from the two glaciers are readily distinguishable from each other. Both kinds were deposited in the valley about Staples.

With the old Mississippi Valley occupied by the glacier from Fort Snelling up to Staples, the streams from the north had to find a new route. The ice waters from the melting glacier sent one large stream down past Brainerd from the northeast, and another past Staples from the northwest. These two united and broke across to the Nokasippi and thus past Little Falls to St. Cloud. Below St. Cloud the glacier stood across this valley also, so that the stream had to go eastward around the edge of the glacier. The course of the glacial Mississippi from this point was north of Princeton across to the Snake and the St. Croix.

After the edge of the glacier had melted back far enough to permit this the river took its present course from St. Cloud to Fort Snelling and across by St. Paul to its old valley above Hastings.

Rivers Flooded by Waters from Melting Ice. The glacial river that made the present Mississippi Valley became for a time a tremendous stream. The melting glacier sent a flood of water from Bemidji southward. Lake Bemidji and Leech Lake and most of the country north of Grand Rapids originally drained northward to the Rainy River, but the glacier blocked this northward drainage so that the waters from the melting ice were compelled to escape southward. Itasca Lake drained southward. Thus a great stream flowed past Brainerd. Another flooded stream came from the direction of Park Rapids, Sebeka, and

Fig. 91. Cottages at Douglas Lodge, Itasca State Park.

Long Prairie, into the Crow Wing and across into the new Mississippi. Another came from near Alexandria down past Paynesville, and then, because the ice still lay upon the region to the south, swept past Richmond and over an old divide at Cold Springs, where the Sauk now runs, and thus joined the Mississippi at St. Cloud.

Where the Mississippi and the Minnesota came together they were each more than a mile wide, and flowed with sufficiently swift currents to carry along gravel and sand. The Mississippi, however, did not cut as deep a valley as did the Minnesota, for the reason that the glacial flood waters did not continue to pour into the Mississippi as long as into the Minnesota. The Keewatin glacier melted back beyond the divide north of Grand Rapids and the Mississippi became a modest stream such as it is now. The Minnesota River, it will be remembered, was the outlet of glacial Lake Agassiz during the long time that this lake discharged southward, and during all the time during which the Keewatin glacier was retreating from Minnesota.

The new valley of the Mississippi was cut by the glacial flood waters deeper than the present valley, the valley having been partly

FIG. 92. Arko Lake and Pines, Itasca State Park.

filled with sand and silt; but the valley is not now as deep as the old valley was in the first place. The old valley had no falls or rapids, but the new valley has many,—Grand Rapids, Little Falls, Sauk Rapids, and St. Anthony Falls,—all caused by the stream being forced to cross old divides between old tributary valleys.

CHAPTER XVII

THE ST. CROIX RIVER

Two Valleys Joined. The St. Croix Valley, before the glaciers interfered with the rivers and their valleys in Minnesota, instead of being one valley as now, embraced parts of two valleys. The two parts were united when the last of the glaciers in Minnesota forced the upper St. Croix to run across a divide and through some rocky hills over into the head of another valley, the present lower St. Croix. St. Croix Falls and The Dalles were made by the cutting of a new valley from one basin to another. It was not the ordinary or normal St. Croix stream that did the cutting, but floods of ice water that came from the melting of three glaciers.

What is commonly called the lower St. Croix is the navigable part of that stream from its mouth at Hastings up to Taylor's Falls or St. Croix Falls. The upper St. Croix was originally not a part of the St. Croix at all. It is full of rapids and riffles,—not navigable except where it is dammed. The lower and upper valleys look different but yet are enough alike so that one might not notice now that they did not originally belong together.

The lower St. Croix was originally a branch of the Apple, which headed where Taylor's Falls is now. It had been there for a long time and had a large valley for such a small stream as it doubtless was. The upper St. Croix was larger. It was tributary to the old Mississippi. Its mouth was near where Delano now is, and its head was near where the St. Croix now begins in Wisconsin.

The old lower St. Croix Valley was deep, and deeper than the new valley is now, except just at the head near Taylor's Falls. When the Patrician glacier of the last glacial invasion came south across eastern Minnesota the lower St. Croix was covered by it down to a little below where Afton now is. As that glacier melted back and then re-advanced making the great moraines that run from Osceola, Wisconsin, southwest across the valley by Stillwater, great outwash plains were made near Hudson, Wisconsin, and near Lakeland, Minnesota. In fact, these two outwash plains as we see them now were probably connected as one, and filled the valley more than 100 feet above the present water level of the river. After the glacier had passed over the landscape the valley was left nearly filled with glacial drift, and outwash sand and gravel. A preglacial valley extended from Afton up to Elmo and White Bear Lakes. This old valley is now filled with drift. This old

Afton-Elmo-White Bear Valley is now much like what the lower St. Croix looked like after the ice had melted away and before the new valley of the lower St. Croix was eroded. The old Elmo Valley was filled at that same time and remained filled. The old lower St. Croix has been partly re-excavated by the new St. Croix River, which became established in the old valley.

Upper St. Croix-Crow Valley. The old upper St. Croix rose on high land in northern Wisconsin nearly where it now rises, and flowed in an old valley that lies nearly in the same place as the new one down as far as Snake River in southern Pine County, running in a southwesterly direction. From there the old valley extended in a southwesterly course to Pine City, Cambridge, Dayton, Rockford, and Delano,

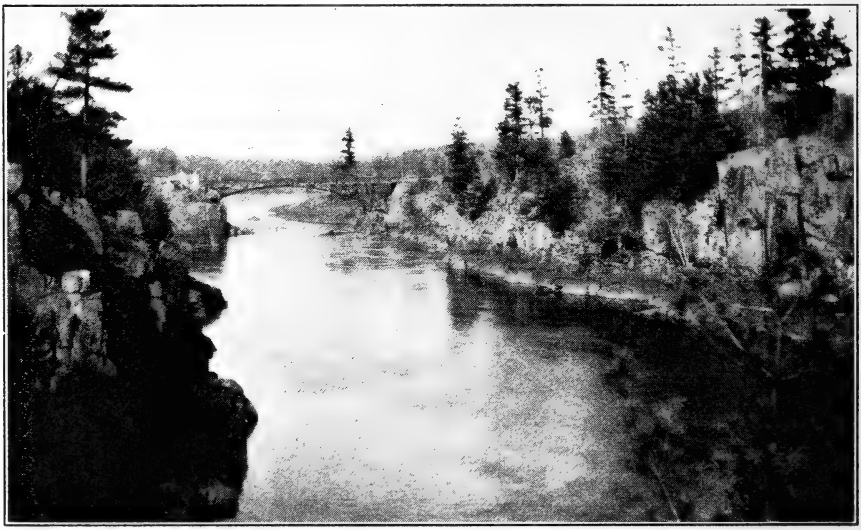


FIG. 93. St. Croix River and Gorge below Taylor's Falls. *Photograph by Brown.*

at which last place it entered the old Mississippi Valley. Even after the Patrician glacier had blocked the old upper St. Croix Valley it was again opened by the glacial streams which poured from the melting glaciers and flooded into the valley. These flood waters washed out some of the drift along the old route to the Mississippi,—down to Delano. The new valley which the upper St. Croix River thus made across the great moraine of Patrician drift at this time is the present valley of the Crow River from Rockford to Dayton. It is a deep, wide valley in which the St. Croix stream flowed in the opposite direction from that in which the Crow now runs.

Glaciers Again Block Valley. Neither the lower nor the upper St. Croix were long undisturbed in their new valleys after the Patrician glacier left them there. Another glacier, the Keewatin, was growing and advancing from the northwest into the valleys of the Red River of the North and the Minnesota, as the Patrician glacier was receding or melting away across the Iron Ranges in northeastern Minnesota. As the Keewatin glacier filled the basin of Minnesota River, pushing its way southward and eastward, it reached the old Mississippi Valley at the point where the upper St. Croix entered this valley at Delano. It then pushed up the low broad basin of the St. Croix in a lobe or tongue-shaped mass. This lobe reached as far east as the Wisconsin boundary, at Taylor's Falls and Pine City.

When the eastern end of the Keewatin glacier was in the vicinity of the Wisconsin boundary and the old St. Croix Valley was filled with ice, the valley from the Wisconsin line to Delano was effectually blocked, and the waters coming down the upper St. Croix from Wisconsin were ponded, the ice acting as a dam. Just as this juncture, when the valley was not able to take care of its own stream, very large floods began pouring down its northern tributaries, the Snake River and Kettle River. Those flood waters came from the melting of a third glacier,—the one from the Labradorian ice fields,—which pushed through the Superior Basin westward nearly to where McGregor and McGrath now are. The Labradorian glacier came from the northeast at the same time that the Keewatin glacier came from the northwest,—just during the time of the melting back or retreat of the Patrician glacier from between them. The Labradorian glacier began to shrink back a little sooner than the Keewatin glacier, and the floods from its melting came down against the ice-lobe of the Keewatin glacier in the St. Croix Valley while the border of this glacier was in the vicinity of Pine City and Taylor's Falls. Very naturally the flood in the upper St. Croix then turned along this (Keewatin) glacier's border south and sought an outlet into the lower St. Croix as the only way out. Then began the washing and cutting of the new valley from the old upper St. Croix near Pine City across to the old lower St. Croix below Taylor's Falls.

Lower St. Croix Valley Reopened. The new lower St. Croix Valley joined the Mississippi Valley below Hastings, and the glacial river of this valley worked with the Minnesota-Mississippi glacial streams in clearing out the drift which had been deposited in the valley below. The Patrician glacier with its outwash of gravel, sand, and silt had filled both the St. Croix and the Mississippi Valleys. Even below Hastings, beyond where the ice of the glaciers reached, the old valley had been filled to a considerable depth, as has been stated in a previous chapter, and the clearing out of the drift from the old lower St. Croix Valley and from the old Mississippi Valley was a work that both streams engaged in, while the flood waters from the melting glaciers to the north continued to come down their courses. The river level at Taylor's Falls and that at St. Paul are just about the same now, and they were just about equal at all stages of the progress of the work. As fast as

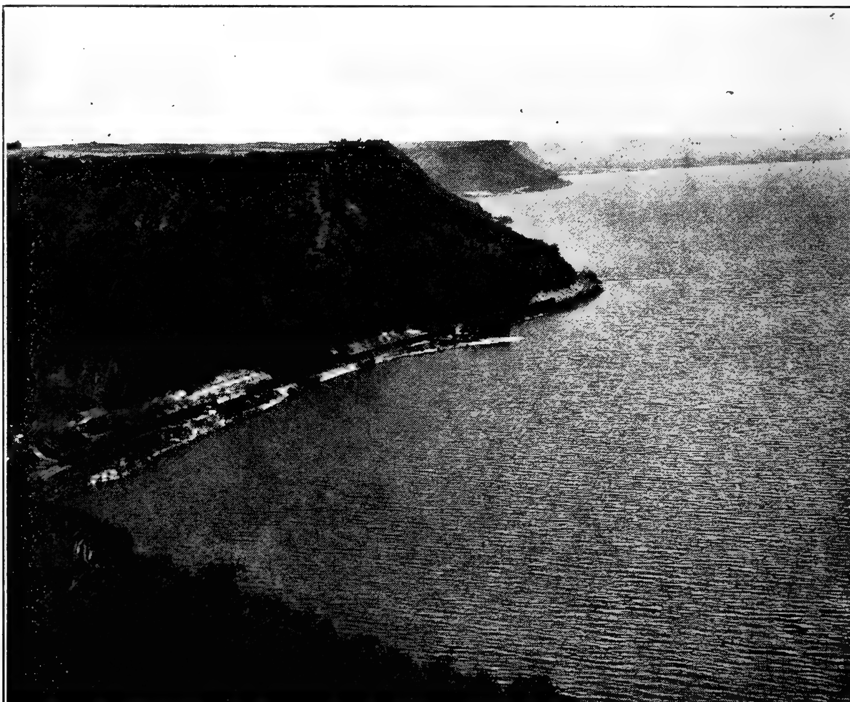


Fig. 94. Lake St. Croix and the Glacial St. Croix River Valley. *Photograph by Sweet.*

the Mississippi Valley was washed out the St. Croix could cut down its valley also as far back as the first rock rapids at Taylor's Falls. It was merely a matter of clearing out from the lower St. Croix Valley the loose drift as far up as the head of the old valley. We have seen already that this had once before been a deep valley. With so deep a valley below Taylor's Falls the glacial River St. Croix had a rapid descent from the higher lands to the north, and it rapidly cut a deep channel through the glacial drift down to bed-rock where the new channel crossed the divide between Pine City and Taylor's Falls. It then cut into the old rock divide, and thus made the gorges that are now known as The Dalles and Rapids.

Upper St. Croix Opens Present Valley. The stream that was making the new St. Croix Valley came at first mainly from Snake River and from the glacial Mississippi drainage which overflowed, as noted in the preceding chapter, (The "New" Mississippi), into the Snake. The Kettle River next became the main tributary. When the Labradorian glacier had shrunken back into the Superior Basin as far as Carlton the St. Louis Valley was also re-opened, and this valley brought glacial floods from a lobe of the Keewatin glacier which lay over the Iron Ranges. The glacial St. Louis River's flood waters could not continue eastward, as that river does now, because the Labradorian glacier occupied the basin of Lake Superior and extended west to Carlton. The flooded glacial St. Louis therefore was turned by the ice wall near Carlton down by Moose Lake, and thus down Kettle River to the St. Croix. A little later a lake was formed between the ice wall of the Labradorian glacier and the higher land at the west end of the Superior Basin. Into this lake, known as Lake Duluth, the glacial St. Louis River discharged its flood waters. The outlet of Lake Duluth was at this time in northern Wisconsin, at Solon Springs, through what is now called St. Croix Lake, which is now the head of the modern St. Croix River. That was the final flood which completed the new valley that runs from St. Croix Lake to Lake St. Croix and the Mississippi River,—the same valley in which the small modern river now meanders through The Dalles at Taylor's Falls. As the Labradorian glacier shrunk farther back into the Superior Basin, Lake Duluth found a new outlet toward the east across Michigan, and the water level in the Superior Basin fell below the outlet by the St. Croix, and the St. Croix River thus suddenly became a modest modern stream.

Terraces Show Stages of River's History. Going up the St. Croix Valley one can easily see how the new valley was made. There is first Lake St. Croix, the deep wide channel of the glacial river up to Stillwater. It is a lake because its outlet to the Mississippi is choked by the deposits in the old Mississippi Valley. The towns of Lakeland, South Stillwater, and the main streets of the city of Stillwater are on terraces of the glacial river. Above Arcola there is a glacial moraine, at Sioux Camp Hill, extending down to the bottom of the valley. There the glacial stream did not entirely clear the drift from the old valley.

The towns of Marine and Copas are on terraces of solid rock on the side of the old valley where it has been swept clear by the glacial river in making its new course. The high terraces at Copas, South Stillwater, and Lakeland show how wide and shallow the glacial stream was which at first flowed along on the drift which first filled the valley. The lower terraces represent the stages of the stream as it gradually again cut down its bottom into the old valley. Main street in the city of Taylor's Falls is on the bottom of the glacial river at its last stage when it was the outlet of Lake Duluth. The later modern river has made the deeper channel which goes under the inter-state bridge. On the Wisconsin side the terrace which was the bottom of the river during the last glacial stage runs along the bank above the bridge. The town of St. Croix is on higher terraces corresponding to those at Copas, Marine, and Lakeland.

CHAPTER XVIII

THE DALLES OF THE ST. CROIX

Approaching The Dalles. After leaving Franconia station on the Northern Pacific Railway the whole panorama suddenly changes. The route from St. Paul has been through a drift covered district in which are many lakes and the characteristic hills of a glaciated landscape. Immediately all is changed. The train passes into a great river valley deeply eroded through the drift into the hard underlying rocks. Along the railway are seen sandstone beds under the drift, and hills of lava rock.

The railroad cut by which the city of Taylor's Falls is entered is in volcanic lava rock, which forms also the walls of The Dalles, and the fallscarp of St. Croix Falls. The great valley has been cut entirely through the drift formations, into bed-rock. Terraces marking stages of a great glacial river appear on either side of the valley, at Taylor's Falls and St. Croix Falls.

The Keweenawan formation is made up of many lava sheets which were poured out from fissures or great craters during early geologic periods. These preceded the Cambrian time so long that the lavas were eroded into hills and later covered by sedimentary formations. They have now been exposed again by the removal of the drift and the sedimentary rocks in the valley.

Sandstones, shales, and conglomerates,—sedimentary formations of Cambrian age,—are exposed in the valley sides lying against and above the Keweenawan lava formations, where they were deposited as seashore formations. Sea shells in them now lie along the river as fossils.

Pot-holes worn into the hard igneous rocks by currents in the swiftly flowing glacial river occur at several points.

A Section through Three Drift Sheets. At the picnic grounds near the station of the Northern Pacific Railway at Taylor's Falls a section shows the drift from the surface soil down to bed-rock. The top or first drift sheet is gray or bluish gray in color, and contains many limestone boulders and pebbles. This is the Young Gray drift. It is the fifth sheet from the bottom up.

The next lowest deposit in turn is red in color, and contains no limestones but many hard granitic boulders. This second from the top is the fourth drift sheet from the bottom, and is that of the Patrician glacier, which came from north of Lake Superior. It is the Young Red drift.

The next drift is that of the Illinoisan, the Old Red drift. (See Chap. IV.) It contains few limestones, but many hard granitic boulders. The upper portion of this deposit in some exposures is discolored by weathering after it was deposited and before it was buried beneath the overlying Young Red drift. This upper portion, the "weathered zone" (see Chap. IV), shows that this was a soil surface for a long time before the later invasion of the Patrician glacier from the North covered it.

The Old Gray drift and the Older Gray drift are not seen in the walls of the valley in The Dalles region for the evident reason that those drift sheets, the second and first, were nearly all eroded away in this region before the later ones were deposited.

Glacial River Terraces. One of the striking features of this remarkable valley is the terraces formed by the glacial river which cut the gorge. That was the river from glacial Lake Duluth. (See Chapters XVII and XX.) These represent bottoms of the river at different stages in the cutting down of the valley by it.

The highest "bench" on the Taylor's Falls side of the valley, called the "picnic grounds," is a prominent broad level plain that is sometimes mistaken for a terrace, but is not a river terrace, but the original drift surface level. Nearly as high, on the Wisconsin side of the valley, near the Soo Railway station, is a terrace or bed of the glacial river, which is more than 200 feet above the water of the present river.

The second terrace marking a lower stage in the cutting down of the river is 90 feet below the highest terrace. This is best seen on the Wisconsin side of the valley. The principal business street of the city of St. Croix Falls is built on this terrace.

Thirty feet below the level of the second terrace a third terrace occurs. It is best seen above St. Croix Falls on the Wisconsin side.

The business portion of Taylor's Falls is built upon the next lower terrace, the fourth, which extends a mile up to the dam. This appears also on the east or Wisconsin side of the river, and is the flat plain on which the mill is located. This is a wide and conspicuous terrace, 50 feet or more above the present river.

A still lower terrace is about 25 feet above the river. It is less extensive than the others. It can be seen near the bridge crossing the river. This terrace belongs to the modern river.

The valley and floor of the glacial river represented by the fourth terrace stage, as described above, is twice as wide as the present river's valley, 50 feet deeper and within it. The large glacial river suddenly ceased when Lake Duluth ceased to discharge through the Brule Pass to St. Croix Lake and River. Then the modern river took possession of

FIG. 95. Wall of Lava Rock at The Dalles, Showing the "Old Man of The Dalles."
Photograph by Brown.

the valley. The modern river has cut down 50 feet in its narrowed channel during the time since the glacial river ceased, or during what is called "recent" time.

Beds of Lava or Igneous Rock. A most interesting feature of The Dalles region is the igneous rocks which are here exposed. These have been deeply eroded by the glacial river which was forced to take its way across this hard barrier. The great quantities of sand and gravel that were carried by the swiftly flowing river made possible the great amount of cutting and wearing of the hard rocks by which the deep gorge has been formed.

These lava rocks are of Keweenawan age, and as a formation are very old. The rocks are volcanic in origin and are therefore called igneous rocks (**Ignis** meaning fire). Centers of greatest volcanic activity from which these lavas were poured out from great fissures in the earth or from craters, were to the northeast in the Lake Superior Region. The Keweenawan formation has very extensive development both north and south of Lake Superior. The Keweenawan period was one of great volcanic activity. Lavas were poured out in immense sheets and spread over thousands of square miles, and accumulated to a depth of several thousand feet. The Dalles region is near the southwestern limit of this formation.

The rocks were laid down in the form of great sheets of lava, which flowed over the land surface and cooled and became solid rock. Several sheets, one above another, occur at Taylor's Falls, each representing a flow or outpouring of molten rock. One flow after another was poured out, some of them at least accompanied by such violent explosive outbursts as to cover the entire surface with ashes and cinders to a considerable distance. Consolidated ash is found between lava flows.

There are two types of igneous rocks or lava here shown. One is a compact hard, dark, crystalline rock, which is known as diabase. This rock makes up the greater part of the total thickness of each flow or sheet, which may be 50 feet or more in thickness. The second kind of igneous rock is a somewhat lighter colored, coarse-grained, ash-like compacted fragmental rock which occurs in thin layers or beds between the successive lava flows. These two kinds of rock are both of volcanic origin. The former was poured out from great fissures in the earth's crust, or from immense craters, in the form of molten lava. The latter was forced out from active volcanoes in violent explosions as fine ash and bombs. Associated with the second form of igneous rock referred to is the broken and shattered material usually found upon the surface of a stream or sheet of solidifying lava as it flows across the land.

This second form of fragmental lava is spoken of as volcanic breccia. It is porous in structure and cavities are often filled with lighter colored green, pink, or white minerals.

There are in all ten different lava flows or sheets shown in outcrops at The Dalles. Seven of these can be distinguished from their exposed and eroded edges where they form successive benches or steps on the west side of the river from the Elbow in The Dalles to the school building in Taylor's Falls and beyond. The several sheets or flows range in thickness from 30 to 50 feet.

After the period of volcanic activity had ceased, a long time elapsed during which the bare rock surface was exposed to erosion. Ravines and gorges were cut into these solidified lavas, and hundreds of feet of thickness were worn away. Old ridges and valleys may still be seen in the vicinity of The Dalles showing a difference in elevation of more than 500 feet. The time required for such erosion is the measure of the interval of time between the close of the Keweenawan and the beginning of the deposition of the sedimentary rocks of the Cambrian.

The Sedimentary Formations. During the time following the long period of erosion referred to, this part of the continent was gradually sinking beneath the sea. The higher ridges stood long as rocky islands and headlands in the ocean as it crept in upon the land. Conglomerates of Cambrian age were formed along the rock-bound and wave-battered shores, as may in places still be seen in the vicinity of The Dalles; for example, below the St. Croix Falls, and near the railroad crossing south of Taylor's Falls. Farther from the shore sands accumulated with mud and the shell remains of animals, which all together were formed into great beds of sandstone and shale. These may be seen in the river bluffs both above and below The Dalles.

Thus the Cambrian sea sediments came to be deposited against and over the lava rocks. These sedimentary rocks are of great thickness. How thick these deposits were at The Dalles we do not know. Certainly all the high ridges of igneous rocks which now crop out there were covered.

A mile below Taylor's Falls, forming the bluffs along the Northern Pacific Railway, the so-called Franconia sandstone outcrops in fine exposures 100 feet in thickness. This is a white friable quartz sandstone. It contains few fossils, and because it is so soft and friable it is of little value for use as a building stone. The dark veins running through it are iron which soaked into crevices in the rock in solution as iron oxide.

A shale formation known as the Dresbach, which occurs below the Franconia sandstone, is seen in a ravine under the first bridge of the Northern Pacific Railway, a mile south of Taylor's Falls. It occurs also at the base of the cliffs above The Dalles on either side of the river. These shales contain more lime and numbers of fossil remains of animals occur.

One of the most interesting of the sedimentary formations is the conglomerates or shore beds of both the Franconia and the Dresbach formations. These consist of deposits of wave-worn fragments of igneous rock in the form of large and small boulders, pebbles, and sand worn from the adjacent cliffs, with the spaces between them filled with sand and other fine materials. The mass is cemented into solid rock by lime and iron which were dissolved in water.

An extensive outcrop of conglomerate may be seen at the crossing of Mill street and the Northern Pacific Railway, where a rugged quarry face or bluff 20 feet in height is exposed. This is one block southwest from the public school building in Taylor's Falls. Another outcrop may be seen in the river gorge on the Wisconsin side, a short way above the old mill. Still another conglomerate bed occurs in the valley on the Minnesota side 2 miles south of Franconia. There a ridge of cemented boulders extends its end from under the bluff in vertical exposure 50 feet above the water level.

All the boulders in these conglomerates show much water wear such as is produced by heavy wave action along shore. They are really wave-worn sea pebbles of the ancient Cambrian ocean accumulated in great beds on the sea shore, and cemented later into hard rock. The boulders and pebbles are fragments of Keewanawan lavas (diabase) which formed the rocky shore, pieces of which have been built into the later Cambrian conglomerate formation. Sometimes a fragment of this Cambrian conglomerate is found far from its home on the drift covered prairies where it forms a part of the glacial deposit, a "formation" many, many millions of years younger.

FIG. 96. A Grinder from a Pot Hole, The Dalles of the St. Croix, Taylor's Falls. *Photograph by Brown.*

Pot-Holes. At The Dalles, and also a mile above The Dalles, are a large number of deep holes worn into the hard igneous rocks. These are known as pot-holes. They are an accompaniment of the destruction of the hard rock barrier—the igneous rock—which stood in the way of the river's progress. They are still forming in the present river bed, and they have been forming and being destroyed from the beginning of the river's attempt to saw its channel through the hard barrier.

It seems clear from a study of the locality that all of these holes have been formed by whirling eddies under swiftly running water in

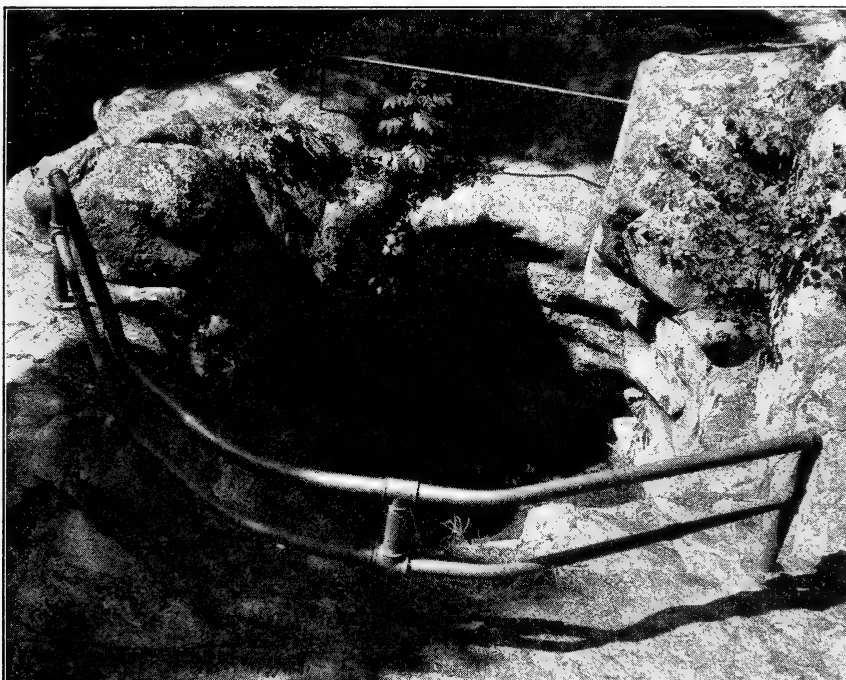


FIG. 97. A Pot Hole, The Dalles of the St. Croix, Taylor's Falls. *Photograph by Brown.*

a river rapids across an uneven rock floor. The whirlpools and eddies carried sand and gravel round and round till great and small holes have been literally drilled into the hard crystalline rocks which formed the river's bed. Each hole was filled with a rotating column of water driven at the top by a whirlpool of the river that furnished power to keep it in rotation. At the bottom sand, pebbles, and boulders rolled round and round, boring the hole deeper and grinding the pebbles to powder, these to be replaced by new ones continually until the wall of one pot-hole broke into another so that the rock barrier gave way, or some other incident caused the whirlpool to quit working. Some pot-holes were left in the making when the glacial St. Croix gave way to the modern river. Others were worn out, and some under the river are still making.

In many places it may be observed that the dividing walls between two or more pot-holes had been worn away forming large irregular cavities. A narrow gorge near the steamboat landing at The Dalles was formed in that way by the destruction of the thin walls between rows of large pot-holes. The position of most of the pot-holes seen now in interstate park is such as to have subjected them to great force from running water of the glacial river.

Time is Long. It should be clearly understood that these great events in geologic history occurred, some of them, a very long time ago, long geologic ages before the glacial period. The earth was young, so to speak, when the great Keweenawan lava flows occurred. These lavas flowed out upon a land surface. During a later geologic period these lavas became covered by the waters of the sea, and the Cambrian sediments were deposited. It was again after the lapse of long æons that the glacial period ensued, and the waters from the melting of great glaciers caused great valleys to be formed in which are exposed now the rocks formed during the early stages of the geologic history of the earth.

It may be interesting here to observe that, for purposes of comparison, geologists have estimated the time from the beginning of Archæan time—the theoretical ''beginning'' of the formation of the continent—to the time of the final completion of the lava flows of Keweenawan time as 27,500,000 years; from the end of Keweenawan to the end of Carboniferous time, the time when the great coal beds were formed, as 17,500,000 years; from the end of Carboniferous time to the closing stages of the glacial period when the great valley of The Dalles was formed, as more than 10,000,000 years. It is only about 30,000 years since The Dalles were begun, as estimated, a geologic yesterday. These figures, it should be borne in mind, are at best only estimates, and are valuable chiefly as showing the great comparative lengths of periods of geologic time.

CHAPTER XIX

THE FALLS OF ST. ANTHONY

A "New" Landscape. When the ice of the latest glacial invasion, the Wisconsin, melted off from the landscape about St. Paul and Minneapolis it uncovered a surface which had been much modified by the passage of the ice over it and by the deposition of drift upon it, and a new set of streams began to flow, finding such courses as they could between the many knolls and ridges. At first some of the streams were swollen with water from the melting ice and flowed with swift and strong currents and were able to cut broad and deep valleys and to do much more work, both in erosion and transportation, than at present. They were laden with debris, partly outwash from the melting ice, partly drift from places where they were actively eroding. This debris was carried along or spread out for miles along their courses in what are now gravel floors and high terraces. A great many depressions were occupied by lakes and ponds. Many of these discharged over the lowest points of their rims to neighboring lower basins, and thus the courses of many new streams became fixed. In time many of the lakes became drained, and streams meandered across their former beds, and so by degrees the present system of drainage was developed.

Beginning of the Falls. Before the Wisconsin ice had finally disappeared from this district, two principal streams had begun to be established,—the glacial Mississippi and the glacial Minnesota. Both were fed by waters from the melting ice to the north and west; both carried considerable debris, and were actively eroding their new channels. These streams joined near what is now Fort Snelling, forming a stream that flowed northeastward in a new course to what is now St. Paul, where it found an old valley (the present course) leading south-southeast back into the old course of the river at Gray Cloud Island above Hastings. The stream was swift and vigorous, a mile wide, and in places 40 feet deep. It soon cut a gorge through a ridge of the Decorah shale (which is here the bed-rock underlying the drift) and into the Platteville limestone. Where the river flowed off the limestone into the old preglacial valley at St. Paul a fall was developed. The crest of this fall crossed the present valley of the Mississippi a little east of the line of Wabasha street, and remnants of the fallscarp are still preserved on both sides of the river. On the north side it extends from the present river bluff northward just east of the Court House to Jackson street and East University avenue. The fall at that time was nearly $1\frac{1}{2}$ miles wide and 40 feet high.

It should be borne in mind that this fall was in the present valley of the Mississippi, which then was flooded by the two rivers combined, the glacial Mississippi and the glacial Minnesota. The Minnesota was at that time the more important or larger of the two. It has been stated that the present valley of the Mississippi below St. Paul had been an old (preglacial) valley, cut into the bed-rock. It was deep, but had been partially filled with drift. (The old part of the city of St. Paul, and McCarron Lake are in the partially filled preglacial valley.) The fall that developed where the glacial stream pitched off from the limestone shelf dug up the drift which lay in the old valley and ex-

FIG. 98. General View of St. Anthony Falls in 1857.
Shows Spirit Island, Cataract Island, and Hennepin Island, from left to right, below the falls. The middle part of the falls has receded 700 to 800 feet since this painting was made. From painting by Fred. Richardt. *U. S. Geological Survey.*

cavated a pool in the soft St. Peter sandstone which lies below the limestone. The limestone formation is only about 30 feet thick, and under it the sandstone was rapidly worn back by the surging water in the pool and by whirling stones and pebbles. The limestone thus undermined broke off in jointed blocks 10 to 30 feet square, exposing the sandstone beneath to still further erosion. Thus, as the falling water continued to dig out the soft friable sandstone from below and the limestone continued to fall because undermined, the fall receded or "moved" upstream.

Recession and Disappearance of the First Fall. The recession of the fall appears to have been more rapid on the downstream or south side of the broad channel. As the fall worked upstream the new deep gorge which formed below it was only about half as wide as the channel above the falls. The river thus became concentrated in a narrower bed, and an abandoned part of the bed of the old channel above the falls remained and still remains as the limestone terrace along the north side of the river between Ft. Snelling and St. Paul. Blocks of limestone that fell at the side of the fall and were not removed by the current in the lower gorge still lie on the eroded surface of the St. Peter sandstone on the north side of the river above High Bridge. (See Fig. 99.)

In a former chapter (Chap. XVI), it was stated that the old course of the Mississippi River was from Lake Minnetonka in a southeasterly direction across the present course of the Minnesota 2 miles above Mendota, thence by Marcott Lakes to Hastings. When the new Mississippi-Minnesota gorge referred to had been cut back to the northeast wall of the buried preglacial valley (2 miles above Mendota), all the limestone in the river bed had then been removed and the fall ceased to exist. Afterward the river rapidly cut down into the drift of the old valley. The sandstone island in the swamp along Minnesota River about 2 miles above Mendota marks the point where the falls ceased on the glacial Minnesota or River Warren.

Beginning of the Falls of St. Anthony. When the head of the Mississippi-Minnesota gorge passed the point where the Mississippi entered, at Ft. Snelling, a fall was formed on that stream, and has cut its way back to its present position at St. Anthony Falls.

From Nicollet Island, at Minneapolis, the glacial Mississippi at first flowed over a bottom of drift and Decorah shale, to the point where it joined River Warren, or the glacial Minnesota, which was then about a mile northeast of Ft. Snelling. Before the falls in the Mississippi-Minnesota glacial river had receded to that point, however, the Mississippi had cut its own channel down to the Platteville limestone, and had narrowed its course because the Mississippi then ceased to be fed from the melting glacier. The modern Mississippi River first joined River Warren (glacial Minnesota) at Ft. Snelling. When the Minnesota glacial river had cut deep its gorge back to Mendota it encountered a buried preglacial side gulch or valley from the old Mississippi channel to the south of Mendota. This old gulch headed northwestward up the present course of the Mississippi about a mile, and ran southeastward past Mendota, by Augusta and Lemay Lakes, to the old course of the Mississippi. River Warren quickly cleared the drift from the part of that buried gulch or valley that lay under its course as the River Warren fall continued receding up its valley, as already described. The

Mississippi likewise rapidly cleared the drift from the old gulch or valley up to its head a mile above Ft. Snelling. There the waters of the Mississippi made a fall where it dropped off from the limestone ledge into the preglacial gulch at its north end. At that time was left on the east side, opposite Ft. Snelling, the abandoned channel north of the small drift hill (a former island in the river) on the north bank

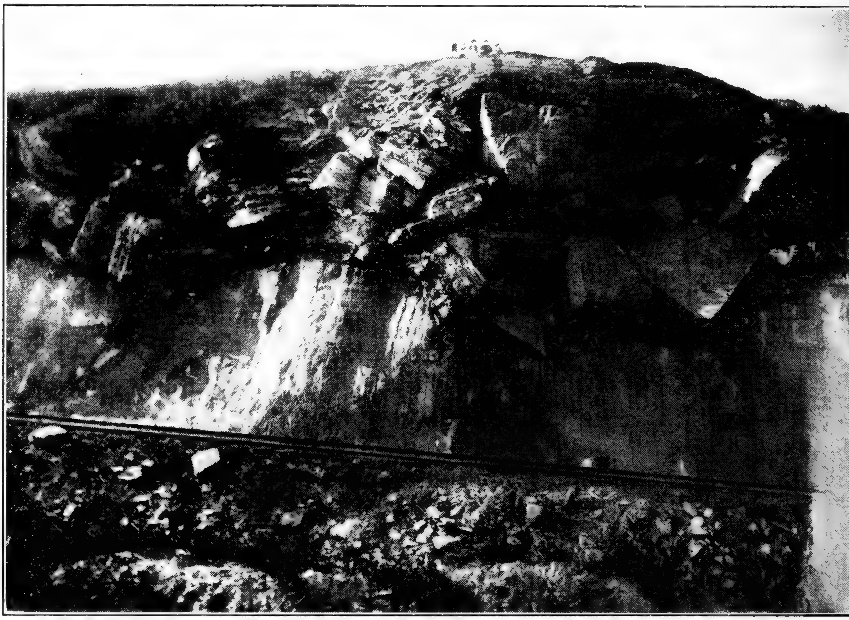


FIG. 99. Blocks of Platteville Limestone on Eroded Surface of St. Peter Sandstone Left in this Position at Foot of Receding Falls of River Warren. West of High Bridge, St. Paul. *U. S. Geological Survey.*

high above the river. This drift hill is at the east end of the bridge at Ft. Snelling, and the old channel can be seen from Seventh Street running across to the River Boulevard.

This was the beginning of the falls of the Mississippi, St. Anthony Falls, a mile above Ft. Snelling. They have since receded to their present position at Minneapolis. This part of Mississippi River was once called St. Anthony River by Father Hennepin, and the falls were named by him St. Anthony Falls.

An Abandoned Fall Below Minnehaha Creek. St. Anthony Falls receded by the washing away of the soft sandstone by water plunging over the limestone ledge and through widening crevices of the limestone. Blocks of limestone from it are still seen at the Cold Springs,—where the falls began. Above that fall, the river divided around an island so that as the falls receded they too became divided. The larger channel was on the east of the island. Its falls receded faster and cut off the west channel above the island, leaving ''Soldier Ravine,'' a gorge with an abandoned fallscarp at its head. This early remnant of St. Anthony Falls is now an historic record that shows how high the fall was at that stage,—about 40 feet. Besides Soldier Ravine on the west side there is a fallscarp remnant on the east side of that old island, hanging now high above the river, but telling the same story.

A Second Abandoned Fall at Minnehaha. During the recession of St. Anthony Falls through the half mile above the mouth of Minnehaha Creek the river and the fall were again divided by an island in the river which is now the point between the gorge of Minnehaha Creek and that of the present Mississippi River. The Soldiers' Home stands on this ancient island, the bridge crossing the old west channel. The channel of the river west of the island (Deer Park Gorge) was the longer of the two and was finally cut off and abandoned as the east fall reached the head of the island first. The existence of the old west channel is shown by a shallow flat valley above the island that leads from the west bank of the river to the head of the gorge in Deer Park opposite Minnehaha Falls. The old fallscarp can still be seen there. Deer Park Ravine is the continuation, for a short distance, of the old west channel from the abandoned fall at its head down to the gorge of Minnehaha Creek. Minnehaha Creek enters this old west channel 600 feet east of Minnehaha Falls, and runs in it to the Mississippi. The bottom of the gorge has been eroded and deepened by the creek since the west falls ceased, but the block-covered terrace on the east side of the gorge shows the position of the former bottom of the Mississippi gorge. The height of the fall was 30 to 40 feet.

Progress of the Falls Above Minnehaha. The main fall, which was on the east side of the island, opposite the Soldiers' Home, and where is now the deep gorge and the power dam, continued to recede, and the fall appears to have increased in height. A fragment of a fallscarp is preserved on the west side of the gorge just above Lake Street Bridge. When the Falls of St. Anthony were at this point the fall was the greatest in height at any time in the history of the gorge. The upper rapids had a descent of 15 feet in 300 feet to the crest of the falls. The fall was from the top of the lower half of the limestone, and was 20 feet in height. From the foot of the falls the lower rapid descended 40 feet in 300 feet. Thus there was a total fall of 75 feet. This fall marks the time of deepest cutting of the deep gorge, which was, of course, when River Warren was in its last days and its channel at Fort Snelling had its greatest depth. This gorge was later partly filled with rock waste.

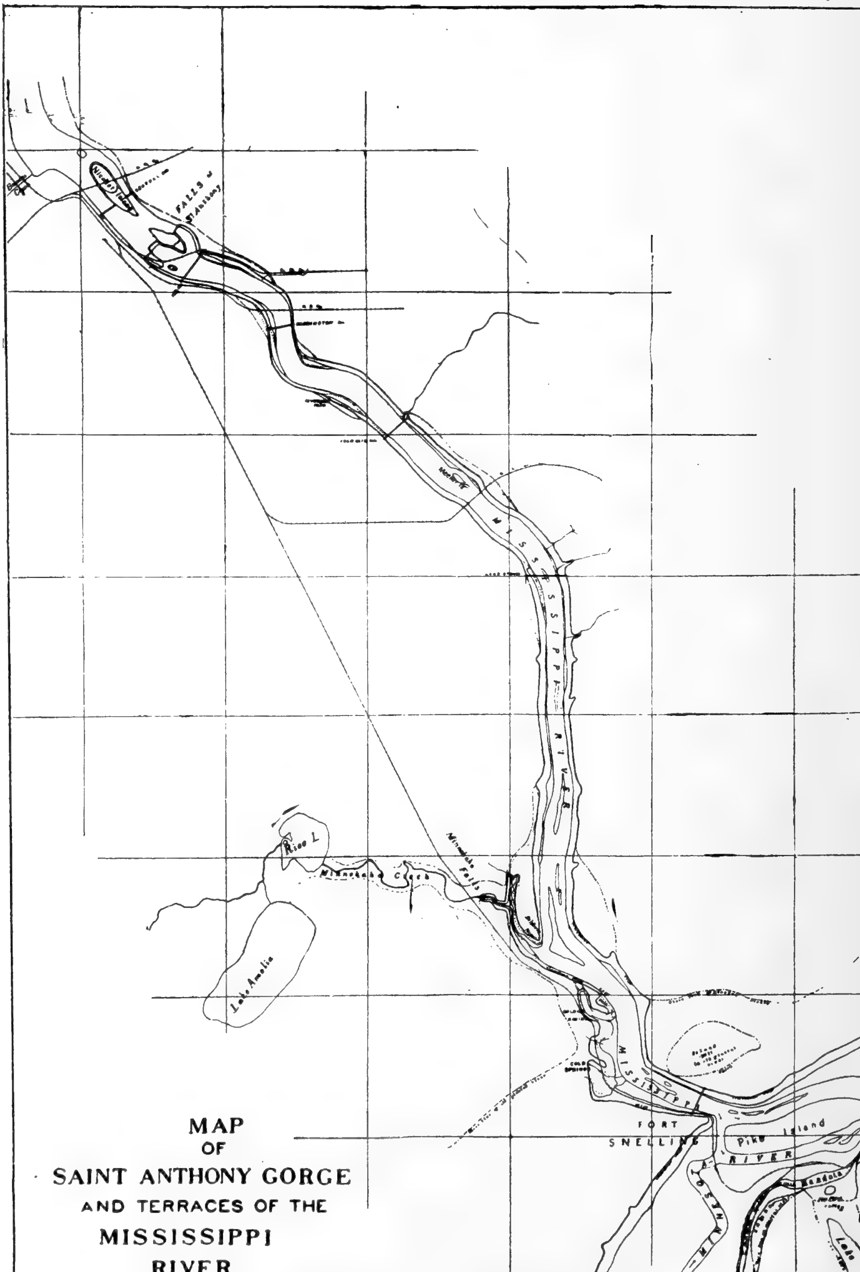


FIG. 100A. *Drawing by F. W. Sardeson*

During the time that the falls have been receding through the last 4 miles to their present location, the river, while excavating the gorge above, has at the same time been partially filling up the gorge below, from Lake Street Bridge to Ft. Snelling and thence on to St. Paul and beyond. When Father Hennepin first saw St. Anthony Falls, in 1680, they were a little above where the site of Tenth Avenue Bridge is now. A part of the fallscarp still remains, on the east side of the river. Since then the falls have entered the lower end of Nicollet Island rapids. The falls as sketched by Richardt in 1857 are shown in figure 98.

Nicollet Island Rapids. The bed of Mississippi River above the upper end of Nicollet Island for many miles of its course is upon glacial drift. At Nicollet Island the stream begins to flow upon the Platteville limestone. The river cut down through the drift and uncovered the limestone while the stream was still being fed by waters from the melting ice. When, however, the glacier had disappeared from the upper drainage basin of the river and the river had subsided to about its present size the narrowed stream flowed over the outcropping edges of the Platteville limestone at the upper end of Nicollet Island. The modern stream developed a rapid at the upstream edge of the limestone. The limestone beds are not quite horizontal above the Tenth Avenue Bridge but dip toward the southeast or nearly in the direction of the river's course. Below that to Fort Snelling the beds are nearly level. The outcropping edges of the limestone offered first resistance to the stream in cutting down its channel, and thus a rapid was formed at Nicollet Island. The rapids are therefore older than the Falls of St. Anthony.

When the river first began to uncover the limestone it was at a higher level than the present surface of the island as shown by terraces there. What is now the west end of the island and its highest part was at first a part of the rapids, but it soon became a rocky island in the stream with the cutting down of the bed of the river. Alluvial terraces on the island show that at this time the river still covered all the part of the island that lies below or east of the railroad. The rapids were then on either side of the smaller island which is now the high west end of Nicollet Island. As the channels were gradually deepened the rapids moved slowly downstream, because the limestone dips in that direction. Thus the rapids at Nicollet Island had been slowly moving downstream by sawing deeper the beveled edges of the limestone layers since the limestone there was first uncovered by the river. The head of the rapids had moved down to the lower end of Nicollet Island, and the whole thickness of the Platteville limestone had been beveled by the river between the head of the rapids and the site of Tenth Avenue

Bridge when St. Anthony Falls arrived at that station in its recession up the stream. This has had an important effect upon the rate or recession of the falls during the last 250 years, due to the fact that the limestone had been beveled by the river, and a steadily decreasing thickness of the upper limestone had to be removed.

Cause of Recession of the Falls. The recession of the falls has been due to the wearing away of the sandstone by the surging waters at the foot of the falls, and by the breaking down along the jointing in the two beds of limestone. This jointing does not, as a rule, coincide in the upper and lower beds of the limestone. As fast as erosion cut away the upper bed from the crest of the falls some water worked down through the joints in the exposed lower bed and by washing away the friable sandstone beneath, helped to undermine the limestone, which then fell in large blocks.

Since 1871 the falls have been artificially protected by an apron and the recession has practically stopped.

From 1680, when Father Hennepin saw the falls, to 1766, when they were visited by Jonathan Carver, they receded 412 feet, or 4.79 feet a year. From 1766 to 1856 they receded 606 feet, or 6.73 feet a year. When Father Hennepin saw the falls in 1680 they were at a point where, owing to the beveling referred to, only about half the upper limestone bed formed the crest of the falls, and by 1856 they had receded so far that none of that upper bed remained.

It is apparent that there was a decided increase in the rate of recession of the falls after the Nicollet Island Rapids had been reached. This change in the rate of cutting back of the falls was due to the fact that the rapids above the falls had thinned off the limestone all the way from Nicollet Island to the falls. Since the limestone layers are practically horizontal below Tenth Avenue Bridge the rate of recession up to this point is thought to have been much slower.

Rate of Recession. There is no exact method by which the length of time occupied in the cutting back of the falls can be determined, and a detailed discussion of the problem would be more tiresome than helpful. It may, therefore, be stated that after allowing for the increase in the rate of recession due to the Nicollet Island Rapids, it is estimated that the rate of recession of the falls before they entered the Nicollet Island Rapids was 2.44 feet a year, or a mile in 2,163 years. It is nearly 4 miles from the point where the Falls of St. Anthony began above Ft. Snelling to Nicollet Island Rapids. On this basis of estimating, the time occupied in cutting the gorge would be about 15,000 years. On the same basis of estimating it is thought that it may have been 30,000 years since the ice melted away from the present site of Ft. Snelling.

It is certain that, had not recession been artificially checked by an apron and retaining wall, the end of St. Anthony Falls would have been reached by this time.

Minnehaha Falls. On another page it is stated that at one time there was an island in Mississippi River above where Minnehaha Creek now enters the river. When the falls in the channel on the side of this island, which is now the site of Deer Park at Minnehaha, receded

FIG. 100. Minnehaha Falls. The Stream Falls 63 Feet over Platteville Limestone Capping St. Peter Sandstone. *U. S. Geological Survey.*

past the point where Minnehaha Creek entered this west channel of the Mississippi, Minnehaha Falls began as a cascade about 40 feet high, over the edge of the new gorge. The cascade has cut its way back 600 feet, in a gorge that is about 200 feet across at the top, and has increased in height to 60 feet as the gorge below the falls has deepened. Minnehaha Creek carries but little sediment because its waters come from lakes (it is the outlet of Lake Minnetonka), and therefore does not wear away the limestone ledge over which it falls but slightly. The recession or cutting back of the falls is caused by the weathering and crumbling of the bed of shale which lies between the St. Peter sandstone below and the Platteville limestone above, about in the middle of the height of the falls. The limestone layers are thereby undermined and slowly break off below so that an overhanging shelf is formed around the head of the gorge. The stream then plunges from the top of the limestone and forms a cascade over a part of the shelf. The sandstone is worn away slowly below and a dry bench remains upon it on which a pony can be ridden across under the overhanging limestone and the falls. Viewed from this bench during the early part of the day a beautiful play of rainbow colors may be seen through the falls.

A small stream enters the head of Deer Park gorge. This small stream follows the example of its larger neighbor, Minnehaha Creek, and forms a tiny fall as its waters tumble over the limestone shelf into the gorge. The story is told that the late Professor N. H. Winchell accompanied a party of scientists to visit Minnehaha Falls and vicinity, and one of the party, observing the miniature falls produced by the little stream, jokingly asked its name. "Oh, that is Minnie Giggle" the Professor replied. And the tiny falls still carry this name!

CHAPTER XX

LAKE DULUTH

How the Lake Came to Be. During the Wisconsin stage of the ice invasion a glacier or lobe from the Labradorian ice sheet pushed into Minnesota by the way of the Lake Superior Basin. The ice entirely filled the basin in which Lake Superior now lies, so that the lake was pushed away as its basin became filled with ice. The front of the glacier was shoved forward over the rim of the Superior Basin on all sides, and the waters of the former lake were crowded out. Even after the glacier's front had begun to recede later by reason of the ice melting more rapidly than it advanced, the run-off from the melting ice went into the Snake and Kettle in Minnesota, and the St. Croix in Wisconsin, directly from the ice. When, however, the edge of the ice had melted back to within the rim of the lake basin a lake began to form again between the ice wall and the rock rim, steadily increasing in size as the ice melted back.

The new lake began at Nemadji, many miles from the present shore of Lake Superior, and about 500 feet above the present lake level. This small high-level lake has been called Glacial Lake Nemadji by N. H. Winchell. The later and larger lake that lay between the rock rim of the Superior Basin and the ice wall is called Lake Duluth. The highest Lake Duluth shore-line was only a little lower around the rock rim than that of Lake Nemadji, the water being held up by the glacier which formed a dam across the basin from the north shore to Keweenaw Point, Wisconsin. After the glacier had melted from the east half of the basin the lake assumed more nearly its present size and level, and can be called Lake Superior.

The outlet of Lake Nemadji was west through Moose River to the Kettle. The outlet of Lake Duluth was south by the present site of St. Croix Lake in Wisconsin to the St. Croix River. At both the Nemadji and Duluth stages of the lake's history a large tributary glacial stream came down the St. Louis River valley.

History of the Lake Shown in Land Forms. The record of the lake's history is found in the old lake beaches, terraces, and channels in and around Duluth. The highest set of shore-lines of Lake Duluth is known as Boulevard Beach, named from the Duluth boulevard or parkway drive, 450 to 500 feet above the level of the present lake, the boulevard being mainly upon the old lake shores. It is interesting to observe how clear these glacial historical records are, and also how economically these geologic features have been taken advantage of in the construction of boulevards, railways, cemeteries, and even towns.

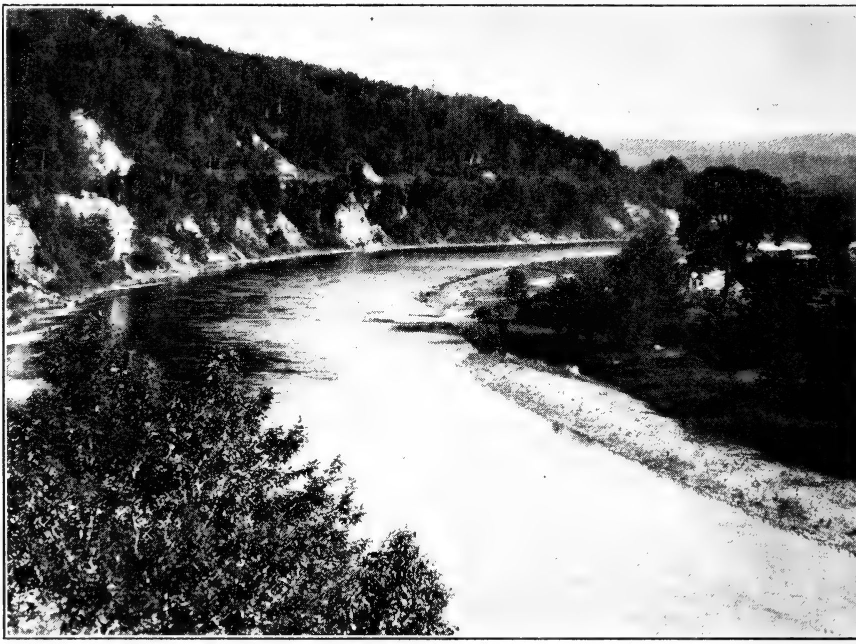


FIG. 101. Glacial Valley of St. Louis River at Jay Cook Park, Duluth. *Photograph by Gallagher.*

The Northern Pacific Railway runs from Moose Lake to Barnum, Mahtowa, Atkinson, Otter Creek, and Carlton along an old channel of St. Louis River, made at a time when that river emptied through the Kettle to the St. Croix. That was at a time when the glacier had melted back just to the rock rim of the Superior Basin. The glacier's edge faced the northwest at Carlton, and was about a mile outside (west of) the site of the town, where the gravel pit of the Great Northern Railway is now, south of Scanlon. A stream flowing away from the ice front had thrown out an apron or outwash plain of gravel at this point about three miles long by one-half to one mile in width, lying along the glacier's front, and the St. Louis glacial river, which came against the ice at Scanlon, was then turned out to the west of that fan of outwash. Its channel, seen at Scanlon, gives us the measure of the stream, one-half mile wide. It flowed southwest to Atkinson, Barnum, and Moose Lake in the valley now followed by Moose Horn River and the Northern Pacific Railway. At that time the ice wall or front of the Superior glacier was only 3 or 4 miles east of Moose Lake, and this was the western end or point of the glacier.

The flood waters of the St. Louis River then came partly from the Cloquet River, which was still fed from the edge of the Superior glacier, but more flood came from Lake Upham, which was fed by the Keewatin glacier from the north. The glacial St. Louis River did not keep to its Scanlon channel at one end nor to the Moose Horn Valley at the other end very long. As soon as the ice wall had melted back at Carlton a mile or so the river followed the St. Louis Valley south to Carlton,

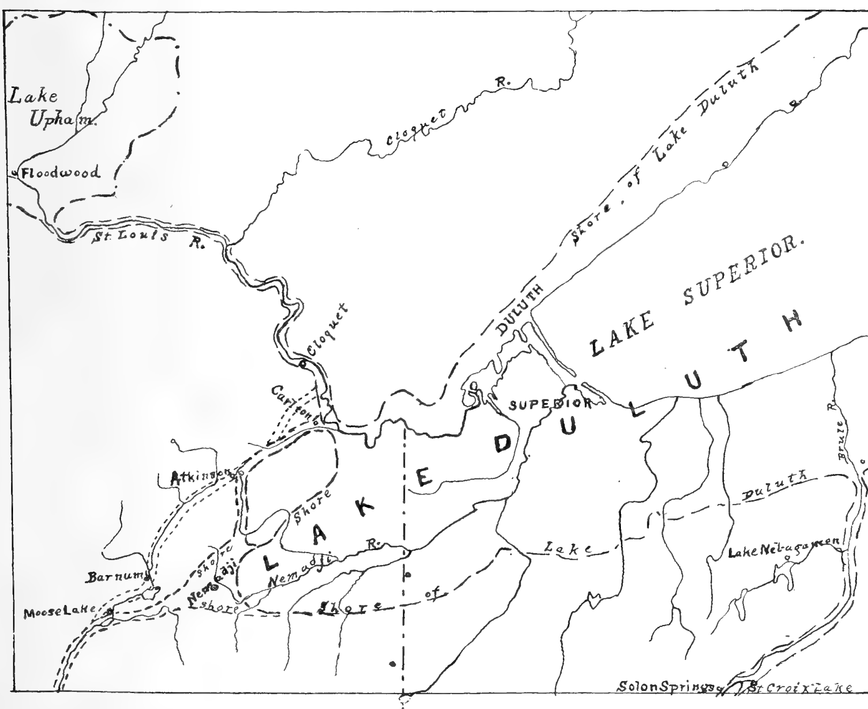


FIG. 102. Glacial Lake Duluth. *Drawn by F. W. Sardeson.*

from which point it turned against the ice wall and went southwest back into the former channel as far as Atkinson. From that point it turned south and discharged into Lake Nemadji at its north end.

Lake Nemadji. Lake Nemadji at this time covered about 15 square miles. Its outlet was large, being about one-half mile wide. It occupied the valley or old river channel that is now followed by Portage Creek to Moose Head Lake at Moose Lake. The Soo Railway now runs along the north side of this old river channel and on the lake's bed, from Moose Lake to Nemadji.

Lake Nemadji increased in size as the ice wall of the glacier melted away, while its outlet remained the same until the lake's area was about 50 square miles. The St. Louis glacial river then changed its route, however, again and came to the east of Carlton, and then southwest along the glacier's border. If, as has been proposed, a boat canal was to be built from Lake Superior to the Mississippi River the natural route would be up St. Louis River by locks from Fond du Lac near to Thompson—a rise from 602 feet to 1,060 feet above sea level. Then the canal would run level along the old glacial St. Louis River course past Nemadji and along Portage Creek to Kettle River.

Changes of Lake Level and Crustal Uplift. The boulder strewn bottom and the shores of the Nemadji outlet remain in condition as if the stream had suddenly abandoned it at full size. And there is no doubt about what happened. A lower outlet drew down the level of the lake's surface to a point below this outlet. The explanation of the development of this new outlet is that the glacier had melted back from the rim of the lake's basin on the south so that the lake—now called Lake Duluth—had access to the Brule Pass to St. Croix Lake at the head of St. Croix River in Wisconsin. The Brule Pass is not necessarily lower than the pass at Nemadji now, but it was then.

It is well known that change in elevation of the land surface has followed the unloading of the glaciers from the continent, and around Lake Superior the relative rise has been to the northeast. This would raise the Brule Pass as compared with the Portage Creek Pass. Near Nemadji the lake surface dropped about 25 feet from the Lake Nemadji level to the Lake Duluth level. There is no such difference between the two old outlets now, however. Lake Duluth fell again several times, as is shown by the occurrence of several beach lines instead of a single beach line. The several Boulevard Beaches at successive levels illustrate this. The falling of the lake surface was from cutting down of the Brule outlet.

It is well known that the Boulevard Beaches and others of Lake Duluth are not horizontal but rise slowly when followed northward or eastward. Frank Leverett has determined that at the time of Lake Duluth the rock surface that is now north of the shore in Canada, and is 602 feet above sea level, was then depressed below sea level. The glacier vanished and the land rose. Whether or not it rose to just the same level as before the Wisconsin stage of glaciation we do not know. As the glacier retreated the Brule Pass was abandoned for lower outlets across Michigan, and the lake fell.

Lake Duluth Bottom. Nemadji River flows into Lake Superior across the former Lake Duluth bottom. All of the Nemadji River gorges are in glacial clay, with bed-rock in few places. The gorges are all "new" and sharp, or ditch-like. These valleys are newer, i. e., younger, than the clay beds of Lake Duluth. The St. Louis River gorge, mainly "new," is partly also an older valley, which was so deep that the deposits from the glacier and lake did not fill it. Duluth harbor, or "the Bay," is an old valley not yet filled, though it is being filled by river sediment and by shore wash. The deepest places are where scour keeps the mud out, i. e., in the straits.

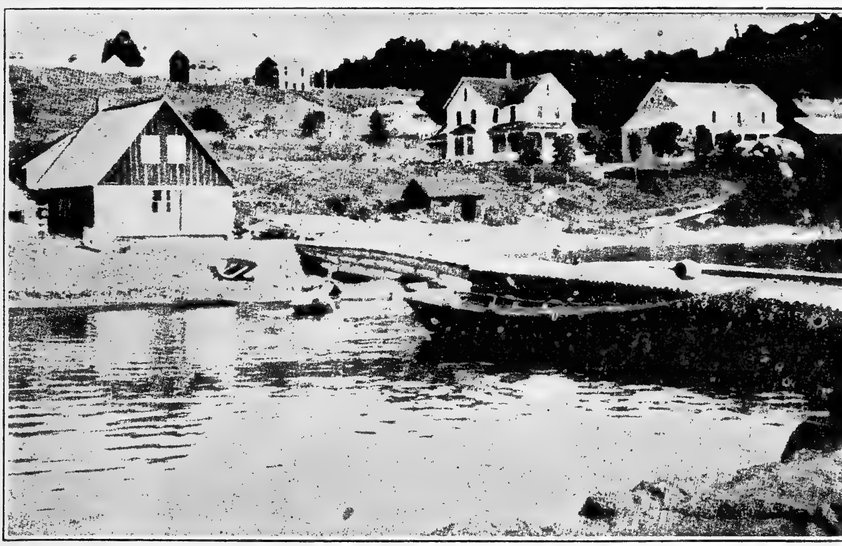


FIG. 103. Terraces Showing the Higher Levels of Lake Duluth at Lutzen, Cook County.

The mouth of St. Louis River was first near Carlton, and moved down by stages as the lake's surface dropped to where it is now. At first the St. Louis River brought from the Ranges much sediment from the melting ice of the glaciers. This sediment, together with that from the melting front of the ice wall in the lake basin, was laid down in horizontal layers on the bottom. This is now the clay used for making brick at Wrenshall. East of Wrenshall there are places (best seen in railroad cuts) where the lake clay has been crumpled up by the pushing forward of the edge of the glacier during short periods of re-advance. Boulders also mark the position of water-laid moraines, which correspond to knolly terminal moraines that were dumped on the land north and south of Lake Duluth. But even with such water-laid moraines in it the old bottom of Lake Duluth was comparatively smooth. The view across the old lake bottom from the rim of the basin out toward Superior, Wisconsin, is a grand one. The ditch-like valley of Nemadji River and its branches do not break the continuity of the slope of the ancient lake basin when viewed broadly.

Superior and West Duluth are built on what was once the bottom of glacial Lake Duluth. The mud came from shore wash and from flood waters of Nemadji and St. Louis Rivers rather than from the glacier, which by this time had receded by melting far from the shore. The old valley of St. Louis River, which was deeper and hence not filled up, was not smoothed over by shore wash, but remained as a part of the lake, extending as a bay to where Fond du Lac now is. The mouth of the river was then near Fond du Lac. It is now at Big Island.

The Struggle Between River and Lake. When storms from the east sweep the lake the water rises in the Bay, as the water west of Minnesota Point is called, and backs up the river at times as far as Fond du Lac. When St. Louis River rages at flood it fills the Bay with muddy water, and a long yellow streak may be seen running out into the lake beyond the Bay. The balance of control between the lake and the river is at Big Island. From Fond du Lac to Big Island the river at all times has a sloping surface. But from Big Island out through the Bay there is room for convection or circular currents to turn, and whether the flow of water is going out from the Bay to the lake or into the Bay from the lake the level of the water of the Bay is always the same as that of the lake. A notable difference between the Bay and the river is that there are levees along the St. Louis down to Big Island, with some lakes or ponds behind the levees, but in the Bay, however, there are only scour channels, where currents in the narrows keep the mud from accumulating and filling up, and outside the scour channels there is naturally a flat, wide, muddy bottom.

Minnesota Point. The Bay was connected naturally only by a scour channel with the outer lake. (The channel at Aerial Bridge was cut artificially.) That scour channel cuts across the most remarkable of all features seen at Duluth,—the Minnesota Point. A view from the rocky hills 500 feet above Duluth shows an arm 7 miles long extending out at nearly right angles to the shore of the lake and Bay. Opposite to it is a shorter but otherwise similar arm extending out from the Wisconsin shore. The scour channel, already referred to, lies between the ends or points of the two arms or spits.

The appearance of the long, low, slender strip of land running boldly out from a rocky shore suggests at once that it (the Minnesota Point) is a rock reef,—but it is not. To a person who knows the glacial history of the lake it looks like a glacial moraine,—though it is not. It is all sand and gravel. It is neither bed-rock reef nor crumpled up boulder-clay moraine. It is just a lake shore. Its position might suggest that it is where a shore was built when the lake's surface was a hundred feet or more lower than it is now, and that the shore built up as the surface of the lake rose. But the lake never was more than a few feet lower than it is now. The truth appears to be that it is an off-shore bar or spit built out into the lake by what is called the 'long shore carrying or transport of sand and gravel by waves. The northeast wind and waves tearing along the lake's shores move sand and gravel—not onto the shore nor into the lake—but along shore, and of course toward the Bay. When shallow water near shore is reached the force of the waves is spread, and whatever load is being moved is also spread. Thus a spit was begun projecting out into the lake, and when once begun it steadily grew at the end. That happened on both sides of the Bay. How Minnesota Point and Wisconsin Point happened to so nearly meet is because of the storm currents of the lake and bay. The spits are built along where the currents of the deeper waters of the lake meet the shallower waters of the Bay. There would have been a continuous shore long ago but that the spits are kept apart by the scour of water rushing at times of storms into the Bay and later out again. Now that the "points" cannot grow longer they are growing stronger by increasing in width. Thus a natural harbor was built with complete natural protection from storms out of an old submerged remnant of a river valley by the work of the storms themselves.

CHAPTER XXI

GLACIAL LAKES AITKIN AND UPHAM

Ancient Lake Bottom in Aitkin County. In northeast central Minnesota, on the upper Mississippi, occur the remains of a lake 50 miles in length from north to south, and varying from 10 to 25 miles in width. Its old shores, with a raised, gravelly beach, by affording suitable well-drained locations, determined the sites of several railway stations and towns,—Aitkin, Kimberly, and Grayling, on the Northern Pacific Railway, and Axtel and Palisade on the Soo. The old mud bottom of the lake is a good "Red River Valley" type of soil where not too swampy for cultivation. Large areas are covered by thick peat-bogs, enough to supply fuel to the state of Minnesota for an indefinite time if coal supplies from elsewhere were exhausted. On the old lake bottom there are a few remaining small lakes, and there would be more of these if the Mississippi River had not deposited so much mud along its course across it.

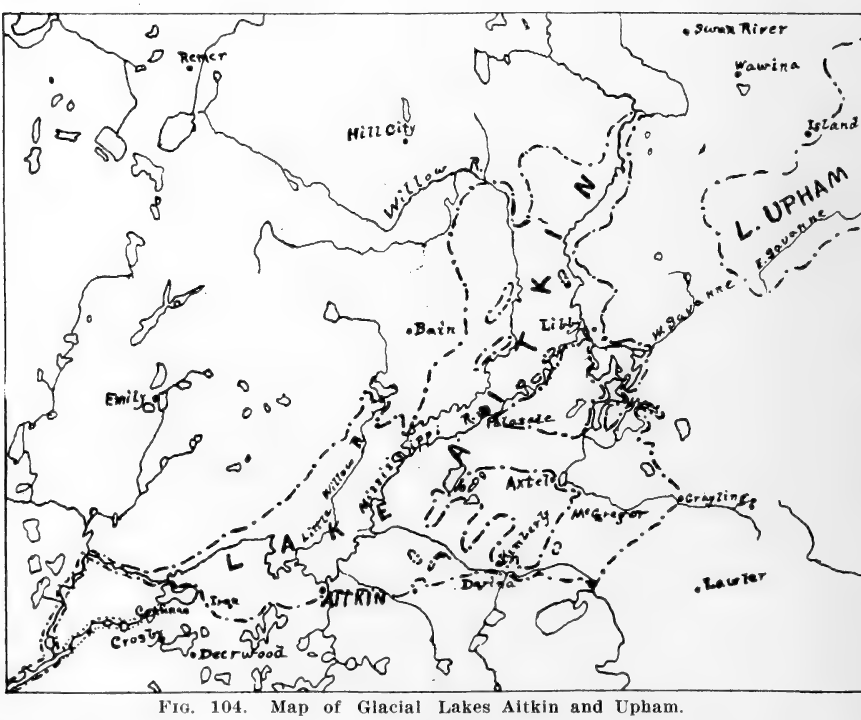


FIG. 104. Map of Glacial Lakes Aitkin and Upham.

Lake Aitkin was a shallow lake with several islands. Its old shore is now about 25 feet higher than the Mississippi River at Aitkin. The lake may have been 50 feet deep in places before the filling of mud by the Mississippi took place. The north side of Lake Aitkin is merged into a great swamp and bog which conceals some of the shore line. The southeast part near McGregor was a shallow bay having a sandy bottom, but is largely overgrown with peat now.

As the Mississippi River, which runs through the basin of the old lake, cleared out its channel and cut down its bed north of Rabbitt Lake down past Brainerd to Little Falls, the lake was drained by the opening of its outlet but filling of the lake basin with mud, and the accumulation of bogs by the growth of vegetation, also tended to destroy the lake. Also the tilting of the land surface by a balancing movement of the crust of the earth aided in causing the disappearance of the lake. The last-named cause probably explains why the lake disappeared or shrunk away so soon after the melting away of the glacier. It built only one set of beaches, showing that it existed for a short time, and then rapidly shrunk away. The shore at Aitkin is about 1,225 feet above sea level now, while at Grayling it is about 1,235 feet, and at Jacobson still higher. Since the shore line at the time of formation of the beach was, of course, level, the present differences in altitude of points on the shore line show that there has been a change in the ''level'' of the earth's surface here after the weight of the great continental glacier was removed.

Lake Aitkin Named. Lake Aitkin was so named by Warren Upham at the time when he discovered the old lake shore at Aitkin. He called it ''Glacial Lake Aitkin.'' It was not, however, a glacial lake in the sense in which Lake Agassiz and Lake Duluth were glacial lakes. These lakes were held up by ice of glaciers acting as a dam at one end while compelling the water to overflow across land barriers at the other end. Lake Aitkin was a glacial lake in the sense that it was brought into existence by obstructions which the glaciers made, but it differed from those named in that it remained after the glacier had melted and disappeared from the country. Most of the 10,000 lakes for which the State of Minnesota is famed are ''glacial'' lakes in that they owe their existence directly or indirectly to the action of glacier ice. Lake Agassiz, Lake Duluth, and Lake Aitkin, however, are called ''glacial'' lakes because they not only owed their existence to the glaciers, but they disappeared with or soon after the melting of the glaciers.

The bed of Lake Aitkin is now only partially occupied by farms. At the time when Upham described and named it, in 1899, the lake's basin was nearly all grown over with timber and bog. He did not then follow out the shores of the lake completely. That work was done later by Leverett and Sardeson while making a soil survey of the State, there being more railways, wagon roads, drainage ditch embank-

FIG. 105. Dairy Farm on Clayey Bottom of Lake Upham, Meadowlands.

ments, and other paths which make the task more easy than when Upham's geological reconnaisance of Aitkin County was made.

Islands and Beaches. There were two large islands with small lakes on them, and several small islands, in Lake Aitkin. Palisade is on one of the smallest islands, located near the Mississippi River,—a beautiful gravelly spot in the midst of mud banks and wide bogs. East of Palisade, across the Mississippi River, is a large island which is marked all around by a well-defined beach. Kimberly, on the Northern Pacific, is located at the extreme south end of another large island, and, at the northeast part, Axtel, on the Soo, is built on the same beach which runs in a very winding course around the irregular shaped island.

The shores of the old lake are fine gravelly beaches where the lake was swept by the northwest winds. At Aitkin the shore is a few feet high, and the beach-ridge is as wide as a roadway from the city west to the cemetery. At Grayling the beach is higher and broader, and a street has been constructed upon it with houses on both sides of it standing high and dry above the lower lake bottom. The beach there is very steep and is a conspicuous landscape feature. It runs several miles north and south and is occupied by a country road. At Kimberly the shore is a sidehill terrace, best seen near the Northern Pacific trestle on the south side of the valley opposite Kimberly. This valley was then a strait between the island on which Kimberly is located and the mainland. Around McGregor a glacial outwash plain was submerged and worked over by the waves of a shallow bay, forming sand-bars. These bars remained as sandy islands in the peat-bog which succeeded the lake there. The town of McGregor is located on a gravelly bar, and the Northern Pacific Railway runs from island to island across from McGregor to Ude, which latter is on an island's beach.

The outlet of the old lake lies directly across the moraine which extends from Deerwood north past Cayuna and west of Rabbitt Lake to Emily. Back from the old outlet the river has eroded into the old lake bed, a deep, nearly straight channel with high banks and high, dry land on either side. This eroded channel extends from north of Rabbitt Lake near Cayuna for several miles nearly to the mouth of Little Willow River. Above this deep, nearly straight channel the river is very crooked and the channel is bordered by banks that are generally higher than the land that lies back of them. The Mississippi River has here the appearance of a stream that flows through a filled basin or valley,—a sluggish, meandering stream with levees, bayous, and bordering swamps, a rich land for the drainage engineer and the farmer, up to the head of Lake Aitkin.

Lake Upham, Named for Noted Geologist. A lake similar to Lake Aitkin occupied the St. Louis River Valley at Floodwood and northward at the same time that Lake Aitkin occupied the position just described on the Mississippi. As Lake Agassiz was named in honor of a noted student of glacial geology, Louis Alexander Agassiz, so Lake Upham was named by N. H. Winchell in honor of Dr. Warren Upham, who has contributed so largely to the literature of glacial geology in Minnesota and the Northwest.

The silty deposits that are characteristic of lake bottoms are well seen at Floodwood in the cultivated fields, but most of the old lake's area is overgrown with peat, being largely peat-bog and swamp. The lake's beaches were not discovered and traced till long after this extinct lake was named. On the road from Floodwood south to Prairie Lake there is a distinct gravelly beach which can be followed for miles east and west along what was the south shore of Lake Upham. Gravel for road construction is now being taken from this beach. Island Farm at Island appears to be on the north shore of the ancient lake, but there may be no raised beach around the north side of the lake, or if any, it is probably covered with peat deposit.

Lake Upham did not remain long. It was a shallow lake having a flat bottom, and its outlet was near the deepest part. St. Louis River soon cut down its channel and allowed the waters to escape. This may all have happened before Lake Agassiz and Lake Duluth shrank away.

CHAPTER XXII

THE LAKES AND RIVERS OF FREEBORN COUNTY

A Detail of Glacial History

A study of the glacial features of Freeborn County is instructive as illustrating the processes by which the present landscape features of a large part of the State have been formed. The geological factors that have been active in Freeborn County are those that have shaped the character of the landscape over a large part of the State as a whole. No two counties or districts are exactly alike, of course. The map of no county is a precise type of the whole State, but the geological history of Freeborn County is suggestive of what has occurred over the greater part of the State in that it has all the common glacial features,—moraines, till-plains, outwash gravel plains, lakes, ponds, swamps, marshes, bogs, rivers, and creeks,—that, as a scientist would say, are consequent to, or in other words that result from, the invasion of a region by a glacier.

If one were to travel from the southeast corner of the State westward across Houston, Fillmore, and Mower Counties, no lakes would be found there because a land surface is being crossed that has been eroded into valleys that drain that surface. Upon reaching Freeborn County, however, many lakes are found, and the surface is covered with a glacial drift deposit so new that valleys are blocked up and well defined lines of drainage have not been established. In other words, the land is not drained. Freeborn County was like Mower and Fillmore Counties now are before the last glacier invaded it and left the surface covered with drift. It is easily seen that new glacial drift and lakes go together. For example, Little Elk Lake lies exactly at the border of the drift of the youngest or Wisconsin glacier, at the outmost limit of its invasion. The southeast corner of the county was not covered by the glacier that made the lakes, and that corner can be taken as representative of the small part of the State that does not have lakes of the glacier's making.

The glacier did not simply move out over the country and then melt away, but the ice advanced slowly while at the same time it was melting. The balance between the pushing forward of the glacier and the wasting of the border by melting fluctuated so that the border advanced, and, as we say, "retreated"; re-advanced and retreated again. The margin of the glacier stood at times stationary, just on the

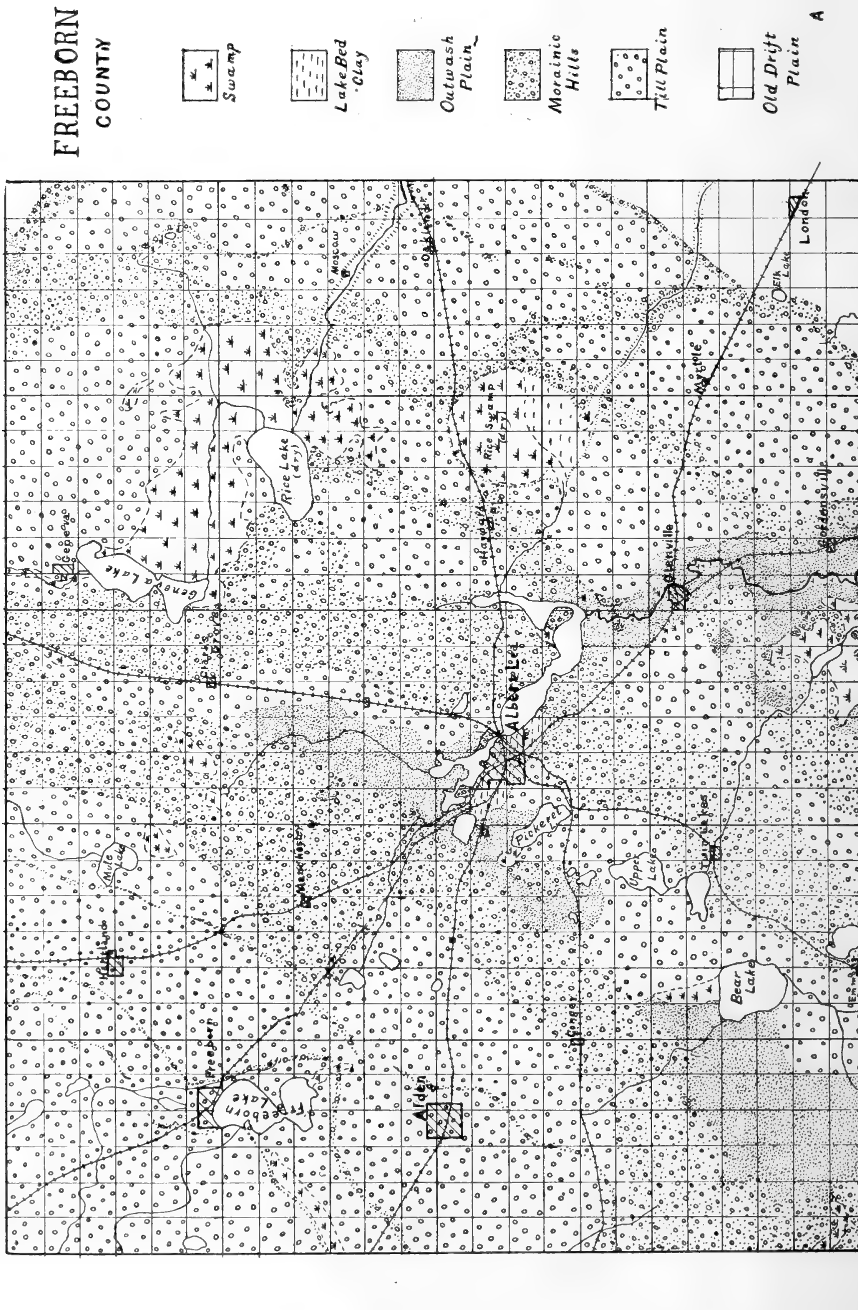


FIG. 106. Map Showing Details of Glacial History in Freeborn County. *Drawn by F. W. Sardeson.*

tremble as it were between advance and retreat. At such times the hilly moraines were formed. A re-advance over a moraine, of course, wiped it out, so that only the moraines that were not over-ridden remain as moraines. Ground moraine, called also till-plain, is practically all over-ridden moraine. During retreats and advances the shape of the glacier's edge changed a little so that it might over-ride and wipe out one part of a moraine and not another part. Many such examples occur in Freeborn County.

Lakes are a very marked characteristic of a landscape that has been recently glaciated. The lakes of Freeborn County offer an interesting study in the manner of formation of lakes and the processes of glaciation.

Among the most interesting lakes in Freeborn County are the Albert Lea Lakes, at Albert Lea. The easiest way, perhaps, to describe these lakes is to explain how they came to be. To do that it is necessary to trace the succession of events in the history of the glacier, as shown by the drift hills or moraines, the till-plains, and the outwash plains. On the accompanying map (figure 106) the lakes and streams and the glacial deposits to which they are related are shown.

First Event: Advance of the Ice. The first activity of the glacier recorded in the county was the spread or advance of the ice border across the county from west to east until all was covered except a very small area in the northeast corner of the county and a slightly larger area in the southeast corner. This position farthest out is marked by a deposit a few feet in thickness of glacial till or clay, with pebbles and boulders, and a belt of knolls and small hills of the same character of material along the margin. From a mile north of Elk Lake that belt runs northeast into Mower County near to the town of Austin, and then turns back again into Freeborn County. All of the land along the border slopes eastward or away from the border belt of knolls, so that the filling of shallow valleys did not make any lakes. Only inside, or west, of the border are there ponds or sloughs, and none of them large enough to be placed upon the map.

Second Event: Retreat and Re-advance of the Ice. The second event in the record of the glacier was that the front of the ice melted back some miles, we do not know just how far, and then advanced again up to a line a mile east of Oakland and east of Moscow. A weak moraine, that is, not very rugged in character, or chain of knolls, marks the position of the ice border. No lakes but only small "kettles" were formed at that time.

Third Event: Formation of Moraine and Lakes. The third event, after the melting back or retreat of the front of the glacier from its second position, was a re-advance of the ice to a third position, which is marked by a moraine about a half mile wide. This moraine is stronger, or more pronounced in character, than the other two. The knolls and hills are higher because by this time the deposit of drift was becoming heavier, and the thrusting of the edge of the ice, a huge ice-plow, tending to build up larger mounds. The width of the moraine also shows that the ice front stood for a longer time at the third position than at the second. This third position is west or back of the second position near Oakland and Moscow, but south and north of these new bulges in the front of the glacier carried this moraine beyond the second, and up to the first position, as may be seen on the map.

Two lakes were developed in the building of the third moraine. Elk Lake near London is just on the border of the new drift, in this moraine, and it occupies a depression which was a small valley no doubt, that drained westward into the head of the creek which still runs southward at the State line. The basin of Elk Lake in short is the result of blocking up by new drift across a shallow valley. Another lake that was brought into existence at this time is represented by the swamp and small lake 5 miles northward of Moscow. (See map.) That basin lies between the second and third moraines, and it still drains westward along the valley the drifting up of which caused the lake to be formed.

From this third position an outwash of gravel and sand was formed at the north boundary of the county. A stream flowing away from the front of the ice and bringing out gravel and sand from the melting ice accounts for such an outwash plain. Except for the filling of outwash gravel there would very likely have been a lake formed there also.

Fourth Event: Re-advance of Ice Front. The fourth position of the ice front was determined by a re-advance of the glacier. At the north boundary of Freeborn County this fourth position of the front of the glacier was close upon the third position, so that the two moraines are closely parallel and in part merged together. The two moraines run in that close relation for a distance of 15 miles southward, to 5 miles north of Myrtle where they divide. The fourth moraine then runs southwest to Gordonsville and the Iowa boundary, where it turns west. Across Shell Rock River it turns north into Minnesota again, and finally into Iowa again. It appears as hills and knolls in and around the swamp which lies from 1 to 5 miles west of Gordonsville. This turning of the moraine shows how the Shell Rock Valley depression influenced the movement of the ice of the glacier. A tongue-like lobe of the glacier about 3 miles in width and 4 miles long pushed down the river's valley.

A lake was formed at that time inside the moraine, and it is still represented by the swamp and Goose Lake, on Goose Creek west of Gordonsville.

This lake, no doubt, occupied the valley as soon as the ice border retreated. The lake would, of course, have extended to and above Albert Lea if the glacier had retired that far before the next re-advance.

Fifth Event: Formation of Moraine and Ponding of Waters. The fifth event is recorded by the moraine at Hayward. From the north line of Freeborn County this moraine, which represents the fifth position of the glacier, is merged with those of the fourth and third positions as far south as the east side of Rice Lake. From the south side of Rice Lake the moraine runs by Hayward and Glenville and then southwest where it again merges with the moraine of the fourth position. While the front of the glacier occupied this fifth position there was a lake where the swamp now is east of the present Rice Lake. It was held in by the ice on the west and the higher land south and east. The valley of Turtle Creek, which runs by Moscow to Cedar River, was the outlet. That lake had the effect of spreading out whatever drift was thrust or dumped into it, and that is the reason why a flat swamp occurs instead of a regular moraine east of Rice Lake.

Another lake nearly 10 square miles in area was held between the moraines east of Hayward where the Rice swamp lies. An outlet of this lake was formed by the water being forced to overflow across the moraines north of Myrtle, southeastward down the little valley now occupied by Woodbury Creek. After the glacier had withdrawn once more this lake appears to have developed another outlet to the west, which was more nearly the original direction of drainage for that basin. The Rice swamp area probably drained westward near to where Hayward now is before the moraine was deposited there by the glacier.

Goose Lake, west of Gordonsville, was greatly changed at this time by outwash sand and gravel carried into it from the melting ice. While the moraine was being made along the ice front from Hayward to Glenville the ice covered the site of Albert Lea Lakes and of Shell Rock River to Glenville. Streams flowing away from the glacier at Glenville filled the valley with their loads of sand and gravel to Gordonsville and below, and west where the swamp is now, where had previously been the larger Goose Lake.

Sixth Event: Moraine Blocks Drainage. The sixth event in the glacier's history, as recorded in moraine building, accounts for the moraine at the south end of Geneva Lake and extending to Rice Lake, and southwest. This sixth moraine blocks the drainage of the Rice Lake Basin, which was originally toward the west. All the rest of this moraine in Freeborn County except this small lobe, or tongue, which reaches out to the west end of Rice Lake, was over-ridden by the glacier when it made the great seventh moraine.

The position of this sixth moraine where it crossed the Shell Rock Valley is somewhat uncertain, but it was probably at the narrows between the upper and the lower lakes at Albert Lea. Being over-ridden by the glacier and smoothed and toned down it is probably represented by the higher land on which the city of Albert Lea is built.

Seventh Event: Old Valley Filled by Outwash. The seventh event accounts for the position of the great moraine which hems in Geneva Lake on the west. The waters from the melting glacier formed a great shallow lake which is now the swamp that extends eastward past Rice Lake, and drains down the Turtle Creek Valley. The border of the glacier at this seventh position also bulged down the Shell Rock Valley to what is now the lower end of the Albert Lea Lakes, and while the glacier stood at this stage the waters from its melting made a high outwash plain down the valley over the fifth moraine. It is this outwash which fills the valley to Glenville. Lake Albert was thus still further separated from the Goose Lake basin, west of Gordonsville.

The Albert Lea Lakes lie in what remains of an older Shell Rock River valley. The valley has been filled with till and outwash from a point below the Iowa boundary up to where the lakes begin. The valley and its branches are also filled above the lakes (north and west). Even where the lakes now are the old valley is partly filled with drift. Between Geneva Lake and the east arm of Lake Albert (nearest Hayward) an old valley is blocked by the moraine. Two other valleys are filled above Albert Lea. In fact, even the basin of the Albert Lea Lakes escaped filling with outwash only because of the high level of glacial Lake Albert Lea.

The shores of what it is convenient to call Lake Albert Lea, to distinguish the high first stage of lake level from the present Albert Lea Lakes, can still be traced, as shown on the map (figure 106), across the present site of the city of Albert Lea. The high level of those shores corresponds to an outlet of Lake Albert Lea which was then over the top of the outwash plain to Glenville, instead of as now, in a deep channel through that plain. This high level marks where the water stood while the glacier was making the large outwash plain above the lakes. If now it is recalled that when streams carry gravel and sand into a lake they build flat deltas whose surfaces are at or above the level of the lake, then it is clear that the high level of Lake Albert Lea caused the outwash gravel and sand which were coming from streams swollen by melting ice to be filled up to a great depth, thus building a high plain instead of spreading down the valley past Albert Lea, as it would have done if the lake level had been as low then as it is now. It thus appears that the filling of gravel in the outwash plain below the lakes both made the lakes in the first place and then by its ponding the valley full of water saved the valley and the lakes from filling up entirely with outwash.

Eighth Event: High Outwash Plain Formed. The eighth event in the history of the glacier, as recorded by its deposits, accounts for the great moraine which lies west of Albert Lea (see map, figure 106). The front of the glacier while in this position bulged forward down the valley and reached what is now the northwestern part of Albert Lea city. The front of the ice stood across the lake there (Lake Albert Lea). A part of the moraine became an island in Lake Albert Lea, and this island is now the hill in the northwest part of the city. Other parts of the moraine near this hill are buried under the high outwash plain. As already explained, the high surface level of Lake Albert Lea caused the streams which brought gravel and sand from within the glacier to build up a high outwash plain close to the front of the ice instead of spreading it out farther down the basin. Consequently part of the moraine is covered under outwash. The shore of the old lake next to the outwash plain is remarkably high, for the reason that the plain was built up above the high level of Lake Albert Lea. Since that time the lake level has been lowered by its outlet, Shell Rock River, which has eroded a channel into the plain below the lakes. Pickerel Lake likewise has high banks of outwash on one side, and it was probably a part of Lake Albert Lea before it was cut off by the deposit of outwash. The outlet of Pickerel Lake is through and under the gravel outwash.

Lakes in Partially Filled Valleys. The lakes of western Freeborn County are more simply explained than those of the eastern part. They occupy generally what was some kind of valley before the glacier advanced over the surface, but they owe their existence, in many cases, to unequal thickness of the glacial drift itself. The deposits made by the glacier in its first position, or near the margin, as has been stated, were only a few feet in thickness. Farther back, however, or behind its seventh and eighth positions, the deposits of drift accumulated to a thickness of 25 to 50 feet. Ten feet less in thickness of drift deposited in one place than was laid down around that place could in itself make a lake basin on what was before only a level prairie. The lake near Emmons, called State Line Lake, is a basin between thicker deposits or ridges of the moraine. Upper Twin Lake is a depression in the till-plain. Freeborn Lake, Mule Lake, and several smaller ones are basin-like depressions in the till-plain. Freeborn Lake and the three smaller lakes north of it express by their succession in a line, and by the elongation of each one in the direction of that line, that they are the faint remnants of a valley. In fact, these four lakes and the two near the railway between Freeborn and Albert Lea are probably surface remnants of what was once the Shell Rock River Valley, now nearly effaced by deep filling of glacial drift.

CHAPTER XXIII

THE LAKES OF MARTIN COUNTY

Three Remarkable Groups of Lakes. A glance at a map of Martin County shows three striking groups of lakes. These are known as the central, east, and west chains of lakes. A row of lakes extending along a definite line for many miles, but not connected, and related to no definite drainage system, at once challenges attention. It is something

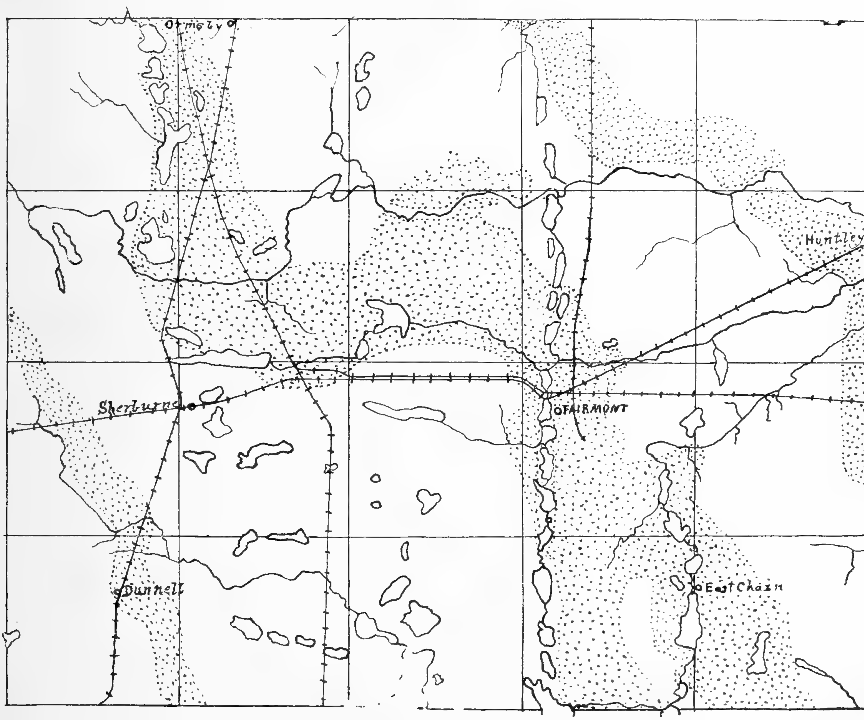


FIG. 107. Map Showing the Chains of Lakes in Martin County. *Drawn by F. W. Sardeson.*

more than accident that a great number of lakes should be thus set in rows upon the landscape. In the central chain there are 18 lakes within Martin County, varying in width from a quarter mile to a half mile or more, and in length from a half mile to a mile or more. The chain extends across the county, in a north-south direction. As may be seen from the map, these lakes are not definitely connected in a series by a stream. The east and west chains are not as definitely arranged in series as the central, but they are, nevertheless, fittingly called chains of lakes.

Chains of Lakes in Old River Valleys. The accompanying map, (figure 107) shows the lakes of Martin County as they were seen by Warren Upham and described by him in 1884.* Upham regarded these chains of lakes as notable features, which indeed they are. His idea was that the lakes lie in chains along river valleys that were formed before the last glacier crossed the country, and that the glacier partially filled the valleys forming chains of basins in the valleys.

The central chain of lakes lies along a valley-like depression part of which is not now a stream valley. All of it could have been a stream valley before the last glacier filled it. Clearly it was. In the east chain the lakes are not so definitely arranged in a series, yet clearly enough, this is another old valley site. The west chain is made up of several parallel short chains arranged crosswise as though in old valleys that were tributary to the old valley in which the central chain is located. The map shows the terminal moraines (dotted area) and the till-plain or ground moraine (plain area) as traced later by Leverett and Sardeson.

It is clear that there were three interglacial valleys. The streams that occupied these valleys probably flowed north to the Minnesota River or to its interglacial predecessor. The last glacier came up the Red River Valley and down the valley of the Minnesota and south as far as Des Moines. As this glacier melted back the ice still moved south although its front retreated north. The three moraines shown on the map (dotted areas) indicate three re-advances of the glacier's front while it was receding across Martin County. The center of the glacier's movement was over Blue Earth River, in Faribault County, to the east. Under these conditions the glacier would naturally force the new drainage in Martin County to the south. The small stream in the southwest corner of the county, near Dunnell, is the East Des Moines, and flows south. If there had been any glacial stream coming from the glacier's front here it would have gone necessarily south to the Des Moines from any part of Martin County. Such a stream would have filled its valley with sand and gravel, and would have established a permanent stream southward. But that did not happen.

Because there were no glacial rivers these chains of lakes remain in the partially filled old valleys. The streams, except the one in the southwest corner of the county, flow to the Blue Earth and the Minnesota, the natural slope of the county being from southwest to northeast.

*Geological Survey of Minnesota, Vol. I., p. 472.

New Drainage System Established. With a glacier moving from north to south a north-south valley would escape filling, while east-west valleys would fill up most with ground moraine. The surface over which the last glacier moved here was, no doubt, a prairie of gentle slope, with valleys as much as 100 feet deep eroded into its surface. The old landscape was the till of an older glacial deposit, the Kansan. This Old Gray drift, with the soil that mantled it, is seen in the cut banks of some of the lakes there now. The last glacier moved from north to south in the direction of the valley of the central chain of lakes. A ground moraine of boulder clay 30 to 40 feet thick accumulated over the surface, filling the cross-valleys but only half filling the north-south valleys. There was no outwash from glacial rivers to fill the basins, no streams to cut great channels southward. Hence when the glacier was gone the drainage turned toward the easiest course, which was northeastward toward the Minnesota.

The central chain overflows by four separate streams to the north and east, following the natural slope. If these streams had all concentrated into one from the head, or south, to the foot, or north end, there would probably have been stream enough to cut down the outlets and fill up the basins, so that no chain of lakes would have remained, but an ordinary river valley would have been formed, flowing north as the interglacial stream probably did. But the old valley was too much filled with drift. There thus remains a series of ponds with dams of drift piled across the old valley. The east and west chains are similarly old valleys in which ponds of water are held by the drift materials which were deposited in the valleys from the glacier, but which were not enough to entirely fill the valleys.

CHAPTER XXIV

THE BEGINNINGS OF MINNESOTA—THE RANGES

The Oldest Known Land. The oldest part of Minnesota of which we have any knowledge may be spoken of as the beginnings of it. Rocks that are literally older than the hills are those beginnings. Such rock formations are seen in what is usually called the Ranges of northeastern Minnesota. There they are at or near the surface of the ground. In other parts of the State they are more covered. At Minneapolis, they were struck in a deep well-boring at 2,050 feet depth or 1,200 feet below sea level. At St. Cloud they are at the surface and are the source of the St. Cloud building stone granites, at about 1,000 feet above sea level. In the Minnesota River valley they are seen at New Ulm, Granite Falls, Redwood Falls, Montevideo, and Ortonville, all at 800 to 1,000 feet above sea level. In fact the beginnings of Minnesota are so near the top that where they are not seen at the surface, they can nevertheless be found by the boring of wells anywhere in the State. If it were not for the covering of glacial drift from 1 to 500 feet thick, the greater part of the State would be seen to consist of those Ranges.

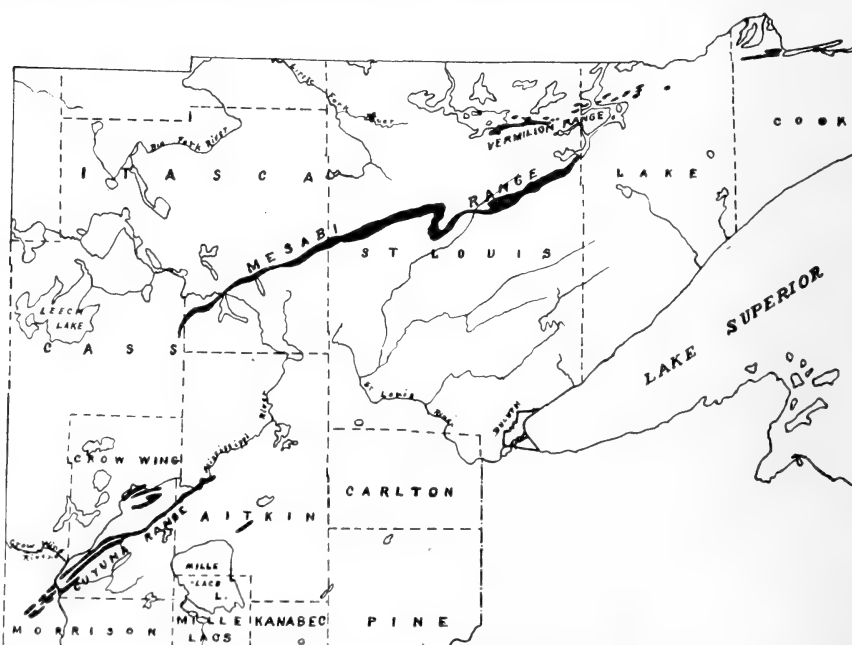


Fig. 108. Map of the Iron Ranges.

What would Minnesota look like if everything was removed from it except those "beginnings" that we call the Ranges? If the level beds of old sea deposits,—the Cambrian sandstones, the Ordovician sand—and limestones, the Silurian (if any), the Devonian limestones, and the Carboniferous beds, with the glacial drift over them,—were all removed, this would take away the level land and hills of southeastern Minnesota, and leave there a lake or a sea. The shore of that sea would run about along a line from Taylor's Falls to Elk River, Mankato, and Fairmont. From that shore, looking north and west, the land would rise 1,000 feet in a few miles, like an old mountain range,—which, in fact, it is. And beyond this old mountain range to the northwest would extend another great valley in which would be probably an arm of the sea covering northwestern Minnesota and much of the Dakotas. So much is known from what we can see at the surface and from well drilling.

The Iron and Copper Ranges. The "Ranges" are spoken of as the Copper Ranges and the Iron Ranges in northeastern Minnesota. The Copper Ranges are great flows of lava or what were lavas before they set into rock. This lava rock came up through fissures or breaks in the Iron Ranges and hence the Copper Ranges are known to be not as old as the Iron Ranges, although they are nearly as old. Dikes or breaks in the older rock that are filled with this lava are found even in the Minnesota Valley and it is easily understood that when these ranges were young mountains, there was great volcanic action all across central Minnesota from the northeast corner to the southwest corner. Only the largest of the volcanic rock masses lasted long enough to endure through the geologic ages till now.

The south Copper Range in Minnesota is mostly in Pine County and runs from there into Wisconsin, parallel to the south shore of Lake Superior. The north Copper Range is the height of land parallel to the north shore of Lake Superior, in northeastern Minnesota. Neither of these "Ranges" has produced much copper though they have invited the prospector at times, because they belong to the same system and class of rocks as those in Michigan that have produced copper in great quantity. The famous copper-bearing rocks of Keweenaw Point, Michigan, give name to all these rocks and to the age when they were in the making,—the Keweenawan.

The Iron Ranges of northeastern Minnesota lie to the west of the Copper Ranges. These are ranges in fact, being the bases or roots, so to say, of old mountain ranges. While we call them the beginnings of Minnesota, they contain evidences of clays, sands, and lime beds that must have been laid down horizontally in some sea there before the folding of them into ranges began. And those clay-sand-lime materials came from some still older land by weathering and washing into that sea. The clay has become slate or mica schist. The same process by which a boy makes an icy ball out of snow, makes, in a more gigantic way, hard rock out of soft rock in the folding and squeezing up of mountain ranges. Some of the rock thus squeezed appears to have become lava, by reason of great heat and pressure, and hence the Copper Ranges of lava rock breaking up through the Iron Range structures.

FIG. 109. Jasper Peak, One of the Highest Points in Minnesota. First Mine in Vermilion Range was Opened near the Tree in Center.

The three Iron Ranges in northeastern Minnesota,—the Vermilion, the Mesabi and the Cayuna Ranges,—trend northeast and southwest. There are other such ranges in the Northern Wisconsin and Upper Michigan region and they also trend northeast-southwest. North of Lake Superior in Canada, there are others. The Ranges in Minnesota are only part of what is called the Lake Superior Iron Region and that is only an extension or wing of the Labrador land mass,—the beginnings of the continent. The Ranges do not end in the Lake Superior region, or northeastern Minnesota, although their names end there. The old mountain ranges continue under deeper drift covering across the Minnesota River valley and even a few points of very hard rock are exposed under the Cretaceous formations and the glacial drift in the southwest corner of Minnesota in Rock County, and in the corner of South Dakota.

North of Lake Superior in Canada and in part of Cook and Lake Counties of Minnesota, the glaciers swept away all the soil and nearly all loose rock fragments. Copper or iron ore there could be seen at the surface if it existed. On the Iron Ranges there is some glacial drift to conceal the ores, until a little exploring is done, but under the drift the ore lies next, as a rule, where the ore bodies exist. To the southwest of the known iron-bearing ranges, the glacial drift is thicker, exploring is more difficult, mining would be too expensive, and not all is yet known. It may be that the best as well as the most of the iron ores are in the Iron Ranges proper, where the glaciers left some drift to cover them but not enough to put them out of easy reach. It seems so.

The workable iron ore deposits of the State, when marked on a common map, look like mere spots and specks, and the Iron Ranges, represented by the real iron ore deposits, would look like a ragged row of dots and bands on such a map. The proportion of good iron ore to the Ranges as a whole may be compared to the nails in a wooden house, and yet the name "Iron Ranges" is not intended to be a deception but only an abbreviation for iron-bearing ranges, or formations,—formations capable of producing from one-fourth to one-third of the iron ore output of the world.

Origin and Occurrence of Iron. If iron were as precious as gold or silver almost any farm in Minnesota would be a mine. Iron, however, is one of the ten most common elements in the earth. Earth or rock is called iron **ore** when the amount of it is large and the proportion of the iron in it is great. "Low grade" ore of iron means iron ore that is not "high grade" and also that which is below grade. A body of rocks in which there is either too little iron or too much of other minerals to be usable, is called low grade ore, generally, though it is only a near-ore. There is much more of "low grade ore" in the State than there is of iron ore proper.

Not only most rocks but also all living things contain some of the element, iron. What is called bog-ore is a residue of iron from plants that have decayed and dissolved away so as to leave a mass of iron rust. The common weed called the sting nettle leaves a bed of iron where it has grown year after year and decayed. The common forms of iron ore are the combinations of the metal iron with elements of the air and water,—iron carbonate, iron hydrate, and iron oxides.

If a hill or a mountain is dissolved away by rain soaking into it and through it for ages, so as to take out lime and other minerals that can be dissolved in water, the iron may remain, with some clay or sand, and become ore. The hill thus shrinks to relatively little and the iron ore in it is known as residuary ore.

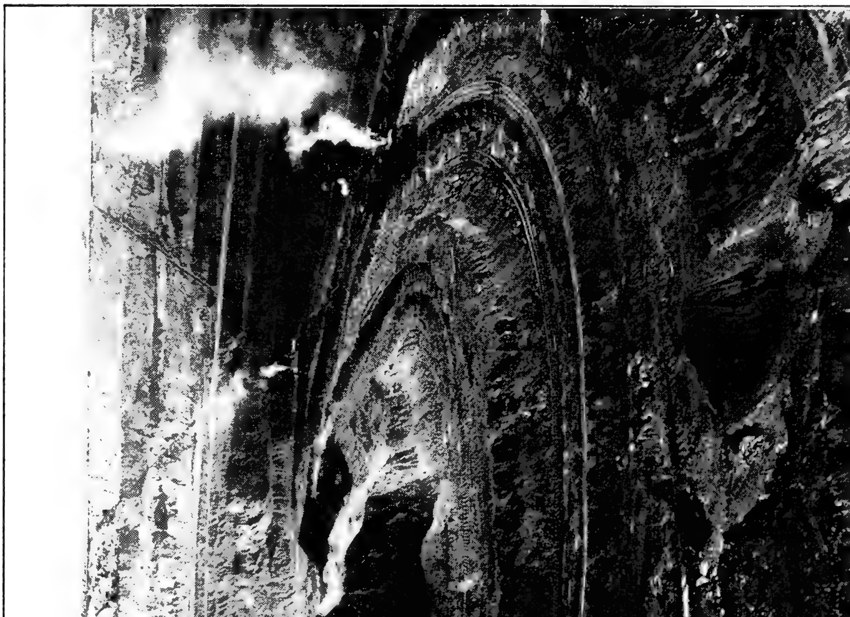


FIG. 110. The Shenango Mine. An Open Pit Mine on the Mesabi Range.

When water that contains a little iron, either from the decay of vegetable matter or from the oxidizing of minerals that contain iron, seeps through a mass of rock that is iron-bearing, the water may, and usually does, give up its little load of iron and comes out iron-free In that way the iron-bearing rock is "enriched" gradually to what is called iron ore.

In a great many places in Minnesota, on hillsides or near peat bogs, may be found residuary iron and enriched iron deposits that are "rich" enough for use as iron ore for smelting. There may be a ton or a few thousand tons of it in a place. That is not enough to be worth while to dig and ship, however. The cost of marketing is more than the market price of iron ore except for large mines that have machines for loading and are on railway trackage and within shipping distance of their particular market. A ton of the best iron ore is worth less than an ounce of gold.

Summary. The map shows the three Iron Ranges in northeastern Minnesota, the Vermilion, the Mesabi, and the Cayuna Ranges. This district of northeastern Minnesota is a part only of what is called the Lake Superior Region, which extends both south and north of the lake. There are other ranges in the north Wisconsin-Michigan region and some in Canada, all having the same general northeast to southwest trend and parts of the same great system. Those of Minnesota are the largest producers of iron. The Baraboo Range in southern Wisconsin belongs to this group of ranges and has produced some iron ore.

The Iron Ranges of Minnesota, Wisconsin, and Michigan are, as a whole, geologically, an extension or wing of the Labrador land mass,—the oldest of rock formations in North America. North of Lake Superior in Canada, and in Cook and Lake Counties, Minnesota, there is mainly bare crystalline rocks at the surface with boulders and pebbles with but little soil or glacial till. On the Iron Ranges, however, there is some till with soil in most places.

The Ranges do not end in the Lake Superior Region but extend, as a whole, to the southwest part of the State, though under an increasing cover of drift. Part of it is exposed in the Minnesota River valley where the drift has been cut through by the former outlet of glacial Lake Agassiz. There is a little of bare rock at the surface in the southwest corner of Minnesota and South Dakota, at Pipestone and Luverne, and Sioux Falls. Otherwise in that region there is Cretaceous formation, shales, and sands, between the drift and the "bed-rock."

The "Iron Ranges" means that the iron ore is found in what may be called the roots of old mountain ranges,—so old that they have been almost leveled off by weathering. The ore masses or bodies are not all quite alike and even expert geologists may not agree in any case as to just how and why an iron ore body is where it is or how it came to be just as it is, but the general manner of their forming is not disputed. There were real mountain ranges there with volcanoes and upfolded rock beds. The mountains weathered, leached, and washed off for geologic ages. The iron ore bodies are incidental to the life history of the ranges.

Last of all,—or nearly so,—glaciers came that tore away some of the iron ore and strewed pieces of it in the drift down across southern Minnesota and Iowa and buried the rest of it on the Ranges under a drift cover or sheet. The drift over the ore is now the ''stripping'' that has to be made for open pit mines.

CHAPTER XXV

CANNON FALLS AND RIVER

Location and Name. Cannon River rises in Shields Lake in Rice County. It flows at first west into LeSueur County as if going to the Minnesota. It reaches Gorman Lake and from there runs south to Tetonka Lake, and thence starts its course east by Waterville back into Rice County. It runs northeast through Sakata, Morristown, and Cannon Lakes across Rice County, and finally across Dakota and Goodhue Counties to the Mississippi River near the city of Red Wing.

In its upper course Cannon River can hardly be said to flow at all, or to "rise" anywhere. Shields Lake overflows and the water ponds its way from lake to lake west, south, east, and north, almost completing a circle. A few rods east of Shields Lake is Mazaska Lake which discharges northeasterly directly to Cannon River.

The chief branch of Cannon River, called Straight River, or Owatonna in the Dakota Indian language, is a very crooked meandering stream. It may have been named "Owatonna" in derision, as is claimed by historians, though it is said also on about as good authority to have been named for a Mr. Straight. Cannon River, however, was not named because it "shoots" so crooked from head to mouth, but by error. It was called Canoe River at its mouth, and the name was changed on maps incidentally, or accidentally, to Cannon. It might have been appropriately called Canyon River, as its valley from Red Wing up to Cannon Falls would warrant that name, as its valley in this part of its course is, in fact, a deep canyon having steep walls of limestone rock 400 feet high on either side.

Two River Systems Combined. Geologically Cannon River is made up of parts of more than one rival river system. Straight River formerly belonged to another system, and flowed into the Minnesota, and Little Cannon River was all the Cannon there was. The glacial invasions of Minnesota, which gave the many lakes to the landscape, also changed the direction of discharge of the river. Straight River formerly ran from above or south of Owatonna straight to where Cannon Lake now is, and thence northwest to the Minnesota. That was before the last invasion of the great ice sheet. Later when the ice still lay over the present valley of the Minnesota, and the present Cannon Valley had not yet been uncovered from the ice, Straight River flowed in the opposite direction, or south by Bixby and east of Blooming Prairie to the Cedar Valley.

At one time a stream from near Northfield ran upstream as directions now are to Cannon Lake. This was also before the last invasion of ice. The change in the direction of discharge, which was caused by the blocking of the valley by the drift deposited by the great ice sheet, is what caused the Cannon Falls to be formed.

The original Cannon was the Little Cannon. Little Cannon River

FIG. 111. Redwood Falls, Ramsey State Park. *Photograph by J. P. Wentling.*

heads near Nerstrand now, and runs by Cannon Falls city, where the big Cannon comes into control. During the long Tertiary time, which is the geologic period preceding the Quaternary or glacial period, when the Mississippi River valley was making, the Little Cannon likewise cut the great canyon-like Cannon Valley from Red Wing to Cannon Falls.

Valleys Filled with Drift and New Courses Established. At the time of the earliest glacial invasion of Minnesota all the Cannon Valley, and that of the Mississippi also down to a point below Red Wing, was covered by the glacier. All was left drift covered after the glacier disappeared. This region was probably invaded by ice twice, and each time the basin of Little Cannon was left drift covered, with many lakes and ponds, and intermittent streams. The springs that had issued from the limestone hills were buried underneath 50 to 200 feet of glacial till, and were dead. But drainage, such as it was, kept in the old course, and, given storms and floods, and time enough, the valley was bound to be washed clear again. The valley has been cleared of the old drift except on the tops of hills and divides and in a few of the branch valleys where stream action failed to follow the old lines.

In the interglacial interval, after the Kansan glaciation, there were two main branches of the stream, one, the Little Cannon as now, and the other the Chub Creek branch. This latter occupied a valley in the south part of Dakota County, not only where Chub Creek now runs, as far east as Randolph, but it continued its course to the north of Randolph, and north of the line of flat topped hills for 10 miles, and joined the Cannon where the southeast corner of Dakota County now is, about 5 miles east of Cannon Falls. (It should be borne in mind that there was no Cannon River at Randolph at that time.) Prairie Creek joined Chub Creek in Dakota County northeast of Randolph. All these streams were free from gravel terraces, such as occur along the valleys of these streams now, and the streams had eroded down into bed-rock.

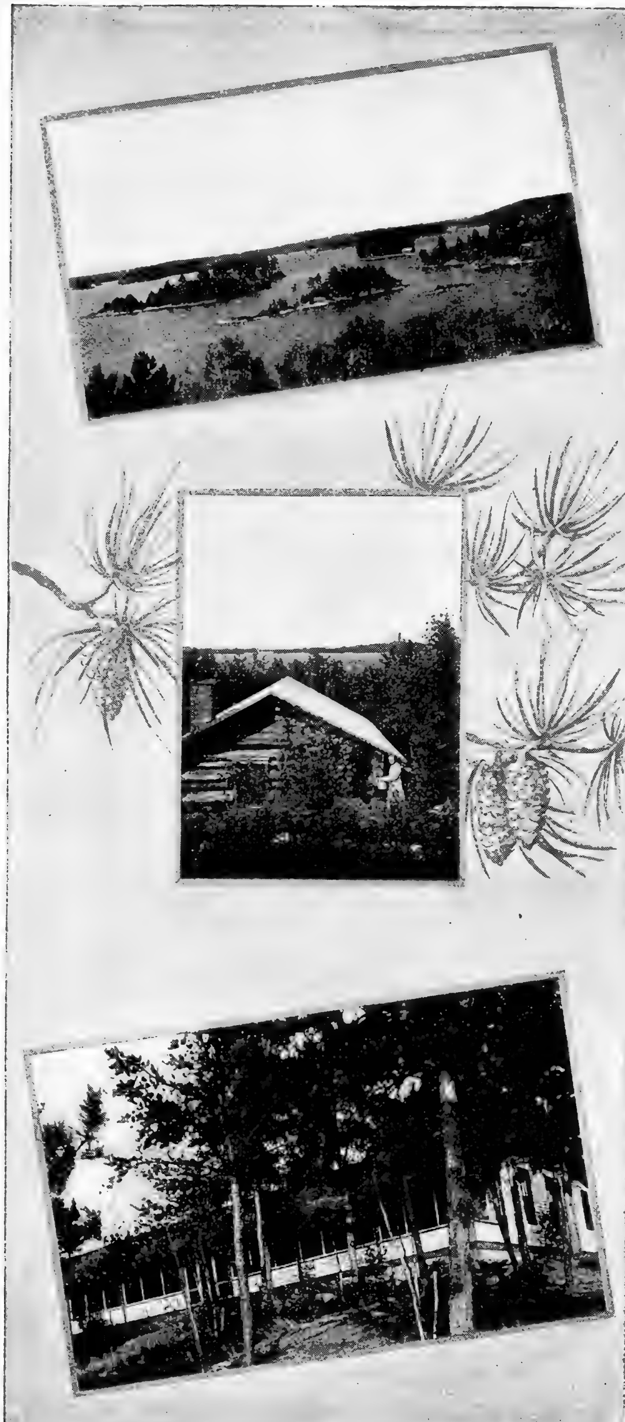
In the Illinoisan glacial stage, at the time when the glacier diverted the Mississippi for some distance across high land at Rock Island, Ill., and a glacial lobe across northern Wisconsin supplied flood waters and outwash of gravel to fill the Mississippi Valley from the St. Croix River downward, the Cannon Valley was back-watered at its mouth above the present level of the valley floor. The lobe of the Illinoisan glacier that came across Wisconsin crossed Dakota County just to the old Chub Creek valley below, or northeast of Randolph, and from its border it discharged floods of water with gravel that filled the valley (as can be now seen) so full that Chub Creek waters had to cut across from Randolph to Cannon Falls to escape. These great gravel deposits now form the broad, flat plain about Randolph. The Chub-Cannon line of drainage was probably not cleared of that Illinoisan gravel deposit enough for the streams to get to bed-rock again except across the old divide below (east of) Randolph. The valley there was widened by erosion during the long time until the coming of the glaciers again in the so-called Wisconsin stage.

Drainage Reversed and Falls Formed. Of the glaciers that came into Minnesota during the Wisconsin, or last stage of glaciation, the one from the north (Patrician) touched only the head of Chub Creek, and affected the Cannon Valley but little. But the glacier that came from northwest down the Minnesota Valley spread out east as far as Northfield, and sent floods of water from there down Cannon Valley. As that glacier's border receded and more water from it came down the Cannon, gravel terraces show that a large stream flowed from above Cannon Lake down to the Mississippi. This new stream made a rock rapids where it crossed the old divide where Northfield now is. (It will be recalled that a stream had formerly headed near the present Northfield and flowed west to Cannon Lake.)

At Cannon Falls the valley of the Little Cannon was filled with gravel and the stream back-watered. The waters escaped so close to the east wall of its valley that a new channel was formed across an old spur of the Shakopee limestone formation that had bordered the valley before the gravel filling was deposited. As the valley below was cleared of the gravel the Little Cannon Falls formed where the stream plunged over the limestone ledges at the spur. Likewise where the new and enlarged Cannon River came into the older Little Cannon Valley that stream formed a fall over the ledge of the Shakopee limestone.

There is now an electric power dam below the falls, which submerges both the fall of the old Little Cannon and that of the larger new or main Cannon, in an artificial lake.

Resume. It is thus seen that Cannon River has a somewhat complex history. The deep canyon from Cannon Falls to Red Wing was cut by the Little Cannon during Tertiary time. This was filled with drift during the glacial period, probably at two different times, only to be cleared out again by later erosion. The Little Cannon was originally fed by Chub Creek and Prairie Creek. A stream heading near Northfield flowed in the opposite direction, its course being reversed by drift which blocked its westward flow. Straight River, now the principal tributary of Cannon River, formerly flowed to the Minnesota, and for a time was compelled to discharge southward, or in opposite direction to its present direction. Finally after the ice of the last (Wisconsin) invasion had melted, waters from Shields Lake, as the modern Cannon River, pool their way west, south, east, and north, "upstream" of the original drainage, past Northfield and across the old divide between the old Straight and Little Cannon systems, and take possession of the old Little Cannon Valley.



1. Burntside Lake, Ely.
2. Camp Van Vac, Burntside Lake.
3. Burntside Lodge, Burntside Lake.

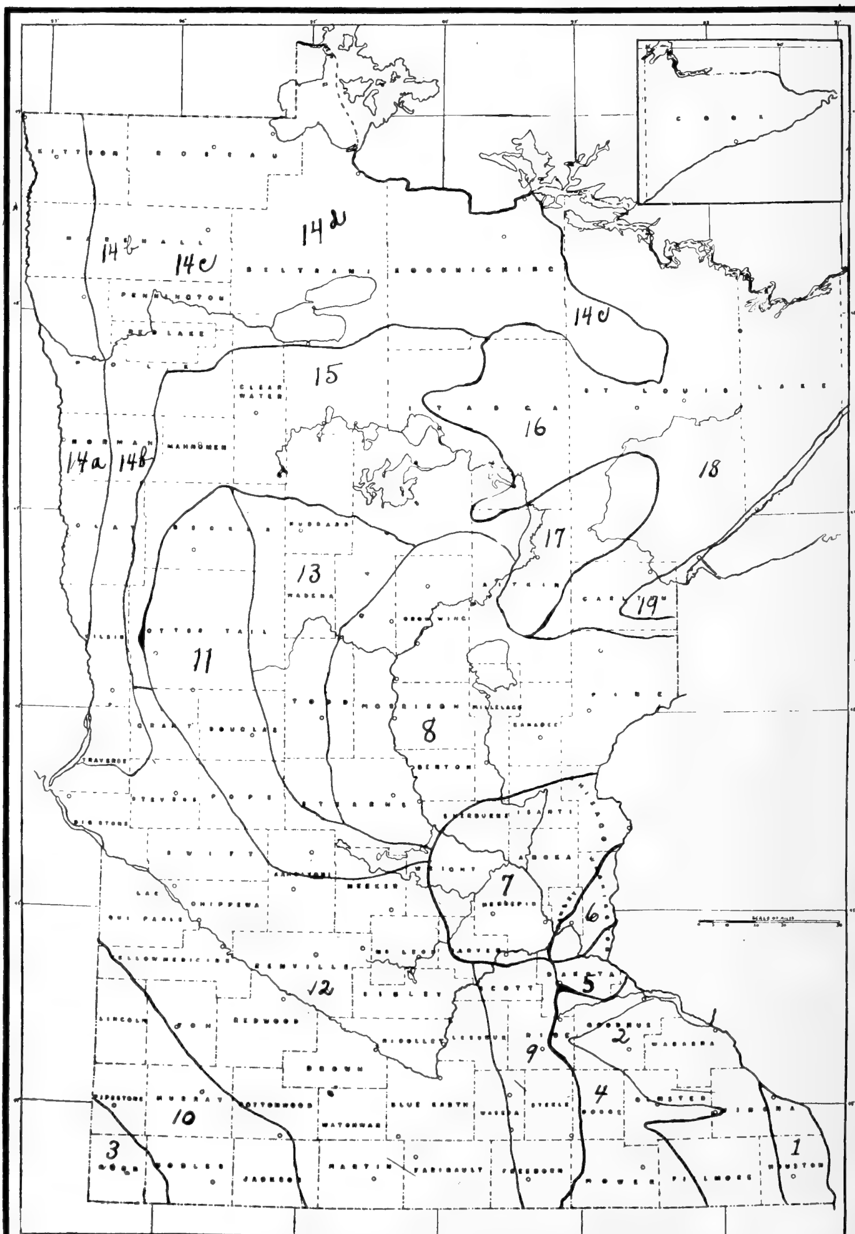


Fig. 112. Map of the Soil Districts.

CHAPTER XXVI

THE SOILS OF MINNESOTA

The Greatest Natural Resource. The greatest of Minnesota's natural resources is her soil. It is the one indestructible storehouse of the food supply for the present and future generations. Its fertility may be reduced but it cannot be destroyed. The term "worn out" as applied to soils is only relative. Mines may be exhausted; forests may be destroyed; soil, however, the source of plant food, cannot be destroyed. By proper management it may be ever renewed and rendered fertile. As long as the earth remains plants will grow.

Definition of Soil. Soil has been defined as that in which plants grow. It has also been defined as broken rock. A good soil has been defined as "rock dust, organic matter, and moisture, well mixed." Plants grow better in some soils than in others. Soils that are alike in richness or fertility may not be equally productive. Rich soils are sometimes unproductive. Other factors beside the chemical elements of the soil influence plant growth.

One of the most important things about soil is subsoil. Subsoil is the layer or zone of the loose-mantle covering of the earth that lies immediately below the soil, and on the one hand is of the same nature as the overlying soil except for changes that have been brought about by weathering, and on the other hand it is like the underlying rock or formation from which it has been formed. Subsoil differs from soil in that it lacks humus, or organic matter, it is less oxidized, and is more compact. Subsoil differs from soil in color, and may often be distinguished by this means. Soil is blackened by the presence of humus,—the charcoal of partially oxidized organic matter. Subsoil is yellow, brown, gray, red, or blue, due to the mineral substances of which the broken rock fragments are composed.

The character of the rocks or formation from which the subsoil has been formed determines the chemical elements that the soil as well as the subsoil may contain. Soluble elements are lost through surface erosion or leaching less generally by the subsoil than the soil.

Character of Minnesota Soils. Minnesota soils are naturally rich because they are made up of a mixture of many kinds of broken rock, with age-long accumulation of decayed organic matter. As has been stated, the character of the rocks determines the chemical elements that the soil may contain. About every kind of known rock has entered into the formation of Minnesota's soils.

The surface formation of the land area of nearly all of Minnesota is a glacial formation, a mixture of fine and coarser rock materials, transported, broken, and pulverized by glacier ice.

General Types of Glacial Soils. The greater part of all the glaciated land surface of Minnesota is what is known as till-plain or ground moraine, and is fairly uniform over wide areas. The formation from which the soils have been formed is till. This consists of clay, the finest of broken rock, silt or rock flour, sand, pebbles, and boulders. The surface has been oxidized by weathering agencies and blackened by the decay of vegetable matter. Many of the thousands of productive farms in Minnesota are tracts of till-plain. The subsoil differs from the soil

FIG. 113. Cut-Over Land Rapidly Becoming Farms, near Baudette.

chiefly in that it has been less leached of its soluble minerals, and contains less of humus or organic matter.

Next in extent and importance are the belts and ridges of terminal moraines. These, like the till-plains, are a direct deposit from the melting ice of the great glaciers. The morainic lands are more varied in character, though mostly clayey soils. The surface of the moraines is more uneven and rolling, with wet basins and lakes, though generally well drained because of the slopes. The soils of the terminal moraines are generally somewhat more porous than those of the till-plains and the moraines are more or less stony. Scattered among the morainic hills are many lakes, ponds, and sloughs. These are in hollows between the hills. Hills and hollows, or "knobs and kettles," are generally a pretty good indication of terminal moraines.

Outwash plains occur often, bordering terminal moraines. They were formed by waters flowing away from glaciers at the time when the moraines were being deposited from the melting ice. They are generally sandy and gravelly in character, but are never stony. There is, perhaps, no surface formation in the State that varies so greatly in character of soil and in agricultural value as the outwash plains.

Drift materials which were assorted and deposited by ponded glacial waters, known as lacustrine or lake deposits, make up another important class of glacial soils. The largest and most important area of this class of soils is that of the Red River Valley, or the bottom of

Fig. 114. Clover on Rolling Moraine in Otter Tail County.

glacial Lake Agassiz. This area lies in northwestern and northern Minnesota.

The soils of this class vary from the heaviest clay soils, deposited in the deeper waters of the lake, to the light sandy and gravelly types at and near the old shores. The lacustrine plains are flat, nearly level surfaces, and in places require artificial drainage for most successful farming. The lacustrine soils are among the most productive in the world.

A secondary effect of glaciation in determining the character of soils is that of the action of the wind in carrying fine particles of broken rock in the form of dust during the closing stages of the Glacial Period, and probably before a soil mantle had been formed. Such are the loess soils. The loess loams of the southeastern counties of the State, and also of the extreme southwestern corner, are dust of interglacial times that was blown off the deserts of the great southwest and lodged in the vegetation-covered hills of Minnesota, as also in Iowa and Illinois, and elsewhere. It is from 1 to 20 feet thick in Minnesota. It is without either pebbles or coarse sand. Of a character related to the loess deposits but of a somewhat different character are the wind-blown sandy tracts north of St. Paul in Anoka and Isanti Counties.

Soil Classification. Practically all soils are composed of sand and clay with a varying admixture of pebbles and larger rock fragments, to which has been added organic matter, called humus, from the decay of vegetal life. The texture of soils is determined by the proportions in which the sand and clay are mixed, and the system of classification is based on this fact.

At one end of the list of soil classes stands clay. Next in order is silt, which is rock ground to fine flour. Then follows sand, fine and coarser, and then gravel. Following this gradation in fineness of rock particles the classes of soils make up the following list: clay, clay loam, silt, silt loam, loam, sandy loam, and gravelly loam. Any one of the soil classes may contain a considerable amount of stone, in which case the word "stony" is prefixed, as stony clay loam, stony loam, and stony sandy loam.

The Term "Clay" as Applied to Soils. The finest grained soils in the world are called clays. Thus there is Fargo clay (Lake bottom or lacustine series); Marshall clay (Upland prairie series); Sioux clay (River-wash series); and many others. It should be clearly understood that the term clay as applied to soils means a clay **soil,** and not clay **rock.** A rock formation may be clay, in which case it is clay rock, not clay soil. The term clay as here used refers to clay soil, not clay rock. Rock is not soil. It is not "broken rock." Clay soil is very finely broken rock. It is rock reduced to the finest powder. Examined under the microscope the particles of clay are tiny "boulders" or fragments of minerals. Of the finest grains of clay as many as ten thousand placed side by side would extend one inch. Of the coarsest grains five thousand would extend one inch.

The term "clay loam" is often popularly used in describing soils when in fact the term loam or sandy loam should be used. A loam soil contains sand and clay in such proportions as to make a very satisfactory soil for cultivation. A sandy loam is somewhat lighter, but is generally a good farm soil. Clay loam, on the other hand, is a heavy soil, and often requires artificial drainage. The term "clayey" is used to indicate that the soil is dominated by clay rather than by sand. Soils are referred to as sandy when they contain more sand than clay, so that they would be regarded as "light" soils.

The Soils of the "Driftless Area." Into the southeastern corner of the State, embracing Houston and the eastern part of Winona Counties, the glaciers never came. This is a part of the "Driftless Area" of the upper Mississippi Valley. There is no till or other deposits of glaciers in this district. The bed-rock is a limestone formation and a residual clay soil has been formed from the weathering of this rock. A wind-blown silt loam known as loess caps the higher lands and covers the gentler slopes, and even cliff slopes where it has not washed away. Along the steeper valley sides limestone rock outcrops in many places, and there is no depth of soil or subsoil. Beneath the loess soil there is a deeper clay subsoil. The subsoil which immediately underlies the soil on the tops of the ridges and on the gentle slopes is of the same character as the soil except that it contains no humus and is less leached and oxidized. In the deeper and broader valleys alluvial or stream deposited soils and subsoils occur, much of which is not notably different from the loess soil.

Fig. 115. Loess-Covered Driftless Area near Caledonia.

Loess Soils of Southeastern Minnesota. West of the driftless area is a district embracing several counties which, like the driftless area, is well drained and has no lakes. It was, however, covered with a mantle of drift (till) during the earlier glacial invasions (Kansan and Nebraskan), this mantle being 20 to 40 feet in thickness in the western portion of the district and thinning to a mere scattering of pebbles and boulders on the eastern edge of the district. This drift deposit has been covered to a depth of 15 to 20 feet with wind blown loess. The deposit made by the ice has been eroded or washed away to a great extent, and it is not sufficient to entirely fill the old valleys. The present surface is that of an old, well-drained landscape having its valleys partly filled with drift, and the ridges capped and the slopes strewn with drift, and mostly overlaid with wind-blown loess. In the eastern portion of the district the residual clay under the loess was formed from the weathering and decay of the limestone bed-rock before the ice came and it is now only thinly covered with scattering drift pebbles. The wind-blown loess formation extends westward into eastern Goodhue, southwestern Wabasha, western Olmstead, northeastern Dodge, and central and western Fillmore. The loess formation is so heavy a deposit that the soils partake of the character of the loess rather than of the drift or the residual clay. The soil is a silt loam in texture, and is very productive. The loess soils are easily cultivated, free from stone, naturally porous so as to give good tilth to the soil, and it is generally rich in plant food. Southeastern Minnesota is noted for its productive farms. Its rank as a livestock and diversified farming section is very high.

Loess Soils of Southwestern Minnesota. In southwestern Minnesota there is an area of Old Gray drift which was not covered by the Young Gray drift of the later (Wisconsin) glaciation. It includes Rock County,

FIG. 116. Loess-Capped Hills in Pipestone County. *Photograph by J. P. Wentling.*

the southwestern part of Pipestone, and western Nobles Counties. Over this old drift there is a deposit of loess several feet in thickness. The soil, therefore, partakes of the nature of the loess rather than of the deeper till. It is a silt loam. The soils have been leached somewhat less than have the loess soils of southeastern Minnesota, due, probably, to the somewhat lighter rainfall and different climatic conditions. The soils of the southwestern part of the State, like the loess soils of the southeastern section, are very fertile, as the fine farms bear witness.

Soils of the Old Gray Drift. West of the southeastern loess covered area to a line extending from southwestern Dakota County through Rice County, and thence approximately along the eastern boundaries of Steele and Freeborn Counties to the Iowa State line, the surface formation is the deposit of Kansan drift, known as the Old Gray drift to

Fig. 117. Eroded Upland in Old Gray (Kansan) Drift Northeast of Zumbrota.

distinguish it from the Young Gray drift which covers it to the west, the latter being deposited during the later Wisconsin glaciation (Keewatin glacier).

This deposit is composed of clayey till. The subsoil is yellowish-brown in color to a depth approximately of 15 feet, but below this the deeper subsoil, which has not been oxidized, is bluish gray in color. The soil is dark due to humus or organic matter. The land is very fertile, and this district ranks among the finest farming sections in the world. The surface is drained toward the east, but the western part of the district is not dissected by streams to any considerable extent, as is the eastern part, and there are no lakes and no hills of noticeable size.

Soils of the Old Red Drift. A small district embracing central and eastern Dakota County, northern Goodhue, and southeastern Washington Counties possesses certain characteristics that are most readily explained by its geologic history. The land was covered by the ice of the Kansan invasion (Old Gray drift), as was the region to the south, just described. But it was later invaded by the Labradorian glacier of the Illinoisan invasion, which, because it came over the iron-bearing

FIG. 118. Plain of Old Gray Drift, East of Luverne. *Photograph by J. P. Wentling.*

regions to the north and east, deposited red drift. This deposit is known as the Old Red drift. As the Illinoisan invasion occurred later than the Kansan the Old Red drift was left over the Old Gray drift.

The deposit of red drift is not very deep, and it forms a covering only a few feet in depth over most of the district. The soil and subsoil have a distinctly red color, particularly in the more clayey portions, differing in this respect markedly from the yellowish brown of the Kansan drift, or the bluish gray, or, where oxidized, yellowish brown of the Young Gray drift (Keewatin).

The soil is very productive, being particularly well adapted to the growth of red clover. The glacier which deposited the surface formation came from a stony region, and there are therefore some quite stony tracts.

A prominent range of somewhat gravelly hills of this formation (Old Red drift) extends across southern Dakota County from west of Hampton southeast in a belt 2 miles wide, thence eastward into northern Goodhue County, and northward to Etter. This is a terminal moraine, and marks probably the farthest extent southward of the Illinoisan glacier.

Soils of the Young Red Drift. A district embracing a large part of Washington and Ramsey Counties, and the northern part of Dakota County, owes the nature of its soils to a drift deposit made by a glacier from the ice-field of old Patricia, lying north of Lake Superior, and spoken of as the Patrician glacier (see Chaper IV). The Patrician glacier left a red or pinkish red deposit from the Iron Ranges over which the ice passed. This is called the Young Red drift, as distinguished from the Old Red drift of the Illinoisan ice invasion.

FIG. 119. Moraine of Young Red Drift, near Stillwater. *Photograph by F. J. Alway.*

The red drift of the Patrician glacier was deposited over probably one-third of the entire State, extending west as far as central Wadena and Todd Counties, and southward beyond Minneapolis and St. Paul. A later invasion of ice from the northwest (Keewatin glacier), however, pushed across and left a deposit of gray drift over the red, except in the parts of the three counties referred to.

The soil of this district is loam and is somewhat stony in character due to the hard rocks brought by the Patrician glacier from the hard-rock region north of Lake Superior.

The red drift stony loam of this soil province is highly productive, being especially favorable for red clover and forage crops.

The moraines are quite rugged, the hills being of such size as to lend dignity to the landscape. The rolling hills of northern Dakota County and central Washington County and eastern Ramsey County are clayey in character. Outwash plains formed by the waters of the melting ice when the moraines were deposited cover considerable areas, and as these outwash plains are sandy in character the soil on these plains is a sandy loam. Central and northeastern Dakota County has a sandy loam soil, and similar sandy loam soils are north and west of St. Paul, and in southern and central Washington County.

Soils of the Red Drift Overlaid by Gray Drift. A district including a portion of northwestern Ramsey County and extending west of the Mississippi and Minnesota Rivers, and embracing Hennepin, northeastern Carver, and eastern and northern Wright Counties was covered by the Patrician glacier, and a heavy deposit of red drift was left, forming strongly rolling moraines. This district was overrun by the Grantsburg lobe of the great Keewatin glacier, and a thin covering of gray drift was laid down over the red drift. The hills were in some measure leveled by the later ice, and hollows were in part filled with gray drift. A considerable mixing of red and gray drift also occurred.

The soil of this region is derived more from the red drift than from the gray drift, but partakes of both. The red is a stony drift whereas the gray (Keewatin) drift is generally but slightly stony.

The soil of this province is very fertile. It is in places stony, and the outwash plains along the Mississippi and Minnesota Rivers are sandy. The variety in these soils makes a great diversity of crops and systems of farming possible. Corn, small fruits, clovers and grasses, and a wide range of garden crops are adapted to the soils in different localities.

The Grantsburg lobe of the Keewatin glacier, already referred to, moved eastward over the red drift deposits of the area just described to and a little beyond the eastern boundary of Chisago County and the State. On the east side of the Mississippi River the area covered by the Grantsburg lobe has been extensively blanketed by dune sand, which covers much of Sherburne, Isanti, and Anoka Counties, and extends to the St. Croix River in Chisago County. There are, however, morainic ridges and narrow till-plains standing in these areas of dune sand, most of these being composed largely of stony drift which the Keewatin ice gathered up from the Patrician (red) drift which it overrode. The dune sands are underlain generally by clayey Keewatin drift. In some cases the dunes have been piled onto moraines and sometimes onto till-plains. The occurrence of clay under the sand deposits adds greatly to the value of the lands for purposes of cultivation, since the clay serves to hold the ground water table nearer the surface.

Red Drift Soils of East Central Minnesota. The red Patrician drift is the formation from which the soils of east central Minnesota have been formed. Other glaciers invaded this region at earlier times and left their deposits, but the Patrician glacier deposited the drift which forms the surface covering, and therefore determined its soil character.

This soil district may be outlined as follows: From northwestern Wright County the western boundary of this soil province extends northwesterly across central Stearns County, a mile east of Cold Spring and 2 miles north of Richmond, to Albany and east of Sauk Lake, 4 miles west of Long Prairie and along the west line of the belt of morainic hills west of Lincoln, northward past Motley, including southern and eastern Cass County to Cyphers and Longville, to Swatara in Aitkin

FIG. 120. Red Drift Till-plain with Forest near Foley. *Photograph by F. J. Alway.*

County, south by Aitkin, thence east to southwestern Carlton County, where the drift of the Patrician glacier is covered by that of the Superior glacier. The southern boundary of the province extends from beyond the State line in Wisconsin across southern Pine County by Pine City, to Braham in Isanti County, and along the course of a small moraine into Mille Lacs County north of Princeton, thence approximately along the boundary of Sherburne County to St. Cloud, and southward to the northwest corner of Wright County. Within this great red drift soil province is therefore included all or nearly all of Benton, Morrison, Crow Wing, Pine, Kanabec, and Mille Lacs Counties, and nearly or quite one-half of Stearns, Cass, and Aitkin and parts of Todd, Wadena, and Hubbard Counties.

There are included in this great soil province three principal soil types, or three kinds of geologic formation which determine soil character. These are (a) terminal moraines, (b) ground moraines or till-plain, and (c) outwash plains.

The hills of the moraines are sandy in character, and therefore the prevailing soil type is sandy loam or loam. The hills are sometimes 75 feet in height, and there are many small lakes and sloughs. There is considerable stone in the drift, which gives rise to stony loam soil in some areas. The soil, as is generally the case on these red drift deposits, is very productive.

This land is a natural home of red clover, and these rugged hills make splendid farms when brought under cultivation. There are no more productive lands in the State, or in any State, when systems of farming to which these soils are adapted are used.

The most extensive and widespread of the deposits of the Patrician glacier, as of all the glaciers that entered Minnesota, is that of ground moraine or till-plain. A till-plain of splendid agricultural quality extends from Cushing and Randall southward to Flensburg and Swanville, Bowlus and Holdingsford, and southward toward St. Cloud. East of the Mississippi River the great till-plain extends from Brainerd south and east beyond Foley and Milaca, nearly to Princeton, thence north and east to the central part of Pine County. In this great till-plain is embraced southern Crow Wing and major parts of Morrison, Benton, Mille Lacs, Kanabec, and western Pine Counties. Another and similar till-plain lies east of Mille Lacs Lake, and embraces northeastern Mille Lacs, southern Aitkin, northwestern Pine, and southwestern Carlton Counties.

As has been said, this is fine agricultural land. It is the natural home of red clover. Corn, oats, clover, and cows will make this a leading agricultural district. The land was originally covered with a pine forest, and the first cost of clearing has held back the development of the territory. There is considerable stone in places. When the lands are improved there are none better for diversified farming. The soil is a reddish dark loam. The texture is such as to give fine tilth to the soil.

Loam Soils of Moraines in Southeastern Minnesota. A belt of terminal moraine from 15 to 30 miles in width extends from the Minnesota River in northern Scott County south to the State line. This soil province embraces much of Scott, Rice, Steele, Freeborn, eastern Waseca, and eastern LeSueur Counties. The moraines making up this belt were formed on the east side of the great Keewatin glacier. In Steele and Freeborn Counties belts of morainic hills are separated by intervening tracts of till-plain or ground moraine. Many lakes abound throughout the district. Several outwash plains having a sandy loam soil were formed by waters escaping from the melting ice during the time of the retreat of the last glacier.

The moraines are largely of clayey till. The till-plains have a dark loam soil. The rolling surface furnishes good drainage from the slopes. The drift from which the soil is derived represents a mixture of many rocks from the north, which were transported and pulverized by the great ice-plow. The region is a fertile one, and embraces many prosperous farms.

Soils of Moraines in Southwestern Minnesota. A series of well defined terminal moraines occurs in southwestern Minnesota. These moraines were formed on the west side of the great Keewatin glacier at the same time that the great morainic belt in southeastern Minnesota, just described, was formed on the east side of the glacier. The outermost of this series of moraines is called the Altamont moraine. Other moraines lie in generally parallel courses to the eastward, and represent successive halting places of the retreating glacier's edge.

The Altamont moraine follows the crest of the Coteau des Prairies across Lincoln, Pipestone, Murray, and Nobles Counties.

FIG. 121. Slope of the Coteau Des Prairies near Canby. Gray Drift Moraine.

East of this moraine, and west of the next later or younger moraine, is a till-plain which is narrow in Lincoln County but grows broader in Murray County, and in Nobles and Jackson Counties becomes about 30 miles in width. The morainic system east of this till-plain is very strong and complex. It is made up of numerous ridges or series of morainic hills. These are separated by narrow till-plains in places, and again merged in broadly extended rolling and hilly tracts. The ridges of this morainic belt all lie on the northeast slope of the Coteau des Prairies, so that the more eastern ones are always at lower altitudes than the western.

These moraines are composed largely of clayey till made up of the broken and ground up rock material carried by the ice. The soil is generally loam, and due to the variety of rocks entering into the composition of the soil it contains all the necessary plant foods. The till-plains have generally a dark and rich loam soil. Some hills are gravelly, and stones carried and deposited by the ice are quite common. The subsoil is clayey in character, which gives good water holding capacity to the soil.

West of the Altamont or outer moraine is a belt varying from 6 to 15 miles in width on which a thin deposit of drift was made by the Keewatin glacier. This deposit is so thin that the valleys which were formed on the old Kansan drift surface (Old Gray drift) were not entirely filled. The soil is thus a mixture of Old Gray drift (Kansan) and Young Gray drift (Keewatin). The region is comparatively well drained, the present streams following mostly lines of drainage that existed before the Keewatin glacier came, whereas east of the Altamont moraine the old lines of drainage are practically all filled and obliterated. West of the Altamont moraine wind drifted silt coats the till to a depth of a few inches. The subsoil is a clayey loam, and contains fewer stones than the subsoil in the moraines to the east.

Soils of the Lake Park Region. On the east side of the Keewatin glacier in central Minnesota was formed a very strongly marked morainic belt or system. This district is known as the Lake Park Region. This region embraces southern Becker, Otter Tail, northeastern Grant, Douglas, Pope, northeastern Swift, and northern Kandiyohi Counties. It is quite irregular in outline on its eastern or outer margin, and more simple and even on the inner or western side. In places this morainic tract is interspersed with till-plains or ground moraine and outwash plains. In northern Kandiyohi it embraces a belt of rolling hills 12 to 15 miles in width; in Otter Tail County, including outwash plains and ground moraine, it is nearly 50 miles across from east to west.

FIG. 122. Homestead on Clayey Moraine in Otter Tail County. *Photograph by F. J. Alway.*

The Lake Park Region of Minnesota is one of the most interesting scenic parts of the State, and of the North American continent. Its lakes and hills are magnificent. No finer example of terminal morainic topography exists anywhere.

On the eastern side of this great moraine the soil is sandy in character, and gravelly and stony knolls and ridges are common. Toward the west and south the soil has a more clayey character. The eastern side is marked by many outwash plains, formed by the waters that flowed away from the great melting glacier. On these sandy and gravelly plains the soil is light in character, and in places the soil is underlaid by deposits of gravel. The surface soil is often a dark or brown sandy loam, and when the subsoil is not too porous so as to allow too ready under drainage such lands are very productive.

On the west side the moraine is bordered by till-plains having a clayey subsoil. In the greater part of this territory the drift is of such a character as to develop a loam soil at the surface, and the subsoil is generally clayey in character.

South Central Minnesota. The broad valley which, in a general way, embraces south central Minnesota formed the main path for the southward movement of the great Keewatin glacier. The region here considered embraces the great undulating plain that extends west of Albert Lea, Waseca, Waterville, Montgomery, Jordan, Hutchinson, and Willmar on the east side of the broad valley approximately to

Jackson, Windom, Tracy, Marshall, and Gary on the west. This great undulating plain includes on the north side of the Minnesota River much of Nicollet, Sibley, McLeod, Renville, Kandiyohi, Chippewa, Swift, Stevens, and Big Stone Counties, and on the south of Minnesota River the western portions of Freeborn, Waseca, LeSueur, Faribault, Blue Earth, Martin, Watonwan, Brown, Cottonwood, Redwood, Lyon, and Yellow Medicine Counties.

The axis of movement of the Keewatin glacier was along the present Minnesota Valley near Appleton in Swift County to the great bend of the Minnesota at Mankato, and south to Des Moines, Iowa. The broad plain rises gradually on either side of the river toward the inner border of the moraines that were formed on the eastern and western sides of the glacier.

On this plain a few moraines were developed, which mark successive positions of the ice border as it was melting back from the vicinity of

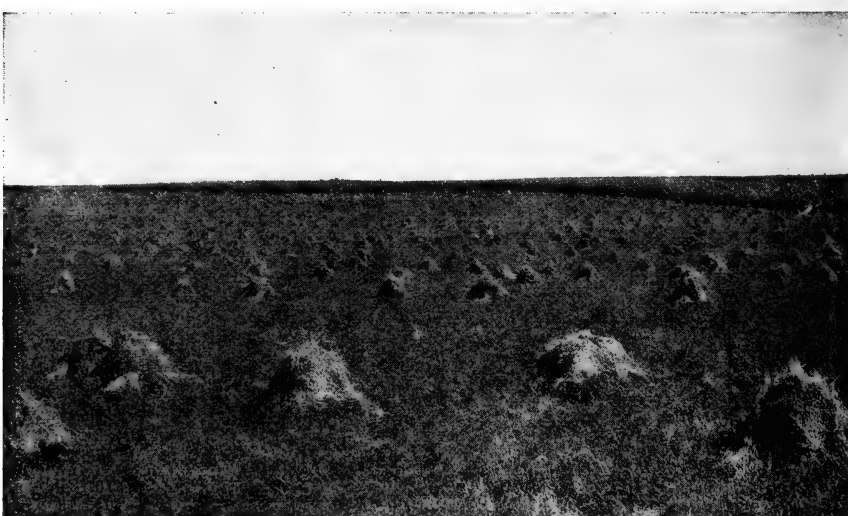


FIG. 123. Oats and Corn on Clayey Moraine in Otter Tail County. *Photograph by F. J. Alway.*

Mankato to the head of the Minnesota Valley. This great plain is largely prairie, and the soil is a rich black loam on its level portions, and a brown or chocolate colored loam on the morainic ridges.

As the glacier receded or melted away waters were ponded along the edge of the ice. A result of this ponding was a deposition of silt over the till to a depth of a few inches. The ponding was so short-lived that beaches or definite shore-lines were not developed. This surface deposit of silt adds a fine-grained quality to the soil.

Extensive outwash plains of fine sandy gravel were developed just outside of the moraine in southeastern Stevens, southwestern Pope, and northwestern Swift Counties, and also in southern Big Stone County. The soil of these outwash plains is generally a sandy loam.

Between this moraine and the shore of Lake Agassiz there is an extensive till-plain covering much of Stevens and Big Stone Counties, and part of Grant and Otter Tail Counties. The greater part of this plain is clayey till having a dark loam soil. The surface is gently rolling or undulating, with numerous small lakes or depressions. Strips of gravelly and sandy soil, formed from the deposits of glacial streams, occur along the Pomme de Terre and Chippewa Valleys. A sandy outwash plain of considerable extent having a sandy loam soil spreads from southeastern Stevens County east and south to Pope and Swift Counties, the city of Benson being on this plain. An outwash plain extends across southern Big Stone County from about Odessa eastward to Appleton and beyond.

FIG. 124. Red Drift Till-plain near Foley. *Photograph by F. J. Alway.*

Gray and Red Drift Soils of Central Minnesota. Lying east of the Lake Park Region and west of the great red drift moraine in western Stearns and Todd Counties is a region of considerable variety of soils. For the most part the soil characters are determined by the gray drift of the Keewatin glacier, but in places there is considerable admixture of red drift deposited by the Patrician glacier, from the northeast.

This region is marked by well defined moraines, by smooth even till-plains, and by sandy and gravelly outwash plains. This region includes some of the finest farming lands in the State. There are extensive tracts that are not yet developed, and much good land remains to be improved. There are some stony tracts, and there are soils that are light and sandy.

The central portion of this province is mostly a smooth, gently rolling or undulating till-plain, though it is interrupted by quite abrupt morainic ridges. The soil is a dark loam. The surface till, from which the soils are derived, is gray (Keewatin) drift. A belt from 8 to 15 miles in width extending from Poplar and Ellis in Cass County south and west to Bertha, Eagle Bend, Clarissa, and Browerville, and southward to Little Sauk and West Union in Todd County, has red (Patrician) drift mixed with gray (Keewatin). There is considerable stone in places, derived largely from the red drift. The soil is a splendid rich loam.

A marked feature of this province is the outwash plains. These were formed by waters escaping from the melting glaciers. Some are sandy and gravelly. On some there is such an admixture of clay and silt with the sands and gravels as to give good quality to the soils. In some places these plains have a rich covering of black or dark loam. In other places the surface soil is a loose sand or gravel.

A large outwash plain extends from north of Glenwood and Villard south and east past Brooten to New London and Paynesville. This plain is generally sandy, and the soil is mainly a sandy loam. The surface is undulating with frequent lakes. Another and smaller outwash plain extends north and east from Alexandria. This is a sandy and gravelly plain, quite uneven in its surface, with a group of magnificent lakes occupying the larger and deeper depressions. About Parker's Prairie in southeastern Otter Tail County is an extensive outwash plain which reaches north and east into Wadena County, where it merges with the large outwash plain that covers a large part of Wadena County and the southern part of Hubbard County.

About Parker's Prairie and northward the plain is uneven of surface and frequent lakes occupy the deeper hollows. The occurrence of many lakes in the basins on these sandy plains indicates that the groundwater table is not far below the surface, and this evident fact accounts for the successful agriculture that is practiced on this, and other similar plains. This outwash plain continues northward, as stated, covering southern Hubbard County, and extending also into Cass and Becker Counties. The part of this plain lying in southern Hubbard and southern Wadena Counties was overridden by the ice after the formation of the plain, and clayey till was thus spread over portions of it. This adds greatly to the productiveness of the soil. The portion of the plain extending west of Park Rapids into Becker County has a sandy loam soil, and many lakes in the depressions.

A glacial lake occupied central Meeker County. Lake sediments consisting of sand, silt, and clay occur in the region from Manannah to Forest City and Kingston. Sandy outwash was deposited along valleys leading into the glacial lake from west of Manannah. At Litchfield and Darwin is a sandy outwash plain that was formed by the waters escaping northward into the lake from the ice which formed the moraine that lies across southern Meeker County.

This glacial lake discharged northward through a broad channel past Eden Valley to the Sauk Valley at Richmond, and thence to the Mississippi. This old valley is now a flat marsh south of Eden Valley, and a gravelly and sandy plain extends below (north) on which a chain of lakes now lies.

The moraines as well as the till-plains in Meeker County are very largely of clayey till, from which a loam soil has developed. The sediments of the glacial lake above noted are of fine sand on the edge, but are a rich silt loam in the deeper part between Forest City and Kingston. The outwash plains have in places a loam soil and subsoil. A considerable part of the outwash, however, has a light sandy loam soil.

The Lake Agassiz Plain. A vast region in northwestern and northern Minnesota is embraced in the region that was covered by the waters of glacial Lake Agassiz. The five counties of Red Lake, Pennington, Marshall, Kittson, and Roseau are entirely included in this area, and portions of the following 12 counties were covered by its waters: Traverse, Stevens, Grant, Otter Tail, Wilkin, Clay, Norman, Polk, Clearwater, Beltrami, Koochiching, and St. Louis.

There are four types or classes of soils formed from the lake deposits. These soil classes occupy somewhat irregular areas of the great lake bottom. The four classes or types are: (a) lacustrine or lake clay soils, formed from the fine sediments deposited in the deeper waters of the lake; (b) sandy soils formed from washed and assorted sediments in the shallower parts of the lake along and near the shores; (c) soils formed from lake-washed till on which only a thin deposit of lake sediments was made, and (d) swamp, including deep peat and muck.

Lacustrine Soils Formed from Deep Water Sediments. The axial portion of the Red River Valley in Minnesota embraces a belt extending east from the Red River of the North from 16 to 18 miles. In this portion of the lake the finer sediments were deposited. The soil in this district is a heavy clay or clay loam. This belt of finer sediments merges into a sandy belt on the east or shore side of the lake bottom.

This great lake bottom tract, including a similar belt lying west of the Red River of the North in North Dakota, and continuing also into Canada, is one of the largest bodies of so nearly level land in the world. It is a region remarkable for its fertility.

The soil is dark due to the presence of organic matter that has gathered in the soil since the disappearance of the lake. Except for occasional patches of boulders, which were either dropped directly from the melting ice of the glacier or were carried by floating ice on the lake and dropped as the ice melted, the area is nearly free from stones. On many fields scarcely a pebble can be found.

Sandy Soils of the Shallow Waters. The lake-washed sand region of the Red River Valley extends from northern Wilkin County northward to the international boundary, bordering the east side of the heavy clay region. In northern Polk County the shore of Lake Agassiz bears abruptly to the east. The belt of lake-washed sand, however, continues northward in an irregular belt to the international boundary. In central Polk, western Red Lake, western Pennington, and central Marshall Counties sandy and gravelly beach ridges are numerous, and between these ridges the soil is clayey in large part.

The lake-washed sand was deposited, in part, from materials brought into the lake by streams and in part from materials that came directly from the melting ice. It is, therefore, in part of glacial origin and in part lake sediments. The soil is usually a light, sandy loam. In places the sand is so thin that boulders left by the ice are only partly covered. There are also areas of sand and gravel extending to a depth of 3 to 5 feet or more. Portions of this lake-sand area have been mapped by the U. S. Bureau of Soils and classed as Fargo fine sandy loam.

Soils from Lake-washed Till. A considerable area of lake-washed clayey till occurs in Polk, Red Lake, Pennington, Marshall, and Roseau Counties. Interspersed throughout this district are also areas of lake-washed sandy till, swamp, muck, and peat, lake sand, and heavy lacustrine clay, as also beach ridges of sand and gravel and wave-eroded moraines. So, also, there are irregular areas of all of these types of soil distributed throughout the great swamp which extends from the counties mentioned eastward across Beltrami and Koochiching Counties.

The soils that have been derived from the lake-washed clayey till are generally loams, varying from heavy clay loam through the series clay loam, silt loam, loam, fine sandy loam, sandy loam, gravelly loam, and stony loam, and all generally with a clay subsoil.

An area of lake-washed sandy till extends from north central Marshall County into southwestern Roseau County. Another area occurs east of Twin Valley in Norman County; another south of Syre and west of Ulen, in Norman and Clay Counties; another south and east of Barnesville and west of Lawndale and Rothsay, in Clay and Wilkin

Counties; one east of Shirley and Euclid, in Polk County, is crossed by well-defined sandy and gravelly beach ridges. Other areas of this character occur in central and eastern Kittson County.

A lake-washed moraine extends across Red Lake and Marshall Counties west of Red Lake and Thief Rivers from south of Thief River

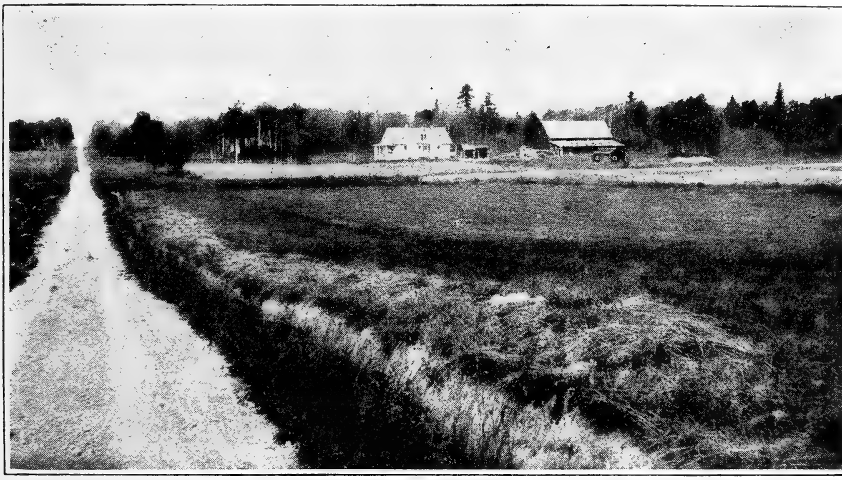


FIG. 125. Farm on Clayey Keewatin Drift East of Cook.

Falls to Thief Lake. It is from 1 to 3 miles in width. It rises above the general level of the lake bottom plain only a few feet. These glacial deposits are of pebbly clay. Low swells 3 to 5 feet high occur, some of which can be observed in the city of Thief River Falls. The soil of the moraine is clayey loam similar to that of the lake-washed till-plains adjacent.

In southeastern Roseau and northern Beltrami Counties are very large and broad sandy and gravelly beach-like deposits which were large sand-bars in Lake Agassiz. They are composed of sandy and gravelly glacial deposits which reached nearly or quite to the surface of the water of the lake. They represent an eastward continuation of the lake-washed moraine that crosses Marshall, Pennington, and Red Lake Counties. The waves of the lake passed entirely over them so that they were smoothed and leveled down a good deal, and as the lake lowered they became for a time islands in the lake. The higher portions were covered by beach sands and gravel, and lake sand was deposited between their higher portions. The soils are sandy and gravelly loams.

Boulders sometimes occur in considerable numbers on the lake-washed till-plain. Their explanation is not entirely clear. They were transported by the ice, and may represent moraines the finer materials of which have been washed away by the waves of the lake. Such boulder

FIG. 126. Clover on Lake-washed Till South of Baudette and Spooner.

plains are unusually noticeable in Kittson County north of Orleans; between Hemmington and Caribou; and north of Pelan. In these areas the boulders are strewn upon the lake-washed till-plain, and indicate that they were deposited by the ice. Boulders are very numerous also on the sandy plain from Bronson south and east past Halma to the county line, a rare feature on so sandy soil. The presence of the boulders indicates that the sand may be largely a deposit made directly from the ice of the glacier, rather than borne in by the waves and currents of the lake.

Soils of the Swamp Area. Clayey lake-washed till and swamp make up the greater part of the ancient lake bottom eastward from Red Lake, Marshall, Pennington, and Roseau Counties. The ancient lake extended across Beltrami and Koochiching Counties as far as Vermilion Lake in St. Louis County. The southern shore line is a little south of Lower Red Lake. The farthest eastern point of the lake was 10 miles west of Tower, south of Vermilion Lake. From this point the shore extended northwest to the international boundary a little east of International Falls.

The highest shore line of Lake Agassiz is marked generally by a well-defined gravel ridge or beach. Numerous gravelly and sandy beaches were developed at lower levels, some of which appear as narrow strips of dry land traversing the extensive swamps.

A considerable part of this great eastern expanse of the lake is now a flat swamp, though much interrupted by islands and strips of dry land having a clayey soil derived from lake-washed till. A large area in northern Beltrami and central Koochiching Counties is known as the Beltrami Swamp, in reality a vast muskeg. The region was covered by the shallow waters of Lake Agassiz, and so uniformly flat is the plain of this part of the old lake bottom that the growth of vegetation has resulted in the formation of extensive peat bogs and muck deposits. Underneath the swamp is the clayey till deposited by the ice.

North of Red Lake is the highest part of the swamp, and it was thought at one time to have been an island in the lake, and was referred to as Beltrami Island. Lake-washed sands, however, cover the highest portions, showing that it was covered by the shallow waters of the lake. Between Upper and Lower Red Lake is a sandy moraine which was an island in Lake Agassiz.

In northern Koochiching County several moraines formed islands in the lake. North of Big Falls the Minnesota and International Railway crosses a moraine which extends southeast into St. Louis County. The part crossed by the railroad was an island in the lake.

Much of the swamp land in this part of the State will become drained without artificial ditches as soon as the natural water courses are cleared of obstructions, such as fallen trees, stumps, and beaver dams. In fact, much land that has been classed as swamp is not swamp at all, but on account of the extensive growth of brush, and of the general inaccessibility of the region, accurate information has not been available.

Soils of North Central Minnesota. An extensive soil province in north central Minnesota extends from the eastern shore line of Lake Agassiz in Clay, Norman, and Polk Counties, eastward to include northern Cass, western Itasca, and southweastern Koochiching Counties, lying south of Lower Red Lake and extending into northern Becker and Hubbard Counties. This province is quite abruptly separated from the ancient lake bottom to the west and north by the Herman beach, which is generally a well-defined sandy ridge.

In this district are three great types of glacial deposits, and consequently three general classes of soils. These are: (a) moraines; (b) till-plains, or ground moraine; and (c) outwash plains.

From Shell Lake and Ponsford, and the height of land in Becker County, eastward across southern Hubbard County, past Park Rapids and Latona nearly to Hackensack, is a large outwash plain. This outwash extends south in Wadena County into the Crow Wing Valley, and southwest to Parker's Prairie in Otter Tail County. South of Fish Hook Lake, Lake Arago, and the Great Northern Railway from

FIG. 127. Gray Drift Till-plain in Mahnomen County. *Photograph by F. J. Alway.*

Park Rapids to Nevis and Akeley, the sandy morainic hills were partially leveled by the outflowing ice waters, forming a rolling plain of gravelly and sandy outwash.

South of the moraine that crosses southern Beltrami County, south of Puposky and north of Turtle River is another outwash plain. This sandy plain is interrupted by tracts of till-plain or ground moraine which are clayey in character. A small but well-defined moraine occurs 4 miles west of Bemidji. The outwash plain extends to Bagley, Shevlin, and Leonard on the west, past Turtle River, Bemidji, and Cass Lake, and to the south of and beyond Lake Winnibigoshish.

The soils of this plain are generally light, and in places are blown into dunes. The intervening till-plains, notably east and south and west of Bemidji, are of splendid clayey quality, and have an excellent loam soil.

A till-plain having a clayey loam soil of good quality, interspersed with clayey morainic ridges and blocked channels containing swamps, extends south of Bagley, in Clearwater County, east across southern Beltrami and northern Hubbard Counties, by Nary and Guthrie, to and beyond Leach Lake, to Boy River and Remer, in Cass County.

Another till-plain lies south of Red Lake, embracing the territory from the vicinity of Island Lake and Nebish south and east to Puposky and Tenstrike. Another till-plain lies north of Lake Winnibigoshish.

The soils of the till-plains are loams of fine quality. The subsoil is generally of a clayey character, and gives good water holding quality to the soil.

From the Great Northern Railway at Gonvick, in Clearwater County, south and west, is a broadly rolling till-plain of excellent soil, better drained locally than the flat lands of the Red River Valley, and having a soil of equal fertility, though somewhat more diversified in character, and having frequent lakes and many undrained depressions.

Between these till-plains, and bordering the outwash plains, are hilly tracts of terminal moraine, with many lakes occupying hollows among the hills. A large moraine extends across the south side of this province, from northeastern Becker County to and beyond Leech Lake. The moraines are frequently stony, boulders strewing the surfaces of the hills and slopes. The soils of these moraines are generally sandy, though south of Leech Lake, and west of La Porte and Lake Kibekona, the soils are clayey in character, and are very productive.

Overridden Moraines of Itasca County and the Iron Ranges. In central Itasca County is an extensive belt of moraines composed, in the main, of Patrician (red) drift, and containing many boulders. This region was, however, covered by the ice of the Keewatin glacier from the northwest, and a thin covering of gray drift was deposited by it over the red drift. The ruggedness of the hills was toned down a good deal by the later incursion of ice. There are many lakes, and practically no drainage streams have been developed since the ice disappeared.

The soils are generally loams, varying from the heavier clay loams to sandy and gravelly loam. There are several outwash plains composed of sand and gravel, and many swamps occupying basins in partially filled water-courses that were blocked by the drift.

Quite an extensive outwash plain extends from 10 miles west of Grand Rapids north through the center of the county. It has many hollows that are occupied by lakes. Another outwash plain extends south from Jesse Lake to the east of Bow String Lake. Another is in the northeast part of the county at the headwaters of Bear River.

In the eastern part of Itasca County, and extending into St. Louis County between the Mesabi and Vermilion Ranges, is a gently rolling till-plain. Between Grand Rapids and Chisholm, and northward, the soil is generally good, but it is stony and rough in places, and sloughs and swamps are of frequent occurrence. Between the Vermilion and Mesabi Ranges are sandy moraines, steep and rugged, with many boulders.

From Chisholm and Hibbing eastward to Iron Junction, Sparta, and Aurora is a fairly flat till-plain having good loam soil and comparatively few stones. A similar till-plain having good soil varying from clayey loam to loam, with occasional patches of sandy and gravelly loam, extends northeast and southwest from east of the Duluth & Iron Range Railroad at Norman, Bassett, and Hornby southwest to the St. Louis River at Brookston.

Two Ancient Lake Bottoms. A considerable part of north central Aitkin County was occupied by the waters of glacial lake Aitkin, and this fact explains many of the soil features of this region. This lake was caused by a ponding of glacial waters, and a broad sandy and silty plain resulted. The shore line of this lake was very irregular as

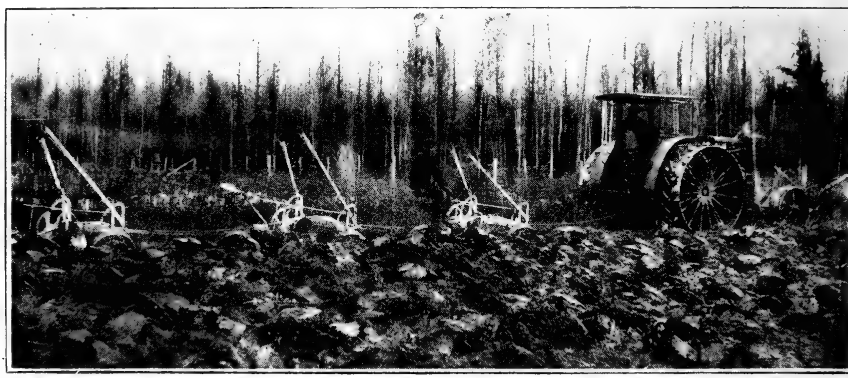


FIG. 128. Breaking New Land on Clayey Soil of Glacial Lake Bottom, Meadowlands.

the lake plain is surrounded, in a general way, by moraines, and the moraines formed headlands on the shores and islands in the lake. Much of the deeper part of the lake is now a swamp. The Mississippi River meanders across the old lake bed, and a deposit of fine sand borders this and other streams that cross the old bottom. Till-plains having a fine sandy soil form islands on the old lake bottom. Gravelly and sandy beaches extend around the irregular shore and around many of the islands.

South of this ancient lake bottom are broad stretches of till-plain interspersed with shallow muskeg swamps and sharp morainic ridges. The knolls and ridges of the moraines are composed of gravel and sand and stony till. The surface of the moraines is often strewn with boulders. The level and gently undulating till-plains which separate the moraines have a productive loam soil.

North and east of the bed of glacial Lake Aitkin, in northeastern Aitkin and southwestern St. Louis Counties, is another flat plain which is in considerable part occupied by muskeg swamp, the bottom of glacial

Lake Upham. The plain of Lake Upham is crossed by Floodwood, St. Louis, Swan, and Whiteface Rivers. The ancient lake had its outlet by the present valley of the St. Louis, and was drained by the cutting down of the outlet by this stream through the moraine at Mirbat below Floodwood.

FIG. 129. Dairy Herd at Meadowlands Farm.

Along the streams which cross this ancient lake plain are deposits of clay, sand, and silt. Muck and peat underlaid with clay, occupy much of the flat portions of the ancient lake.

The Northeastern Counties. A considerable part of Cook, Lake, and St. Louis Counties is too rough and rocky to be of much value for general agriculture under present day conditions. In time, as the demand for land becomes greater, districts that are now regarded as of no value for agriculture will be regarded more highly.

It would probably be a wise policy if these lands could be devoted systematically to forest purposes for a few generations.

A tract extending across northern Cook, Lake, and St. Louis Counties is mainly barren rock from which nearly every vestige of soil was swept southward by the Patrician glacier from the north. For a distance of 30 to 35 miles south from the Canadian boundary, or as far south as Pelican, Vermilion, and Birch Lakes, in St. Louis County, and about 6 miles south of Bald Eagle and Parent Lakes, in Lake County, the drift is very scanty on the hills and ridges. The Mesabi Range is mostly thinly coated with drift, though the south slope and the portion west of Chisholm is more heavily covered with drift.

The northern part of Lake County is a very broken district, with rock knobs among which are lakes and swamps. There is very little land that is suited to agriculture. The greater part of this rocky area is included in the Superior National Forest.

Rough 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 about 14 per cent. Of the remaining one-third a considerable part is stony loam, with many cobbles and boulders in the soil and on the surface.

Bare rock, or rock with a very scanty covering of drift, occupies about one-third of the area of Cook County, mainly in the National Forest, in the northern part of the county. There is also a strip of rugged land known as Sawtooth Mountains which lies near the Lake Superior shore, west from Grand Marais. The combined areas of rocky

FIG. 130. Field of Oats on Keewatin Till-plain in St. Louis County. *Photograph by F. J. Alway.*

land, swamp, and lakes in Cook County embrace about 60 per cent of the surface. Of the remainder much is very stony and difficult to clear. Much of the land would probably be advantageously devoted to forest purposes.

The moraines, which extend in a northeast-southwest direction through the southern part of the county, have generally rough surfaces, with sharp knolls including small swamps. The till-plains, however, which occupy a much greater area than the moraines, and which lie in belts extending northeast and southwest through the county, are gently undulating with slopes easy to cultivate.

The prevailing type of soil in the morainic areas and on the till-plains in Cook, Lake, and St. Louis Counties is stony loam. When these stony lands are improved they are generally very productive. The finer particles of which the soils are composed have come from the

FIG. 131. Section in a Gravelly Outwash Plain in Lake County.

wearing and grinding of the hard rocks, and there has been little leaching or washing since the ice melted off from the landscape to carry away the soluble mineral elements from the soil.

The Lake Superior Clay. Bordering Lake Superior is a belt of lake-formed deposits extending back from the lake from 1 to 6 miles on the north shore of the lake. West of Duluth these deposits, formed on the bottom of glacial Lake Duluth, extend to Thompson and Wrenshall, and west of Blackhoof to Nemadji and Moose Lake. The south line of these deposits is at Holyoke, east of which the deposit continues into Wisconsin.

The drift which underlies the lake sediments is clayey in character containing few stones in comparison with the drift deposits outside the lake area. The strip along the shore which was covered by the waters of Lake Duluth and lower stages of the lake down to the present Lake Superior, includes numerous gravelly ridges and 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, cobbles, gravel, and sand.

The sediment deposited on the shore of Lake Duluth in Cook County and most of Lake County was sandy in character, there being

FIG. 132. Pioneer Marketing at Cook. *Photograph by F. J. Alway.*

but little fine sediment. In the southwestern part of Lake County and across the part of St. Louis County that borders Lake Superior, and

FIG. 133. Roseau River at Roseau, Minnesota.

embracing a considerable area in eastern Carlton County, is a heavy clay soil having few stones. This is the famous red clay which borders the west end of Lake Superior, and is noted for the growth of red clover.

CHAPTER XXVII

OUT DOORS IN MINNESOTA

The great ice sheets fashioned the landscape of most of Minnesota. The same great forces that changed river courses and established lakes determined also forests and prairies and the nature of the soils. These things in turn determine the character of plants and animals.

The agencies that have shaped the landscape and determined the quality of the soil made some places suited to be the abode of fishes, birds, and mammals. It thus comes about that every part of the State has its own features of special interest to the nature lover, the tourist,

FIG. 134. Out Doors at Lake Itasca.

the hunter, the fisherman, the camper seeking rest, the canoe voyageur seeking adventure. Lakes, rivers, swamps, and prairies offer a natural habitat to wild life. The ten thousand lakes embraced within the boundaries of Minnesota are unsurpassed on the continent for camping, fishing, boating, recreation, and rest. The great river systems of the southern and southeastern regions of the State offer in their deep valleys and shaded slopes a natural home for fishes and many game birds. The prairies of the west and northwest teem not only with the products of fertile soil but are the home and feeding ground of great numbers

FIG. 135. Mille Lacs Lake.

FIG. 136. Moonlight on Lake Itasca, at Forest School Camp.

of game birds of the field, while the sluggish streams and shallow lakes are a feeding ground for migratory bands of ducks and geese. The swamps and the forests of the north and northeast are the home of the bear, the deer, moose, and many animals sought by sportsman, hunter, and trapper.

The Great Provinces of the State. The contrast in the great geographic provinces of the State is very great. The great southeast has no lakes, but streams flow in deep valleys. Here the trout, large-

Fig. 137. Moose in Red Lake.

mouthed bass, rock bass, crappie, and other fishes find their natural home. The shaded pools and rocky gorges afford natural hiding places for fish. The botanist and bird lover find also here an attractive field.

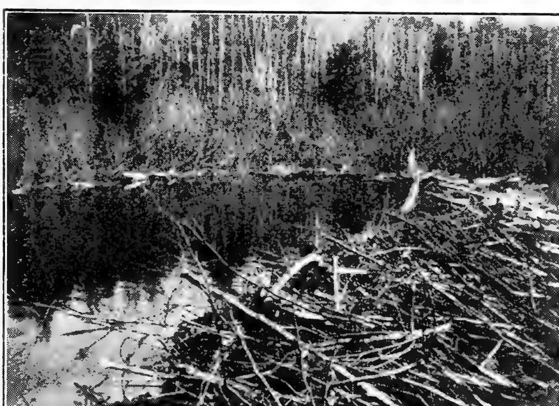


Fig. 138. Beaver Dam, North Arm Burntside Lake, Superior National Forest, St. Louis County.

The forest plants of the valleys compete with the prairie loving plants of the uplands. Birds nest in both. The rough ledges furnish protection and hiding to the Fox, Raccoon, and occasionally the Timber Wolf.

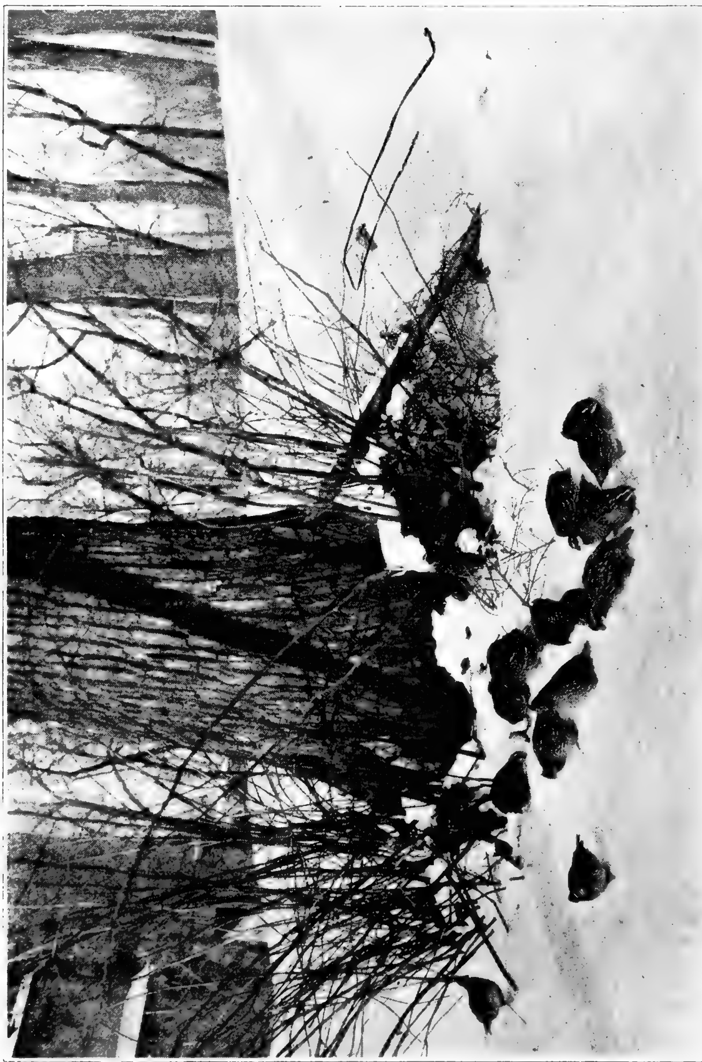


Fig. 140. A Covey of Quail.

Roads follow the stream courses, or wind along the ridges that divide the valleys. The panoramic view from a ridge top is often one of the finest. Trees abound in the valleys; grasses, flowers, and birds on the uplands.

An auto tour in almost any direction across the State leads to some region of special interest. Well-graded roads, long reaches being hard surfaced or gravelled, lead in all directions.

A drive through the Lake Park region offers a strong contrast in scenery to that of the river region of the southeast. It is also in marked contrast to the prairies to the south and west. The roads wind around lakes and over hills. On the shores of the lakes are the most inviting camping sites. Hotels and permanent summer camps are everywhere. Crappies, Pike, and Bass invite the bait-thrower. Beautiful drives through ever changing scenery invite in all directions. Once it was possible to get lost among the lakes and hills. Now goods roads lead everywhere. Directions—compass directions—go all to pieces here, as in the river region of the southeast. But follow the "main traveled road," or the blazed highway and the end of the road will be where you wish to go.

In the prairie regions compass lines are systematically laid out at right angles. Here the fields are broad; the horizon extends far in a uniform line. Here are feeding grounds for flying myriads of geese and ducks. The shallow lakes, the sluggish streams, abound in the natural foods for birds. Here the Canadian Goose, the Canvas-back Duck, Red-head and Teal halt on their journey southward and fatten on the wild rice and other aquatic plants. Reeds and rushes offer them hiding and thus are an inducement to the passing flocks to alight and tarry.

In the great north and northeast the forests of pine and hardwood add their charm to what the great ice sheets have done in fashioning the landscape. Fine roads lead through forests and over landscapes of rocks, amidst the native breeding haunts of wild fowl that in the fall hie to southern lands.

Game, Past and Future. When the region that is now included in the State of Minnesota was first visited by white men, wild life was very abundant. The early explorers found great herds of Buffalo and Elk grazing along the bluffs of the Mississippi River. Deer filled the woodlands. Beaver abounded in all the streams and lakes, and the primeval forests of the north sheltered great numbers of Moose, Caribou, and Black Bear. The diversified and fertile upland and the equally varied and bountiful waters supported a vast bird population. Ducks of many species bred in vast numbers. The honk of the Canadian Goose resounded far. About the margins of many shallow lakes Trumpeter Swans reared their young.

With the advance of civilization and settlement some of these wild denizens of forest, lake, and prairie have disappeared. The catalogue of wild game animals, game birds, and game fish of Minnesota is, however, a long one today, and thanks to the wise provisions that have been made through game and fish and forest protection, the list of attractions to the sportsman, hunter, trapper, fisherman, camper, and the nature loving tourist will probably continue to be a long one.

Wild Four-footed Game. It is not intended or attempted to catalogue here all the wild animals, birds, and fishes of Minnesota. The common game animals, birds, and fishes in which the hunter and fisherman would be interested, and which appeal to the lover of nature, and to visitors and residents of the State generally, are given in this chapter.

Among the most interesting of the larger wild game animals is the Northern White-tailed Deer. Its range is approximately the northern one-half of the State, in the forested regions. The Wapiti or Elk is probably now extinct in Minnesota. It formerly ranged throughout the forested regions of the State. The Moose or true Elk ranges throughout the northeastern portion of the State. This is the largest member of the Deer family. The Black Bear and the Beaver are now found only in the timbered districts of the northern half of the State. The Gray Wolf or Timber Wolf is now found only in the extreme north and northeastern portions of the State. The Prairie Wolf is widely distributed over the State. The Badger and Raccoon inhabit all the State except the northeastern portion. The range of the Mink is State wide. The Porcupine's range is only in the north. The Red Foxes (Prairie and Eastern) occur in the prairie and forested regions respectively.

Game Birds. Of game birds in Minnesota there are 25 kinds of ducks, 17 of which breed within the State. Four species of geese are found, and one species of swan.

Nine species of river or surface-feeding ducks are of regular occurrence in Minnesota. These are the Mallard, Black Duck (called Black or Dusky Mallard) Gadwall or Gray Duck, Baldpate or Widgeon, Green-winged Teal, Blue-winged Teal, Shoveler or Spoonbill, Pintail, and Wood Duck. All except the Baldpate breed in the State. They are all valuable as food, as objects of legitimate sport, and as destroyers of noxious weeds and insects.

Four species of diving or sea ducks are of special importance as game birds. These are the Canvas-back, the Redhead, the Lesser Scaup or Blue-bill, and the Ring-necked Duck. These four species of ducks formerly bred in large numbers in all suitable places throughout the

State. All still breed here though in greatly reduced numbers, and it is probable that the Canvas-back has about reached extinction as a summer resident.

Four species of wild geese are found in Minnesota: the Snow Goose, called also the White Brant or White Wavie, the Blue Goose or Blue Wavie, the White-fronted Goose (sometimes called Brant), and the Canada Goose or Honker. All the geese are now spring and fall migrants, except, perhaps, an occasional pair of Canada geese which may remain to breed in some remote part of the State, a lonely reminder of the time when they were common summer residents throughout the whole of this region. Although but a remnant of the former vast flocks,

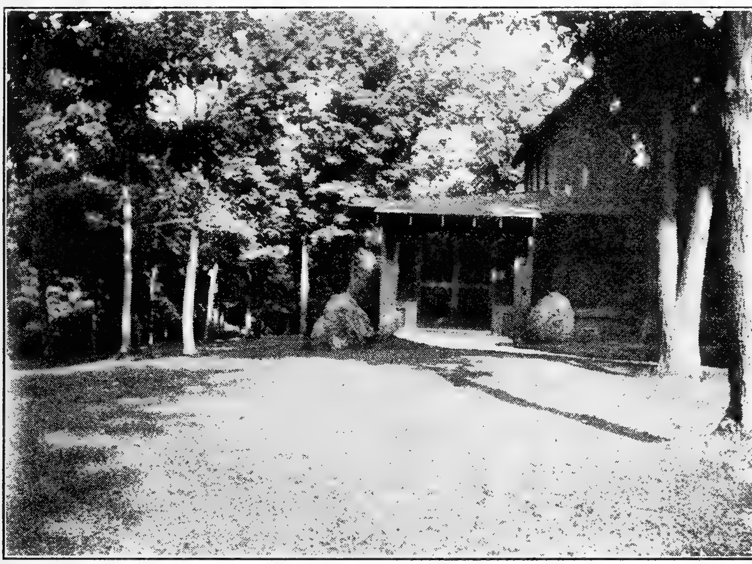


FIG. 141. Wolf Lodge, Lake Home of Mr. & Mrs. D. F. DeWolf, Lake Minnetonka. The Hills are Morainic Hills. The Boulders are from Far North in Canada. Many Game Birds Nest in the Region.

geese still pass back and forth across Minnesota in considerable numbers, chiefly over the western half. The Canada geese, for the most part, flock by themselves, but the three other species commonly mingle in migration.

There is now only one kind of swan found in Minnesota, the Whistling Swan, which passes across the State in its migrations, and now and then alights to rest and feed. It breeds in Alaska and on the islands of the Arctic Ocean and winters on the sounds and bays of the South Atlantic and Gulf coasts. It was formerly very abundant and was killed in large numbers in the far north and elsewhere for the "swan's-down" as well

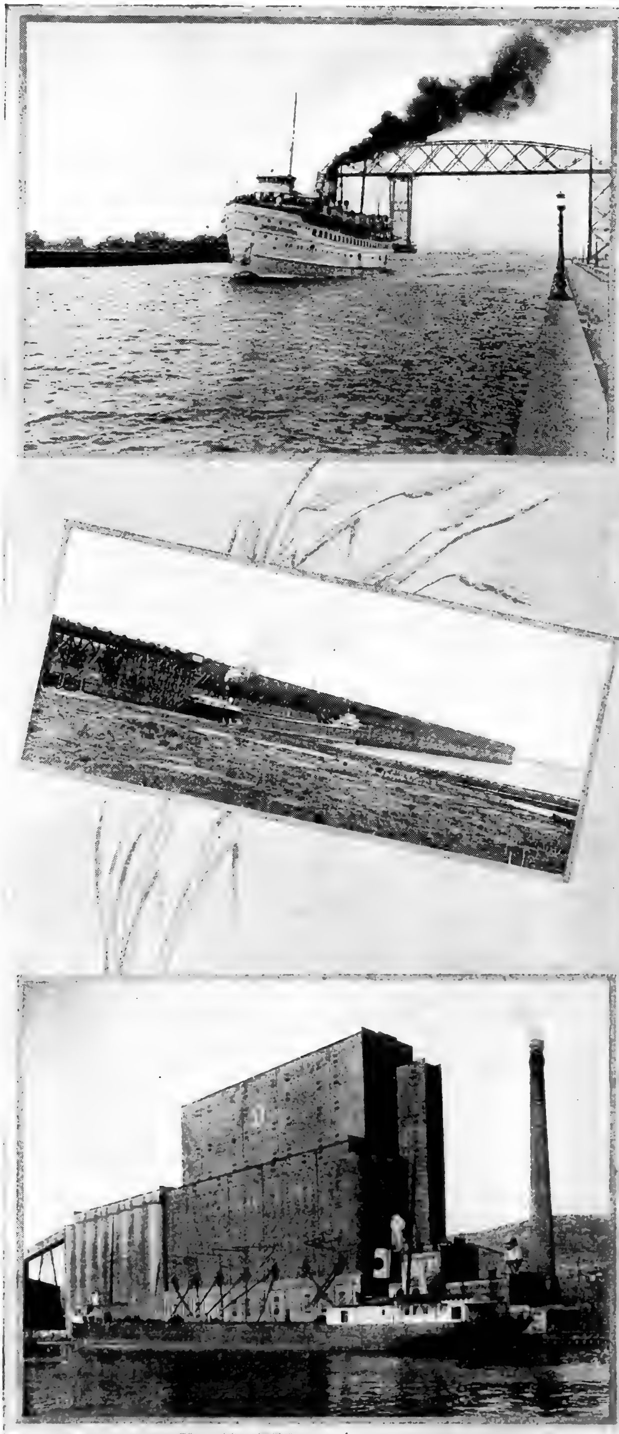


Fig. 111A. Duluth. Steamer Passing Aerial Bridge; Ore Docks; Concrete Grain Elevators.

as for its flesh. Each spring and fall flocks of considerable size may still be seen on our larger lakes and on the Mississippi River.

Four kinds of gulls and the same number of terns are found in Minnesota. The Herring Gull, the largest, nests at Lake of the Woods, along the north shore of Lake Superior, and probably about other large

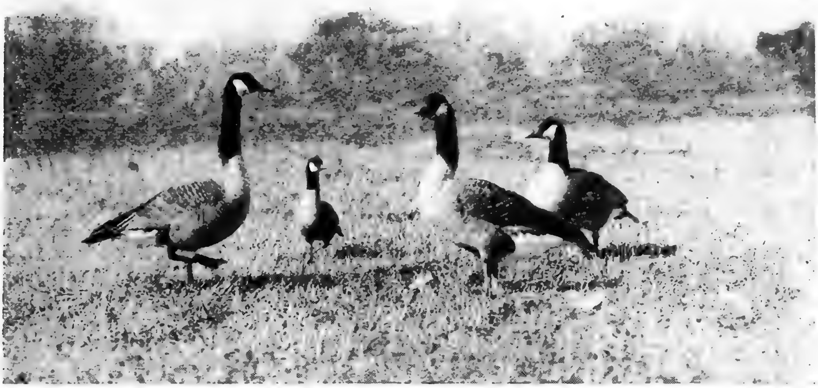


FIG. 143. Canada Goose and Cackling Goose. *Photograph by Jenness Richardson.*

FIG. 144. Snow Goose and Blue Goose. *Photograph by Jenness Richardson.*

lakes in the northern part of the State. Franklin's Gull nests in immense colonies throughout the western prairie portion of the State.

Of the four terns, three breed in the State, Forster's Tern chiefly in the prairie regions, the Common Tern chiefly northward, and the

FIG. 145. Franklin Gull, Heron Lake, Minn. *Photograph by L. O. Dart.*

FIG. 146. Black Tern and Nest. *Photograph by Jenness Richardson.*

Black Tern, which far exceeds in numbers all the others put together, breeds everywhere in sloughs and ponds.

The gulls and terns are economically of great importance. The gulls are not only of special value as scavengers, particularly about harbors and along water-ways, but collectively they destroy an incalculable number of injurious insects. Franklin's Gull alone is of immense value to the farmers of the western part of the State. It is a common sight in that region to see great flocks of this bird following the plows and alighting in the freshly turned furrows to pick up the insects and worms brought to the surface. At other times they are constantly win-

FIG. 147. Pied-billed Grebe—Nest open. *Photograph by Thos. S. Roberts.*

nowing back and forth over the prairies and meadows, or of evenings circling about in the air, devouring vast quantities of grasshoppers, beetles, moths, and other insects. The terns perform a similar service, the Black Tern especially, because of its great numbers being of great importance as a destroyer of insects.

The family of Rails, Gallinules, and Coots is represented in Minnesota by only a few species but in number of individuals it comprises by far the greater part of the aquatic bird life of the marshy lowlands of the State. Sloughs, ponds, and marshy lakes teem with members of this family in the fall.

FIG. 148. Pied-billed Grebe—Nest covered. *Photograph by Thos. S. Roberts.*

FIG. 149. Franklin Gulls Following the Plow.—Significant of Their Economic Value, June, 1916. *Photograph by Jenness Richardson.*

In addition to the economic value of this family as insect destroyers, which is of considerable importance, the members of the family may all be regarded as game birds of some importance. The flesh of the Rails and of young Gallinules in the fall, when they have been feeding largely on wild rice and other vegetable food, is well flavored and suitable for the table. Since ducks have become scarcer many hunters have been

FIG. 150. Spruce Grouse.

turning their attention to Coots, calling them "Rice-hens" as a more appetizing name. When the food taken is largely wild celery, wild rice, and pond weeds these birds are, if properly cooked, of good flavor and nutritious, and much better than some ducks. What they have been eating and how they are prepared and handled in the cooking determines largely their desirability as food.

Game and Food Fishes. It is stated on competent authority that an acre of inland water surface will furnish more food each year under proper "cultivation" than will the most fertile and productive acre of land. When the great potential food-producing wealth of Minnesota's water surface is reckoned, in addition to all the pleasure-wealth that these waters carry, it may indeed be said that Minnesota is most fortunate in her natural location. Few States have so many long rivers. Her ten thousand lakes make up what is among the most wonderful groups

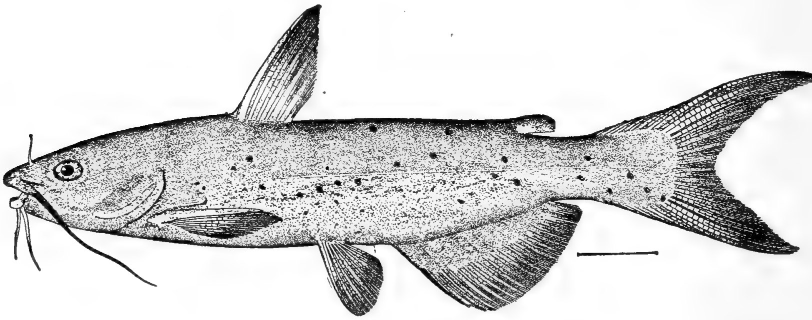


FIG. 151. Channel Cat-Fish. Fiddler. Speckled Cat-Fish. Blue-Cat.

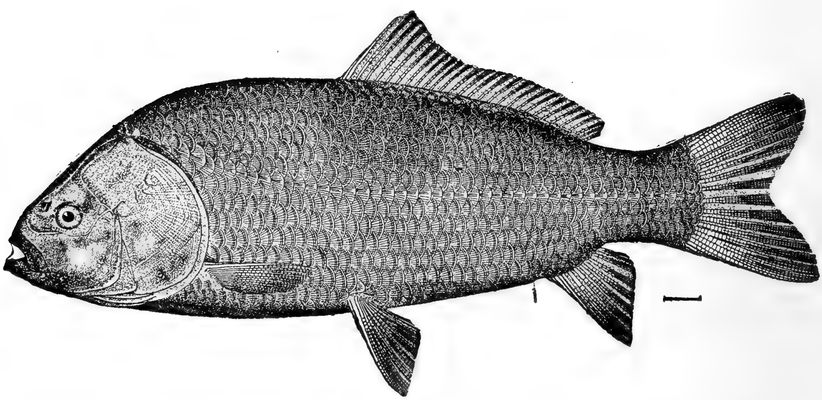


FIG. 152. Common Buffalo-Fish. Red-Mouthed Buffalo.

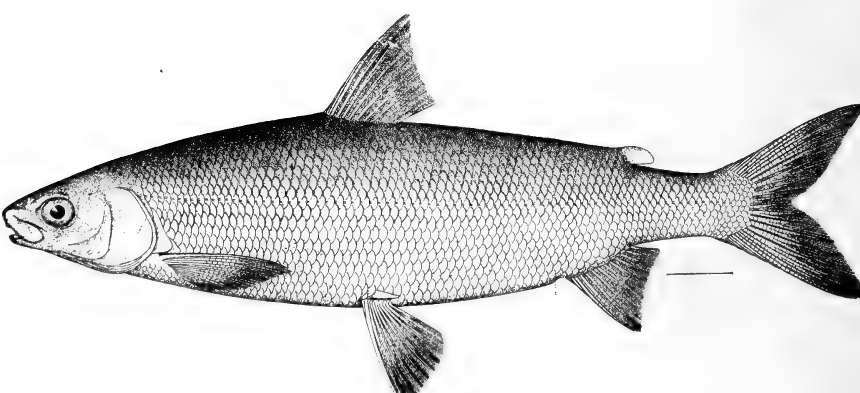


FIG. 153. Labrador Whitefish.

in the world. The rivers and lakes are the home of many valuable food and game fishes.

Among the most widely distributed of the food fishes are Crappie, Pike, and Bass. These are caught in nearly all the waters of the State. The clear waters of many lakes and swift flowing streams are the favorite haunt of Bass. Crappies are commonly encountered in "schools"

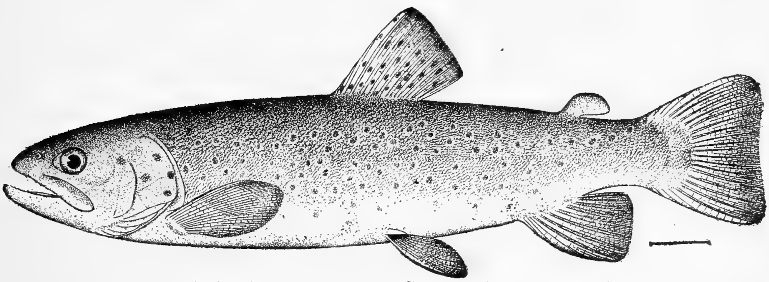


Fig. 154. Brown Trout. German Brown Trout.

and it is good fisherman's luck when a school is met with. Pike are found in most of the lakes and streams particularly in the northern two-thirds of the State. The Pike is a gamey fish and responsible for many a thrill.

Brook Trout were originally caught in the waters of small, swiftly flowing streams entering Lake Superior, and in the streams in the deep

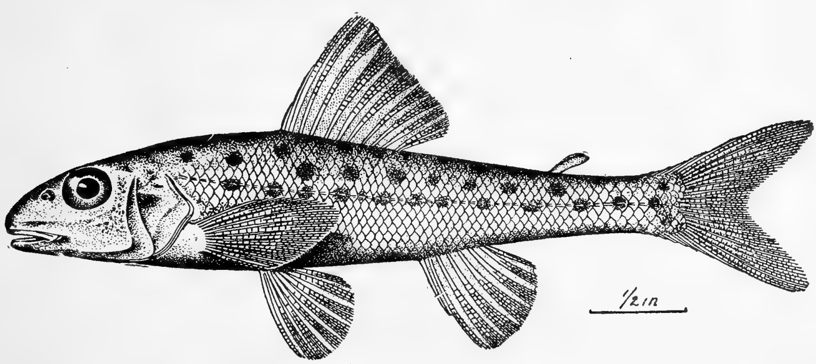


Fig. 155. Trout Perch.

rocky valleys in the southeastern part of the State. This valuable and gamey fish has been successfully introduced into many other streams in the northern part of the State. It formerly abounded in the streams of the southern districts but the advance of civilization has in considerable measure driven it out. The Brown Trout has been found to thrive where the Brook Trout has disappeared. The Brown Trout is highly regarded as a sportsman's fish but is not as delicate in flavor as a food fish.

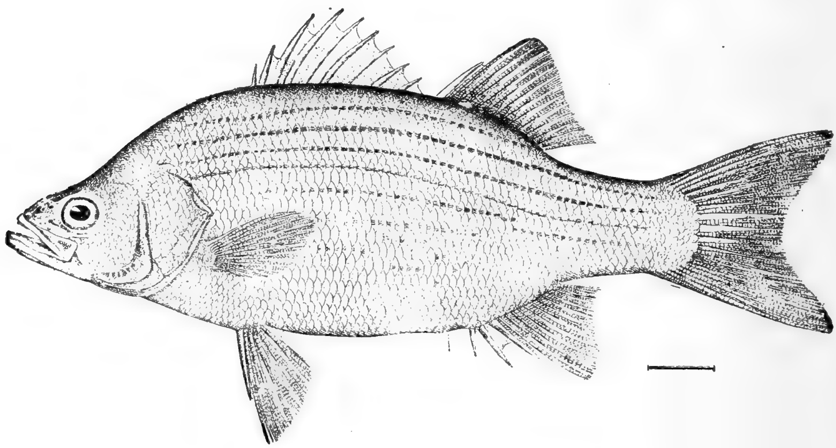


FIG. 156. White Bass. Striped Bass.

The Perches, Black-headed Minnow, Bull-head, Channel Cat Fish, Lake Red Horse, Labrador White Fish, Lake Trout, Blue-gill, and Lake Carp are among the many valuable food fishes which are widely distributed.

CHAPTER XXVIII

GEOLOGY FROM A CAR WINDOW

CHICAGO, MILWAUKEE & ST. PAUL RAILWAY

MAIN LINE (WEST)

St. Paul.—0 miles; Alt. 704 feet. (Ramsey County.)

Leaving Union Depot the railroad skirts the east bank of the Mississippi River (actually on the west side). St. Peter sandstone is exposed in the bluffs, on both sides of the river. By a heavy grade the limestone terrace, which extends to the bend of the river at Fort Snelling, is reached. The flat terrace has the Platteville limestone for a floor, and its surface is about 100 feet above the river. The railroad crosses this broad terrace, taking advantage of an old partially filled valley to rise to the upland east of Merriam Park. A moraine of red drift is crossed east of Merriam Park, with an intervening flat plain of red outwash. West of Merriam Park the deep gorge of the Mississippi is crossed on a high steel bridge. Bordering the gorge on either side is a high terrace of glacial gravel and sand.

Minneapolis.—11 miles; Alt. 825 feet. (Hennepin County.)

The depot in Minneapolis is on the glacial terrace. The line west is across a flat outwash plain. West of Lake of the Isles and Lake Calhoun gray drift hills with intervening flat gray outwash plain to Hopkins.

St. Louis Park.—19 miles; Alt. 917 feet.

St. Louis Park is on an outwash plain lying west of Lake Calhoun.

Hopkins.—22 miles; Alt. 920 feet. Chanhassen.—29 miles; Alt. 955 feet. Augusta.—38 miles; Alt. 970 feet. Cologne.—43 miles; Alt. 947 feet.

Terminal moraine. Morainic lakes and sloughs, knobs, pots and kettles.

Norwood.—50 miles; Alt. 990 feet. Plato.—56 miles; Alt. 995 feet. (Crossing M. & St. L. Ry.) **Glencoe.**—62 miles. (McLeod County.)

Rolling till-plain, clayey in character, Cologne to Glencoe. Many lakes and sloughs in shallow depressions.

Brownton.—72 miles; Alt. 1,018 feet.

Winding belt of terminal moraine west of Glencoe.

Stewart.—79 miles; Alt. 1,063 feet. Buffalo Lake.—85 miles; Alt. 1,073 feet. Hector.—90 miles; Alt. 1,081 feet. Bird Island.—99 miles; Alt. 1,089 feet. **Olivia.**—104 miles; Alt. 1,082 feet. (Renville County.)

Danube.—108 miles; Alt. 1,083 feet. Renville.—115 miles; Alt. 1,067 feet.

From Stewart westward for 50 miles the landscape is that of an undulating till-plain or ground moraine. A tiny moraine 3 miles in length and one-fourth mile wide lies south of Danube. Small moraines one-half mile to 1 mile in width lie north of Bird Island, Olivia, and Danube 2 to 3 miles.

Sacred Heart.—121 miles; Alt. 1,063 feet.

West of Sacred Heart about 4 miles, Hawk Creek is crossed, deeply cut into the till-plain. West of this creek is a moraine a mile wide. The railroad then descends to the terrace plain of the Minnesota Valley (glacial River Warren).

Minnesota Falls.—127 miles; Alt. 1,025 feet. **Granite Falls.**—131 miles; Alt. 935 feet. (Yellow Medicine County.) (Crossing G. N. Ry.)

Outcrop of rough blocky granite rock as railroad descends into the valley of the Minnesota. This is the old Archæan granitic rock of the primitive continent here exposed by the cutting of the Minnesota Valley.

Wegdahl.—148 miles; Alt. 927 feet. **Montevideo.**—144 miles; Alt. 922 feet. (Chippewa County.)

Granite rock embossments stand out strongly on bottom of Minnesota Valley. The railroad climbs out of the valley of the Minnesota by the mouth of Chippewa Creek. Granite exposed in the valley sides shows that the River Warren, when it was carrying the waters from glacial Lake Agassiz, had eroded deeply into the granite rock. Glacial gravel filling occurs in the valley bottom in many places.

Watson.—150 miles; Alt. 949 feet. Milan.—159 miles; Alt. 989 feet. Appleton.—167 miles; Alt. 1,001 feet. (Crossing Great Northern Railway.)

Channels of glacial outwash lie in courses parallel with the Minnesota Valley, with belts or ridges of rolling terminal moraine between them. These morainic ridges were islands in the River Warren. The Minnesota Valley was cut about 100 feet below the bordering till-plain. Appleton is at the northwest end of one of these long morainic islands on the level sandy outwash plain.

Correll.—174 miles; Alt. 974 feet. Odessa.—184 miles; Alt. 957 feet. **Ortonville.**—189 miles; Alt. 985 feet. (Big Stone County.)

The railroad follows the valley of the Minnesota from Appleton to Ortonville. The sandy and gravelly outwash plain of the glacial Minnesota River (River Warren) is 50 to 75 feet above the bottom of the Minnesota Valley. Odessa stands on an island of outwash. Marsh Lake, south of Correll, is caused by the silting up of the valley so as to pond the waters of the river. At Ortonville granite rocks are exposed in the valley. Many polished surfaces, known as **roche moutonnée,** or sheep's back, can be seen from the passing train. A fine view of Big Stone Lake, northwest of the city of Ortonville. North of Odessa a terminal moraine is seen, bordered by the broad outwash plain of sand and gravel.

MAIN LINE (EAST), ST. PAUL TO LaCROSSE

Newport.—8 miles from St. Paul; Alt. 750 feet.

Leaving Union Depot, St. Paul, the railroad skirts the steep bluffs on the east side of the river. White St. Peter sandstone is exposed below with Trenton limestone strata projecting above. Toward Newport the drift covered bluffs are skirted, and a broad, flat terrace of Shakopee limestone is crossed.

Langdon.—13 miles; Alt. 812 feet.

Broad outwash plain of sand and gravel. The railroad runs along an abandoned river channel cut in this old sand plain. Shakopee limestone outcrops near the river opposite Hastings.

Hastings.—19 miles; Alt. 707 feet. (Dakota County.)

An island of Shakopee limestone is surrounded by glacial outwash. Hastings stands on the limestone. Numerous lagoons or river-lakes occur in depressions in the glacial sand and gravel which form the valley floor.

Etter.—28 miles; Alt. 690 feet. Eggleston.—32 miles; Alt. 692 feet.

From Etter to Red Wing the railroad runs along the west side of the broad plain of glacial sand and gravel close to the overhanging limestone bluffs, which rise 300 to 400 feet above the river. Cannon River is crossed above Red Wing. The filling of glacial sand and gravel extends up this valley, continuous with that of the main valley.

Red Wing.—40 miles; Alt. 686 feet. (Goodhue County.) Wacouta.—46 miles; Alt. 710 feet. Frontenac.—57 miles; Alt. 720 feet.

The Mississippi River below Red Wing is expanded into Lake Pepin, the valley being filled by in-carried sediments so as to dam the river. In and east of Red Wing are lowlands that were filled with glacial sand and gravel. These are generally open both up and down the valley. The railroad east of Red Wing runs west of rocky hills that were islands when the glacial river deposited the gravel filling. For some distance the railroad follows an abandoned channel below Red Wing.

Frontenac stands on the east end of an "island" in the gravel filling. Well-defined terraces are east and west of Frontenac, also west of Wacouta.

Lake City.—57 miles; Alt. 713 feet. King's Cooley.—63 miles; Alt. 685 feet. Read's Landing.—68 miles; Alt. 683 feet.

Terraces border the valley at Lake City. The limestone bluffs rise 450 feet above the river. A fine view of Lake Pepin is obtained east of Lake City.

Wabasha.—70 miles; Alt. 709 feet. (Wabasha County.)

Opposite Wabasha are many sandy and gravelly islands in the river. These are part of the filling which is the cause of Lake Pepin. The Chippewa River in Wisconsin brings a large amount of debris from the sandy formations of its drainage area. When the current enters the broad valley of the Mississippi its speed is lessened and sediment is thrown down in greater quantity than the Mississippi can carry away. The Mississippi Valley has thus been filled across till a dam has been formed which holds back the water, and thus Lake Pepin is formed.

The loess-capped bluffs, which rise 450 feet above the river, here crowd close upon the river. Limestone ledges outcrop in the steep cliffs.

Kellogg.—76 miles; Alt. 701 feet.

Kellogg is located at the mouth of the valley of the Zumbro. Glacial drainage deposits of sand and gravel form a filling in this valley similar to those of the Mississippi Valley. Terraces appear at different levels. The highest terrace is 65 feet above the railroad, and 108 feet above Lake Pepin. The Zumbro is blocked by the filling in the Mississippi Valley so that it meanders widely before being able to reach the Mississippi.

Weaver.—83 miles; Alt. 673 feet. Minneiska.—86 miles; Alt. 670 feet.

The railroad runs near the foot of the limestone bluffs, crossing the mouth of the Whitewater River at Weaver. Terraces appear where the Whitewater Valley comes into the valley of the Mississippi. At Minneiska the river runs near the foot of the bluffs, and the railroad follows the narrow plain of glacial filling. The height of the terraces indicates the amount of clearing out of the valley that was accomplished when the glacial flood waters from the melting ice sheets to the north surged down this great valley. The bottom of the valley is as far below the present floodplain as the present floodplain is now below the highest floodplain marked by the highest terrace.

Minnesota City.—97 miles; Alt. 678 feet. **Winona.**—103 miles; Alt. 678 feet. (Winona County.)

The Mississippi Valley has been filled with glacial sand and gravel to a level more than 100 feet above the present river, and the tributary valleys were correspondingly filled. The glacial river which carried the waters of Lake Agassiz removed much of this filling in the main valley, but much of the glacial deposit still remains in the tributary valleys. The higher uplands overlooking the valley are 600 feet above the river, and the distance across the flat valley plain is from 3 to 6 miles.

Homer.—107 miles; Alt. 662 feet. LaMoille.—112 miles; Alt. 659 feet. Richmond.—117 miles; Alt. 660 feet. Dakota.—120 miles; Alt. 658 feet. Dresbach.—122 miles; Alt. 675 feet. North LaCrosse, Wis.—132 miles; Alt. 651 feet.

The railroad runs on the glacial filling of sand and gravel close to the foot of the bluffs to Bridge Switch. Broad valleys silted up with sand and gravel enter the large valley, separated by high bluffs which rise to more than 1,200 feet above sea level, and more than 600 feet above the Mississippi. Gwinn's Bluff, below Richmond, is a conspicuous and precipitous highland capped by the St. Lawrence limestone, with St. Croix sandstone below.

ST. PAUL-AUSTIN-CALMAR LINE

Mendota.—6 miles from St. Paul; Alt. 743 feet.

Leaving Union Depot the railroad crosses the Mississippi, skirting the steep bluffs in which the St. Peter sandstone is exposed below and the Trenton limestone above. The historic Sibley House, home of General H. H. Sibley, is near Mendota, constructed from limestone quarried from the cliffs. Mendota stands on the valley bottom of the Minnesota south of Pike Island, an island of St. Peter sandstone which lies below the junction of the Minnesota and Mississippi Rivers.

From Minneapolis a line to Mendota runs across a broad gravelly terrace of the glacial Mississippi to Minnehaha Falls. Here Minnehaha Creek is crossed, and the railroad soon descends across the outcropping Platteville limestone to the St. Peter sandstone. Fort Snelling is on the high gravel terrace. The railroad follows the side of the gorge to the point where the Mississippi and the Minnesota join, at the head of Pike Island, then across the broad valley of the Minnesota to Mendota.

South of Mendota the railroad leaves the Minnesota Valley following the old preglacial valley of the Mississippi. (See Chapters XV & XVI.) Augusta and Lemay Lakes are passed, occupying depressions in the old filled valley.

Westcott.—14 miles; Alt. 882 feet.

Westcott lies in the old Mississippi Valley, which from here southeast to the bend of the river is marked by glacial river-washed sand and gravel. The plain which is crossed south of Westcott is that of the roughly rolling morainic hills of Young Red drift.

Rosemount.—19 miles; Alt. 963 feet.

Rosemount stands on the edge of a broad sandy outwash plain which extends to and beyond Hastings.

Farmington.—26 miles; Alt. 903 feet.

Farmington is on the sandy outwash plain referred to. Between Rosemount and Farmington a mesa-like upland stands nearly 200 feet above the surrounding sandy outwash plain. A capping of limestone over the soft sandstone protects the sandstone from erosion. Over the top of the mesa and surrounding it the surface formation is that of the Old Gray drift (Kansan). A loess-covered area lies west of the railroad north of Farmington.

Castle Rock.—33 miles; Alt. 945 feet.

The plain of the Old Gray drift extends 2 miles west and 4 miles north. Between Farmington and Castle Rock a low mesa is crossed. Its eastern and higher part is capped with limestone. South the gravel-filled valley of Chub Creek is crossed. (See Chap. XXV.)

Northfield.—40 miles; Alt. 915 feet.

The boundary between the Old Gray drift (Kansan) and the Young Gray drift (Wisconsin) is a mile east of Northfield. The rapids of Cannon River were caused by the change in the direction of flow of this valley's river and forcing the waters to cross an old divide. (See Chap. XXV.) The St. Peter sandstone outcrops in the valley sides, overlaid by the Trenton limestone.

Dundas.—43 miles; Alt. 958 feet. **Faribault.**—52 miles; Alt. 1,003 feet. (Rice County.)

The railroad follows the valley of Cannon River to Faribault. St. Peter sandstone with overlying Trenton limestone continues in the valley sides. On the west rolling morainic hills of Young Gray drift crowd upon the valley. Cannon River is crossed at Faribault.

Medford.—62 miles; Alt. 1,101 feet.

Rolling till-plain Faribault to Medford. Valley of Straight River is followed to Owatonna.

Owatonna.—67 miles; Alt. 1,145 feet. (Steele County.) (Crossing C., R. I. & P. Ry. and C. & N. W. Ry.)

Owatonna is built on a gently rolling moraine. The surrounding country is undulating till-plain, a high quality farming country.

Pratt.—73 miles. Bixby.—80 miles; Alt. 1,300 feet.

Pratt is on gently undulating till-plain. A moraine can be seen 2 miles east and another 3 miles west. These two moraines join north of Bixby. South from Bixby is a sandy channel by which Straight River probably at one time flowed south to the Cedar.

Blooming Prairie.—85 miles; Alt. 1,290 feet.

The boundary line between the Young Gray drift and the Old Gray drift is about a mile west of Bixby. A sandy outwash plain extends down the valley of the Cedar past Lansing and Ramsey to Austin.

Austin.—100 miles; Alt. 1,195 feet. (Mower County.)

A gently rolling low moraine lies west of Austin. This was formed at the edge of the Keewatin glacier (Wisconsin stage) and marks the eastern limit of the Young Gray drift. The gently undulating broad expanse of the Old Gray drift extends away to the east. The sandy outwash deposit continues down the valley of the Cedar to the State line and beyond. This was a channel of drainage from the melting Keewatin ice sheet.

Rose Creek.—108 miles; Alt. 1,285 feet. Adams.—114 miles; Alt. 1,286 feet. Taopi.—118 miles; Alt. 1,241 feet. (Crossing C. G. W. Ry.) LeRoy.—126 miles; Alt. 1,285 feet. (Crossing C. G. W. Ry.)

Flat or gently undulating plain of Old Gray drift.

LaCROSSE-AUSTIN-PIPESTONE LINE

LaCrescent.—4 miles from LaCrosse; Alt. 647 feet.

The town stands on a fine gravelly terrace which is 50 feet above the floodplain of the Mississippi. This terrace is related to the gravel terraces deposited by glacial waters that border the Mississippi Valley. Another terrace 40 feet higher lies back of the town against the bluffs. This latter represents an early floodplain of Root River.

Hokah.—9 miles; Alt. 654 feet.

The railroad follows the broad valley of Root River, which is about 2 miles broad between the bordering bluffs. It is approximately this width across Houston County. The valley is in the St. Croix sandstone and is about 500 feet deep. Some of its tributary valleys are equally deep and wide, but the smaller tributary valleys become shallower and more rocky as the gorges ascend into the St. Lawrence limestone. Hokah stands upon a terrace 65 feet above the floodplain of Root River. A well more than 60 feet in depth reached a bed 4 feet in thickness of vegetable matter, sticks, leaves, muck, and snail shells, showing that the terrace deposit was long ago filled into the valley as a floodplain deposit, and the deeper valley was later cut into this deposit. Mt. Tom, at Hokah, is a limestone-capped hill standing 530 feet above the floodplain. Building stone for the railroad shops was quarried from this hill.

Mound Prairie.—15 miles; Alt. 665 feet.

The name is suggestive of the local topography of the valley bottom. The broad valley is marked by mounds of sandstone which have resisted the erosion by which the valley has been formed. Sandstone bluffs of varying height border the valley sides.

Bluffs in the tributary valleys south are beautifully sculptured, and isolated columns and tables, with some rounded buttresses, which afford fine examples of wind erosion, occur. The bluffs themselves are the result of water erosion that began long ages ago in preglacial time, but the present sculptured character and the peculiar forms are due to wind erosion in conjunction with the work of moisture and frost.

Houston.—22 miles; Alt. 684 feet.

The bluffs north of Houston are 520 feet above the water of Root River. West of the city a terrace 65 feet above the bottom of the valley shows the level of an ancient floodplain.

Money Creek.—26 miles; Alt. 704 feet.

Money Creek comes into the Root from the north between Houston and Money Creek station by a broad valley similar to the Root Valley itself. Terraces border the valley, being 30 feet above the flood-plain.

Rushford.—33 miles; Alt. 727 feet. Peterson.—37 miles; Alt. 763 feet.

Continuing up the valley of Root River, sandstone bluffs capped with limestone border the broad valley.

"The larger streams have gorges of enormous depth into the rocky floors on which they run, but every little creek and tributary runs in a gorge which shows the same rock-sculpture. Even the freshet creeks, and the rivulets born of every summer shower, dry entirely the greater part of the year, find their way to the main valleys through rock-bound canyon-like valleys."—(Upham.)

The valley is here about 2 miles in width, with fine farms on the bottom lands. The bluffs are rounded off with age, and mostly have a covering of soil, though there are frequent rock exposures. The river is 565 feet below the tops of the bluffs. The floor of the valley is on St. Croix sandstone, and this formation extends into the bluffs, with St. Lawrence limestone above. The valley floor is entirely alluvial, completely burying the sandstone. Rushford stands upon a terrace 40 feet above the river.

Whalan.—46 miles; Alt. 791 feet.

At Whalan the St. Lawrence limestone is finely exposed in the bluff half a mile below the town. This bluff is 250 feet high. The river is 470 feet below the top of the Trenton limestone.

Lanesboro.—51 miles; Alt. 846 feet.

The river is 285 feet below the immediate bluffs, and 440 feet below the top of the Trenton limestone, which is the highest formation capping the bluffs. Fine farms are on the bluffs, and the upland prairie is a fine farming country. The valleys are deep and wide. Owing to the thickness of the loess-loam the slopes are softened and broad.

Isinours.—63 miles; Alt. 904 feet.

Battlements of Shakopee limestone enclose the valley, rising about 31 feet above the water of Root River.

Fountain.—62 miles from LaCrosse; Alt. 1,306 feet. Wykoff.—69 miles; Alt. 1,318 feet.

The railroad rises 400 feet in the distance of less than 6 miles from Isinours to Fountain. Fountain is on the high plain of the Galena member of the Trenton limestone, which is here mostly covered with loess and a little of the oldest drift. The western limit of the loess is about 3 miles west of Wykoff. The railroad runs along the high ridge over Trenton and Maquoketa limestones, in which there are many natural sink-holes, marked usually by a bunch of trees or bushes. One or two miles north the surface is cut by small streams which descend through canyon-like valleys to Root River.

Spring Valley.—77 miles; Alt. 1,271 feet. (Crossing C. G. W. Ry.)

About 5 miles east the old Kansan drift is encountered. This is its eastern edge, and the transition to the loess-covered plain is not sharply marked. The country is broadly undulating, though trenched by Spring Valley Creek, and by Deer and Bear Creeks to the north. The quarries at Spring Valley mark the east edge of a Devonian limestone.

Grand Meadow.—86 miles; Alt. 1,344 feet. Dexter.—92 miles; Alt. 1,416 feet. Revona.—98 miles; Alt. at Crossing C. G. W. Ry. 1,379 feet. Brownsdale.—101 miles; Alt. 1,275 feet.

Gently undulating prairie. Kansan drift over Devonian limestone. Imperceptible divide between Mississippi drainage and that to the Cedar.

Ramsey.—106 miles; Alt. 1,218 feet.

At Ramsey the landscape changes markedly. To the east is the undulating prairie of the Old Gray (Kansan) drift; to the west is the rolling topography of the younger (Wisconsin) drift belonging to the Keewatin glacier. (See Chap. IV.) To the east the land is well drained and there are no lakes; to the west drainage is but feebly developed and lakes are everywhere. The Cedar River marks the boundary of the younger drift and the limit of the eastern advance of the Keewatin glacier in this region. The valley of the Cedar is that of an outwash channel by which water from the melting Keewatin glacier escaped southward.

Oakland.—118 miles; Alt. 1,369 feet. Hayward.—127 miles; Alt. 1,254 feet.

Four narrow morainic belts are passed between Ramsey and Albert Lea, the topography being distinctly rolling, and many lakes and undrained areas occupying the depressions. Between the moraines are belts of rolling ground moraine or till-plain such as are characteristic of the Young Gray drift.

Albert Lea.—133 miles; Alt. 1,225 feet. (Freeborn County.)

East arm Albert Lea Lakes is crossed 4 miles east, then moraine, and narrows connecting Albert Lea Lakes, to depot. Depot on clay lake bottom of glacial Lake Albert Lea. West of city the railroad runs on the ancient lake bottom, then crosses gravelly outwash plain west. (See Chap. XXII.)

Alden.—144 miles; Alt. 1,266 feet. Wells.—153 miles; Alt. 1,162 feet. Easton.—162 miles; Alt. 1,060 feet. Delavan.—168 miles; Alt. 1,071 feet.

Two large moraines crossed between Albert Lea and Alden. Two small moraines south of Freeborn Lake, between Alden and Wells. Morain south between Easton and Delavan. Headwaters Maple River north.

Winnebago.—175 miles; Alt. 1,111 feet. (Crossing C., St. P., M. & O. Ry.) Huntley.—180 miles; Alt. 1,103 feet. Grenada.—186 miles; Alt. 1,133 feet.

The Blue Earth River is crossed west of Winnebago. The general surface is flat. The river is nearly 100 feet below the general prairie level, meandering over a flat floodplain one-fourth to one-half mile in width. This broad valley with its steep sides was eroded by glacial waters. A moraine is crossed between Huntley and Granada, and another at Fairmont.

Fairmont.—192 miles; Alt. 1,195 feet. (Martin County.)

Flat or gently undulating till-plain north. Moraine south. Middle chain of lakes west of city. (See Chap. XXIII.)

Welcome.—200 miles; Alt. 1,143 feet. (Crossing C. & N. W. Ry.)

Railroad skirts a moraine on the south. Moraine also west; Fox Lake north, draining to Blue Earth River.

Sherburn.—206 miles; Alt. 1,295 feet. (Crossing M. & St. L. Ry.)

Railroad passes between Temperance and Manger Lakes east. Gently undulating till-plain. Moraine between Sherburn and Alpha, bordered on west side by glacial channel of East Fork of Des Moines River.

Jackson.—218 miles; Alt. 1,485 feet. (Jackson County.)

Jackson is located in the deep glacial valley of the Des Moines River. This glacial channel is bordered on either side by a moraine, that on the west side being ten miles in width, extending to Lakefield. The city is built on gravelly terraces of glacial outwash.

Okabena.—238 miles; Alt. 1,433 feet. Miloma.—241 miles. (Crossing C., St. P., M. & O. Ry.)

Undulating till-plain from Lakefield west. Heron Lake north.

Kinbrae.—246 miles; Alt. 1,471 feet. Fulda.—255 miles; Alt. 1,532 feet. Iona.—265 miles; Alt. 1,629 feet.

Gently rolling prairie (till-plain or ground moraine). Clear Lake north of Kinbrae, Graham Lakes and Eagle Lake south. Seven Mile Lakes south of Fulda. West of Iona to Chandler, to the north, a moraine sandy in character. Clayey moraines south of Iona and Chandler.

Chandler.—274 miles; Alt. 1,654 feet.

Northwest and northeast from Chandler are sandy moraines, and to the south a clayey moraine. This the outermost moraine, called the Altamont. Buffalo Ridge, 4 miles northwest of Chandler, rises 150 feet above the surrounding plain.

Edgerton.—284 miles; Alt. 1,574 feet.

At Chandler the railroad enters the valley of Chanerambie Creek, a glacial outwash channel which was cut by the glacial waters from the great ice sheet at the time the great Altamont moraine was being formed. This channel is cut into the drift to a depth of about 75 feet. At Edgerton the railroad turns abruptly and ascends the valley of Rock River, also a deeply eroded glacial channel.

Hatfield.—291 miles; Alt. 1,685 feet.

Four miles north of Edgerton the railroad leaves the deep valley of Rock River and crosses the undulating till-plain to Pipestone.

Pipestone.—298 miles; Alt. 1,732 ft. (Pipestone County.)

The country surrounding Pipestone is nearly flat till-plain bordering the Altamont moraine on the west. The deposit of drift is very thin, and at Pipestone hard quartzite rock overlaid with soil is the surface formation. The boundary between the Keewatin gray drift and the old Kansan gray drift is immediately west of the city. Split Rock Creek heads south of Pipestone, and becomes a rock-bound gorge in the Sioux quartzite 10 miles south.

Airlie.—304 miles; Alt. 1,664 feet.

Airlie is on the plain of the Kansan or Old Gray drift. This formation was last noted on this line of road 200 miles east, at Ramsay in western Mower County. The journey from Ramsay to Pipestone has been on the deposits of the Keewatin (Wisconsin) ice sheet.

Between Pipestone and Airlie the deeply eroded glacial outwash channel of Pipestone Creek is crossed.

RENO-ISINOURS LINE

LaCrescent.—4 miles from LaCrosse; Alt. 637 feet. Brownsville.—14 miles from LaCrosse; Alt. 639 feet. Reno.—21 miles; Alt. 636 feet.

Towns on the plain of the glacial bottom of the Mississippi Valley. The Old Mississippi Valley had been filled for fully 100 feet with sand and gravel, and then was scoured out for about 75 feet by the waters that came from glacial Lake Agassiz. It has since been filled again with sand and silt about 25 feet. Reno is 16 feet above the river on a terrace, the modern channel of the river being in the modern alluvial floodplain. The bluffs here rise 500 feet above the ancient floodplain of the glacial Mississippi River. The railroad ascends Crooked Creek, traversing a gravelly terrace or ancient floodplain, which continues from the Mississippi Valley up the tributary valleys. The glacial floodplain of the main valley continues up the tributary valleys because of the fact that the glacial streams entering the Mississippi were backed up and deposited their burdens of sand and gravel. Loess from the uplands has also been washed down and spread upon the valley bottoms and mixed with the sand and gravel.

The walls of the valley rise steep on either side. The formations here exposed are the Oneota dolomite (limestone) over the Jordan sandstone. The limestone is harder and the rock strata project out as hard shelves, because the soft friable sandstone crumbles out from under the harder limestone leaving projecting cliffs. Huge blocks of hard dolomite or limestone lie on the sides and bottoms of the valley, rolling down the slopes as they break off from the ledges outcropping above.

Caledonia.—14 miles from Reno; Alt. 1,177 feet. (Houston County.)

Do not get mad if the train does not make rapid time approaching Caledonia. The grade is heavy. A climb of 300 feet is being made from the terrace plain up to the undulating prairie at Caledonia. Caledonia is on the upland plain of the Oneota-Shakopee limestone formations. Loess covers the surface and softens the topography. East of Caledonia quarries in the limestone are operated.

Spring Grove.—24 miles; Alt. 1,322 feet.

From Caledonia to Spring Grove the railroad winds amongst hilly crags of Trenton limestone, following a ridge on the high prairie which here is not much loess-covered. The railroad is here more than 600 feet higher than the valley bottom of Crooked Creek 6 miles east of Caledonia.

This ridge is formed of the Trenton limestone (Platteville and Galena), which overlies the St. Peter sandstone. The ridge is a long "island" of hard limestone which has been cut into and eroded by streams but has not been carried away. The irregular character of the landscape is due to the hard quality of the limestone. The hard limestone caps and protects the underlying soft sandstone.

Mabel.—33 miles; Alt. 1,115 feet.

Three miles west of Spring Grove the railroad leaves the Trenton limestone and passes onto the St. Peter sandstone, and about a mile east of Mabel passes onto the still lower Shakopee limestone. Mabel is on the edge of the St. Peter sandstone. The railroad descends 200 feet from the Trenton limestone ridge west of Spring Grove to the Shakopee limestone east of Mabel. Mabel is near the head of Riceford Creek, which flows into Root River on a flat plain of erosion. This valley has been cut deep into the Shakopee limestone. Loess covers the uplands on either side of the valley.

Canton.—42 miles; Alt. 1,334 feet. Harmony.—47 miles; Alt. 1,336 feet.

From Mabel to Canton and Harmony the railroad follows the high prairie, which is here covered with a mantle of loess. Trenton limestone underlies the loess covering most of the way to Harmony. The stream courses to the north have been eroded through the Trenton limestones into the St. Peter sandstone, and farther north into the Shakopee and Oneota. East of Harmony a remnant of the Kansan drift is crossed. This represents one of the easternmost points of the drift sheet in this part of Minnesota. This is a remnant that remains upon the ridge while that over the valleys has been carried away by erosion.

Preston.—57 miles; Alt. 925 feet. (Fillmore County.)

Preston is 350 feet lower than the high prairie east of Harmony. The railroad dsecends the gorge-like valleys of Danbury and Camp Creeks. Root River valley has been eroded into the Oneota dolomite (limestone). The Trenton limestones and the St. Peter sandstone both extended over this region but have been carried away by erosion. The valley bottom all the way down to the Mississippi is terraced to that of a glacial floodplain. The sand, gravel, and mud of the valley came from the erosion of the valley and its tributaries together with glacial material from the Kansan drift sheet to the west. The river at the stone mill is 335 feet below the flat surface of the Trenton limestones which forms the general prairie surface above the valley to the south. The water-power at this mill is formed by the descent of the river from the Oneota limestone to the Jordan sandstone. This sandstone is well exposed opposite the mill, where it rises 25 feet above the level of the river. Above this the Oneota limestone is exposed for about 35 feet.

WABASHA-ZUMBROTA-FARIBAULT LINE

Dumfries.—12 miles from Wabasha. McCracken.—17 miles; Alt. 728 feet. Thielman.—19 miles; Alt. 737 feet. Keegan.—24 miles ; Alt. 753 feet. Millville.—28 miles; Alt. 779 feet. Jarrett.—30 miles; Alt. 786

feet. Hammond.—33 miles; Alt. 800 feet. Zumbro Falls.—41 miles; Alt. 836 feet.

The railroad ascends the Zumbro Valley following its winding course. The valley is terraced along its course, the terraces representing ancient floodplains formed during successive stages of the river's work in removing the drift sands and gravels carried down from the melting ice sheets. The terraces are, in part, composed also of materials derived from the erosion of the rocks in which the valley has been excavated. Definite glacial filling occurs as far up as the mouth of South Branch, which enters the main stream west of Zumbro Falls. From Kellogg to Thielman the valley is 2 miles in width and more than a mile most of the way to Millville, and lies about 400 feet below the upland plateaus both north and south of the valley. The lower valley is terraced by successive remnants of ancient floodplains at higher and higher levels above the river. Millville stands on a terrace 30 feet above the depot and 48 feet above the river. From the mouth of the valley up to Zumbro Falls the valley has been cut down into the St. Croix sandstone, the higher bluffs being capped by Shakopee limestone. Two mounds of St. Peter sandstone rise 70 feet above the surrounding plain about a mile south of the railroad and river between Jarrett and Hammond. The Shakopee limestone forms the valley sides and upland plain above Jarrett. The surface of the upland is covered with a deposit of loess.

Mazeppa.—51 miles; Alt. 929 feet. Forest Mills.—57 miles; Alt. 969 feet; Zumbrota.—59 miles; Alt. 974 feet. Wanamingo.—66 miles. Kenyon.—76 miles; Alt. 1,159 feet. (Crossing C. G. W. Ry.)

From Mazeppa across Goodhue County the valley is cut into Shakopee limestone. Zumbrota stands in the valley at the edge of a plain of Old Gray drift. Two gravelly hills of glacial deposit, known as kames, lie to the south. Another such kame-hill lies south of Wanamingo. The railroad west of Zumbrota runs on the Old Gray drift plain to Kenyon.

Epsom.—80 miles; Alt. 1,112 feet. Ruskin.—80 miles; Alt. 1,139 feet. **Faribault.**—93 miles; Alt. 1,003 feet. (Rice County.)

West of Kenyon the railroad again runs in the old glacial valley. Above Epsom glacial outwash sand and gravel form the valley floor. The eastern boundary of the Young Gray drift is crossed at Ruskin. Low-rolling morainic hills are crossed to Straight Valley and Faribault.

NORTHFIELD-RED WING LINE

Randolph.—9 miles from Northfield; Alt. 915 feet. Cannon Falls.—15 miles; Alt. 810 feet. Welch.—25 miles; Alt. 715 feet. **Red Wing.**—36 miles; Alt. 685 feet. (Goodhue County.)

Gravelly flat outwash plain above Randolph to Cannon Falls and below. Two mesas of sandstone capped by limestone, one north of Cannon River and the railroad, the other south, east of Randolph. Another similar mesa lies north of Cannon Falls. Chub Creek originally flowed north of these mesas and joined the Little Cannon east of Cannon Falls. (See Chap. XXV.) North of the valley between Cannon Falls and Welch a moraine of the Old Red drift caps the bluffs above the deep valley. (See Chap. IV.) The deep canyon-like valley from Cannon Falls to Red Wing was cut in preglacial time. (See Chap. XXV.) Limestones and sandstones outcrop in the steep sides of the canyon-like valley. The canyon bottom is glacial sand and gravels that have not been entirely removed by erosion since the ice sheet melted.

HASTINGS-COLOGNE LINE

Vermillion.—8 miles from Hastings; Alt. 843 feet. Empire—12 miles; Alt. 859 feet. (Crossing C., G. W. Ry.) Farmington.—17 miles; Alt. 903 feet.

These towns all on the red drift outwash plain (Young Red drift). South one mile is the Old Red drift, of the Illinoisan glacier.

Lakeville.—5 miles from Farmington, or 22 miles from Hastings; Alt. 967 feet. (Crossing Dan Patch Line west.)

Near western edge of outwash plain formed from the moraine of Young Red (Wisconsin) drift to the north, but town stands on Old Gray drift (Kansan). Lake north on boundary between Young Gray drift and Young Red drift. Loess area north of town.

Prior Lake.—33 miles from Hastings.

Rolling morainic hills of the great moraine formed on the east side of the Keewatin glacier. Prior Lake crossed by railroad west.

Shakopee.—29 miles; Alt. 751 feet. (Scott County.)

Railroad descends into the valley of the Minnesota, which is marked by high glacial terraces. Shakopee limestone outcrops in the valley sides. This is the original locality where this limestone was studied, and from which the name was given.

Chaska.—32 miles. (Carver County.) Carver.—35 miles.

These towns stand on gravel terrace across the river from Shakopee. The railroad ascends to the rolling till-plain and passes among the rolling hills of the great moraine which was crossed east of the river. The main line of the railroad is joined at Cologne.

FARMINGTON-MANKATO-WELLS LINE

Elko.—36 miles from St. Paul. Lonsdale.—45 miles; Alt. 1,094 feet.

The red drift outwash plain extends about 2 miles west of the crossing of the Dan Patch line. An "island" of Old Gray drift in the outwash plain lies north of the railroad crossing. Near the boundary of Dakota and Scott Counties is the eastern limit of Young Gray drift. Rolling morainic hills to Lonsdale and Montgomery. A fine group of morainic lakes is passed between these two places.

Montgomery.—53 miles; Alt. 1,060 feet. (Crossing M. & St. L. Ry.)

Montgomery is at the western edge of the great moraine which was formed along the eastern side of the Keewatin glacier.

LeSueur Center.—62 miles. (LeSueur County.) Cleveland.—68 miles; Alt. 1,046 feet.

Gently undulating till-plain. Numerous small lakes.

Kasota.—78 miles; Alt. 877 feet.

The Minnesota Valley is about 250 feet deep. Sandy and gravelly deposits of glacial outwash fill the valley in places 150 feet in depth. The River Warren, while it was carrying away the waters from Lake Agassiz, cleared out much of the gravel and sand, leaving terraces marking earlier floodplain levels. Rock ledges are exposed in the valley sides 50 to 75 feet above the river.

Mankato.—85 miles; Alt. 785 feet. (Blue Earth County.)

From Kasota to Mankato the railroad runs on the gravel filling of the valley. South of Mankato the line climbs to the rolling till-plain, then crosses Maple River valley. Limestone ledges are exposed in the valley sides of the Minnesota and of the Maple. The till-plain is flat about Rapidan and south to Good Thunder. The soil is a fine quality of silt loam. The big valleys of the Blue Earth west and of the Maple east, can be seen from the train between Rapidan and Good Thunder.

Good Thunder.—99 miles; Alt. 979 feet. Mapleton.—106 miles. Minnesota Lake.—115 miles; Alt. 1,043 feet. Wells.—123 miles; Alt. 1,162 feet.

Gently rolling till-plain, in places flat, with frequent lakes. Definite drainage lines have not become established by modern streams since the last invasion of the ice sheet.

ST. CLAIR BRANCH

Freeborn.—13 miles from Albert Lea.

Two large moraines are crossed between Albert Lea and Freeborn, with intervening gently rolling till-plain. Freeborn Lake south, and small lakes and sloughs west. This district is nominally drained by Cobb River, but is really not drained. It is a typical young landscape of the Keewatin drift sheet.

Matawan.—21 miles. Waldorf.—28 miles. Pemberton.—33 miles.

Gently undulating till-plain or ground moraine. Splendid farming lands. The Keewatin drift is called a "gray" drift because of the presence of limestone from the great limestone fields of Canada from which it came. There has been little leaching of the soil since the glacier disappeared, and the soil possesses great fertility.

St. Clair.—40 miles.

Continuation of the till-plain. LeSueur River has eroded a channel 50 feet in depth. There has been little erosion of the adjacent lands as few tributary streams have yet developed.

HASTINGS-STILLWATER LINE

Afton.—14 miles from Hastings; Alt. 693 feet. Lakeland.—18 miles; Alt. 725 feet. **Stillwater.**—25 miles. (Washington County.)

The St. Croix River joins the Mississippi opposite Hastings. From the junction of the two rivers up to Afton the surface formation is that of the Old Red drift. (See Chap. IV.) Lakeland and Stillwater are on terraces of the large glacial stream that one time carried the waters of Lake Duluth to the Mississippi, and cut the gorge at The Dalles. (See Chap. XVII.)

HUTCHINSON LINE

Hutchinson.—14 miles from Glencoe; Alt. 1,042 feet.

Rolling till-plain Glencoe to Hutchinson. North of Hutchinson is the large moraine which extends in an irregular belt from St. Paul to Fergus Falls and beyond. A group of typical morainic lakes lies north of Hutchinson. These are distributed in the grandest confusion amongst the morainic knobs and tumbling hills.

ORTONVILLE-FARGO BRANCH

Clinton.—13 miles. Graceville.—21 miles; Alt. 1,111 feet. (Crossing Great Northern Railway.)

Leaving the Minnesota Valley at Ortonville, and passing the southeastern end of Big Stone Lake, rolling till-plain is crossed on which are many small lakes and ponds.

Collis.—26 miles; Alt. 1,066 feet.

Collis stands on the gravelly Herman Beach, the highest shore-line of Lake Agassiz. The surface of the lake plain slopes gently to the northward. The plain is lake-washed clayey till.

Dumont.—31 miles; Alt. 1,043 feet. **Wheaton.**—38 miles; Alt. 1,019 feet. (Traverse County.) White Rock (South Dakota).—47 miles; Alt. 973 feet.

Dumont is on the lake-washed plain. A mile north the Norcross Beach of Lake Agassiz is crossed,—a well-defined sandy and gravelly ridge. Wheaton is on the Tintah Beach, and Mustinka River is crossed immediately north. The plain is that of lake-washed clayey till. Lower Tintah Beaches are crossed to the north. White Rock, S. D., is across the Bois des Sioux River. Lake Traverse lies to the west, from which the Bois des Sioux flows north, being the upper portion of the Red River of the North.

CHAPTER XXIX

GEOLOGY FROM A CAR WINDOW

CHICAGO & NORTHWESTERN RAILWAY

MANKATO-BLACK HILLS LINE

Mankato.—86 miles from St. Paul; Alt. 783 feet. (Blue Earth County.) (For Mankato-Winona Line see p 284.) (For Nicollet Line see p. 287.)

The valley of the Minnesota is here broad and deep, and bordered by glacial terraces.

Judson.—96 miles; Alt. 809 feet.

From Mankato west the railroad runs across a terrace of limestone to Judson, west of which are gravel terraces. Cambria stands on the gravel filling of the glacial terrace.

New Ulm.—112 miles; Alt. 842 feet. (Brown County.)

The railroad follows the plain of glacial deposits in the valley. A bluff of pinkish red quartzite is exposed on the east side of the valley below New Ulm. This rock stood out as an island in the sea when the limestones that outcrop in the valley were deposited. (See Chap. XI.) At New Ulm terraces of the glacial Minnesota River (River Warren) are well seen. The station is on a terrace above the river, the business part of the city is on a higher terrace, and the residence section is on a still higher terrace, and the cemetery stands on a fourth and the highest terrace. The residence part of the city was at one time an island in the great broad glacial river. The old channel lies west of the city.

Essig.—112 miles; Alt. 1,007 feet. Sleepy Eye.—126 miles; Alt 1,039 feet. (Evan-Marshall Line see p. 289.) (Redwood Falls Line see page 289.)

After leaving the valley west of New Ulm the plain is gently undulating ground moraine till the Cottonwood Valley is reached west of Springfield. The clayey till contains enough sand to make a splendid soil. A moraine extends southwest from Sleepy Eye, and bordering this and related to it is an outwash deposit in Cottonwood Valley to the south.

Cobden.—132 miles; Alt. 1,038 feet. Springfield.—140 miles; Alt. 1,028 feet.

Deep broad valley of Cottonwood River was cut by glacial waters. West of Springfield a moraine borders the Cottonwood Valley on the north, and this moraine continues south of the railroad along the north side of Little Cottonwood Valley. The valley is silted up with sand and gravelly outwash from this moraine, or from the ice by which the moraine was formed. The glacial Cottonwood River originally flowed by Sanborn to Dotson and by the present valley of Little Cottonwood. Later, as the ice melted, the stream took the course by Springfield.

Sanborn.—148 miles; Alt. 1,099 feet. Lamberton.—155 miles; Alt. 1,145 feet. (For Vesta Line see p. 289.) (For Mason City Line see p. 287.)

Sanborn stands on the glacial outwash filling of Cottonwood Valley. Lamberton is on the gently rolling till-plain immediately south of the outwash-filled valley.

Revere.—160 miles; Alt. 1,153 feet.

Small sandy terminal moraine. Undulating till-plain west.

Walnut Grove.—166 miles; Alt. 1,216 feet. Tracy.—173 miles; Alt. 1,399 feet. (Marshall-Redfield Line see p. 289.)

Three low moraines crossed Walnut Grove to Tracy. A fourth moraine between Tracy and Garvin. These moraines were formed on the west side of the Keewatin glacier. They are clayey in character, generally, and not very strongly rolling. The soil of these and of the intervening till-plains is of fine quality.

Garvin.—180 miles; Alt. 1,538 feet. Balaton.—186 miles; Alt. 1,526 feet. Burchard.—193 miles; Alt. 1,647 feet. (Crossing under G. N. Ry.)

On gently rolling till-plain between two broad moraines.

Tyler.—200 miles; Alt. 1,748 feet. (For Astoria Line see p. 290.)

Rolling till-plain, with many small lakes in depressions.

Lake Benton.—208 miles; Alt. 1,755 feet.

Lake Benton (lake) lies in an old partially filled valley. The great Altamont moraine is here crossed, the high hills of which can be seen both to the north and south. The valley in which Flandreau Creek flows is a channel of glacial drainage, silted up with sand from the edge of the melting ice sheet. The moraine and the sand filling in the old valley prevent the waters of lake Benton from flowing away.

Verdi.—214 miles; Alt. 1,768 feet.

The railroad runs down the broad outwash plain of the Flandreau Creek valley, and then turns west to Verdi, which is on gently undulating till-plain bordering the outermost moraine. At the State line a sandy outwash valley is crossed, and the Old Gray drift of the Kansan ice sheet extends into South Dakota.

MANKATO-WINONA LINE

Eagle Lake.—9 miles from Mankato; Alt. 1,019 feet.

The railroad swings out of the deep valley of the Minnesota to the rolling till-plain at Eagle Lake.

Smith's Mill.—16 miles; Alt. 1,060 feet. Janesville.—19 miles; Alt. 1,070 feet.

Undulating or gently rolling till-plain to Waseca. Beautiful Lake Elysian north.

Waseca.—29 miles; Alt. 1,159 feet. (Waseca County.) (Crossing M. & St. L. Ry.) Meriden.—35 miles; Alt. 1,137 feet.

Rolling-hilly moraine east of Waseca nearly to Meriden. Group of fine morainic lakes east. Gently rolling till-plain continues to Owatonna.

Owatonna.—44 miles; Alt. 1,150 feet. (Crossing C., R. I. & P. Ry., C., M. & St. P. Ry.) (Steele County.)

City stands on moraine, which extends 1 mile west. A belt of low morainic hills extends east, north of Havana. The very crooked Straight River flows through the city toward the north.

Havana.—49 miles; Alt. 1,219 feet. Anderson.—53 miles; Alt. 1,275 feet. Claremont.—59 miles; Alt. 1,287 feet.

A moraine 2 miles wide is crossed east of Havana, and east of this is a belt of undulating till-plain. This is the easternmost moraine formed by the Keewatin glacier of the Wisconsin ice sheet. Half a mile west of Claremont is the edge of the Young Gray drift and the beginning of the Old Gray drift (Kansan). (See Chap. IV.) The topography is now less rolling. Valleys are more deeply eroded, and there are no more lakes.

Dodge Center.—66 miles; Alt. 1,243 feet. (Crossing C. G. W. Ry.)

The Old Gray drift plain is flat at Claremont, gently undulating about Dodge Center, and becomes gently rolling at Kasson. The valleys of the head streams of Middle Branch of Zumbro River are deep and bordered often by trees. The valleys were eroded by the ice waters from the melting of the Keewatin glacier, and flowed away across the old Kansan drift plain.

Kasson.—72 miles; Alt. 1,242 feet. Byron.—77 miles; Alt. 1,262 feet. **Mantorville.**—Alt. 1,166 feet. (Dodge County.)

The deposit of Old Gray drift is very thin here, and wind-blown loess occurs on the knolls. At Byron the surface is that of loess rather than drift. The surface is more rolling, owing to the piling of the fine loess dust by the winds before vegetation had formed a cover over the land. A gravelly knoll, technically known as a "kame" lies south of the railroad about 2 miles, between Kasson and Byron. Mantorville, 4 miles north from Kasson, is in the valley of Middle Branch of the Zumbro. Limestone is exposed in its sides. A fine view of this valley from the plain east of Byron. Eastward there is almost no drift. The

"Driftless Area" is being entered. No lakes mark the landscape, and the valleys become increasingly deeper.

Rochester.—86 miles; Alt. 994 feet. (Crossing C. G. W. Ry.) (Olmstead County.)

Rochester is located in a large amphitheater-like basin in which several upper tributaries of South Branch of Zumbro River meet. The valley bottom is broad, silted up with glacial sands and gravels together with materials derived from the erosion of the surrounding rocks. The basin is surrounded by limestone capped hills, on top of which are loess deposits. South the surface is that of the Old Gray drift, though very thin, and the capping of loess is very light. (For Rochester-Zumbrota Line see p. 300.)

Haverhill.—92 miles; Alt. 1,125 feet. Eyota.—99 miles; Alt. 1,235 feet.

Haverhill is in a small valley, a tributary of the Zumbro, which has been eroded into the limestone. Eyota is on the Old Gray drift plain which is covered with loess to the north.

Dover.—104 miles; Alt. 1,147 feet. (Crossing C. G. W. Ry.) St. Charles.—108 miles; Alt. 1,143 feet. Utica.—114 miles; Alt. 1,174 feet.

The railroad here runs on a ridge which forms the divide between Root River to the south and Whitewater to the north. This ridge is covered with a thin mantle of Old Gray drift as far as Utica. A gravelly kame lies north of Dover 1 mile. A tributary of the Whitewater between Dover and St. Charles is eroded into the limestone.

Lewiston.—117 miles; Alt. 1,214 feet. Stockton.—125 miles; Alt. 769 feet. Minnesota City.—130 miles; Alt. 677 feet. **Winona.**—136 miles; Alt. 671 feet. (Winona County.)

Lewiston is on the loess-covered upland. The surface is gently undulating to rolling. Stockton is in the deep valley of a tributary of the Rollingstone. The stream is a tiny brook, yet the valley is large, its broad bottom filled in with glacial outwash and detritus from erosion of the country rocks. Minnesota City is still farther down, upon a glacial flood-plain or terrace. The railroad swings around upon the broad glacial flood-plain of the Mississippi to Winona.

PLAINVIEW BRANCH

Viola.—6 miles from Eyota; Alt. 1,130 feet. Elgin.—11 miles; Alt 1,071 feet. Plainview.—16 miles; Alt. 1,169 feet.

Viola and Plainview are situated upon the loess-covered upland plain. Elgin stands on the glacial and alluvial filling of the north branch of Whitewater River. The valley becomes rapidly deeper downstream. Limestone outcrops in the valley sides south of Elgin. It is a magnificent and fertile valley, this loess-covered plain. A drive long to be remembered and well worth the making is from Plainview to Winona via Beaver, Elba, Altura, and down the Rollingstone Valley to Minnesota City and Winona.

CHATFIELD BRANCH

Chatfield.—12 miles from Eyota; Alt. 980 feet.

Chatfield is located in the terraced valley of Root River. The Old Gray drift plain extends 3 or 4 miles south of the C. G. W. Railway crossing, then the railroad descends rapidly down a tributary valley to Chatfield, which stands on terraces above the river bottoms. Limestone rocks outcrop in the valley sides. Surrounding landscape outside the valleys is loess-covered, and fine farms testify to the fertility of the country.

MANKATO-NICOLLET-NEW ULM LINE

Kasota.—6 miles from Burdette; Alt. 812 feet. **St. Peter.**—8 miles; Alt. 817 feet. (Nicollet County.) Traverse.—13 miles; Alt. 996 feet. Oshawa.—18 miles; Alt. 983 feet. Nicollet.—23 miles. Courtland.—30 miles; Alt. 939 feet. New Ulm.—37 miles; Alt. 842 feet.

The railroad crosses the Minnesota River below Kasota to St. Peter, then swings around upon the flat till-plain at Traverse. St. Peter stands upon glacial terraces of the Minnesota Valley. Many lakes lie upon the flat or gently rolling till-plain. Goose Lake is crossed by the railroad near Oshawa. Swan Lake is a large sheet of water having many islands to the northwest of Nicollet. Courtland is near the rock promontory described in Chapter XI as Old Redstone. New Ulm is on terraces of the Minnesota Valley. (See Chap. XV.)

MASON CITY LINE

Dotson.—7 miles from Sanborn; Alt. 1,072 feet.

Hilly sandy moraine both north and south. The railroad follows the old glacial channel which has been referred to as extending far west of Sanborn bordering the moraine. The ancient channel continues south and east. When the moraine north of Dotson was being formed the waters of this glacial stream probably discharged through the valley of the Watonwan.

Comfrey.—14 miles; Alt. 1,129 feet. Darfur.—19 miles; Alt. 1,147 feet.

Moraine half way to Darfur, then gently rolling till-plain. West of Darfur a ridge or low hill of quartzite rock extends westward about 20 miles. This is a remnant of the ancient pre-Cambrian formations. It was probably an island in the sea when the Paleozoic formations were laid down in this region. (See Chapters X & XI.) Markings made by stones carried in the ice sheet are preserved on these hard rock surfaces and show a movement of the ice to have been south by a little east.

Butterfield.—26 miles; Alt. 1,174 feet. (Crossing C., St. P., M .& O. Ry.) Odin.—33 miles; Alt. 1,211 feet. Triumph.—40 miles; Alt. 1,218 feet. (Crossing M. & St. L. Ry.) Fox Lake.—46 miles; Alt. 1,241 feet.

The railroad follows the course of the moraine from Darfur to Fox Lake, mostly on it. Odin, Triumph, and Fox Lake are on the moraine. Near Odin Watonwan River is crossed. This river drains the West Chain of Lakes, which borders the moraine on the west. Elm Creek crosses this moraine 3 miles north of Fox Lake, passing near the south end of the Chain of Lakes, but does not tap them. Northeast of Fox Lake this creek taps the north group of the Middle Chain of Lakes, and finally reaches Blue Earth River. Center Creek drains Fox and Eagle Lakes, and crosses the Middle Chain of Lakes at Fairmont, entering Blue Earth River 2 miles above Elm Creek. (See Chap. XXIII.)

Welcome.—49 miles; Alt. 1,228 feet. **Fairmont.**—57 miles; Alt. 1,187 feet. (Martin County.) (Crossing C., M. & St. P. Ry.)

Welcome is amongst morainic hills, which extend to Fairmont and south. Fairmont is at the east side of the moraine, with flat till-plain to the east. The moraine extends south to the State line, and the Middle Chain of Lakes lies immediately west of the moraine. Here are some of the most beautiful lakes in the State (or any other State). About 5 miles east is the East Chain of Lakes, a moraine lying on both the east and west. (See Chap. XXIII.)

Imogene.—63 miles; Alt. 1,130 feet. Guckeen.—69 miles; Alt. 1,113 feet. **Blue Earth.**—75 miles; Alt. 1,087 feet. (Faribault County.)

From Fairmont to Blue Earth and beyond the landscape is that of a flat or gently undulating till-plain, except that a low moraine is crossed west of Guckeen.

Frost.—85 miles; Atl. 1,129 feet. Bricelyn.—92 miles; Atl. 1,184 feet. (Crossing C., R. I. & P. Ry.) Kiester.—96 miles; Alt. 1,231 feet.

Gently undulating till-plain continues to Bricelyn where a moraine with rolling hills is entered. North of Bricelyn, is an ancient sandy lake bottom, the lake caused by ponding of the glacial waters from the melting ice sheet. The moraine continues from Kiester beyond the State line.

BURT LINE

Ceylon.—10 miles from Fox Lake; Alt. 1,261 feet.

Gently rolling till-plain from Fox Lake south to Ceylon and the State line, with numerous lakes. North fork Des Moines River is crossed north of Ceylon in an outwash valley from the moraine west of Sherburn. A small moraine at Ceylon.

REDWOOD FALLS LINE

Evan.—134 miles from St. Paul; Alt. 1,029 feet. Morgan.—140 miles; Alt. 1,046 feet.

Gently undulating ground moraine or till-plain, Sleepy Eye to and beyond Morgan. Narrow sandy moraine 10 miles long and one-fourth mile in width, 2 miles west of railroad and parallel with it. Another narrow sandy moraine crossed east of Redwood Falls.

Redwood Falls.—152 miles; Alt. 1,036 feet. (Redwood County.)

A picturesque gorge has been cut in the gránite rock at and below Redwood Falls by the Redwood River.

"The beauty of this deep rock-walled gorge, about 1½ miles long with its cascades and rapids and meandering river, can scarcely be over-stated."—(Upham.)

EVAN-MARSHALL LINE

Clement.—144 miles from St. Paul; Alt. 1,057 feet.

On long winding sandy moraine which extends from north of Cobden in a narrow belt a fourth of a mile to a half mile in width northwest to Vesta, where it joins the larger moraine.

Wabasso.—155 miles; Alt. 1,080 feet. Lucan.—160 miles; Alt. 1,093 feet. Milroy.—170 miles; Alt. 1,105 feet. Dudley.—176 miles; Alt. 1,150 feet. **Marshall.**—180 miles; Alt. 1,167 feet. (Lyon County.)

Gently undulating till-plain. Marshall is on the moraine which lies north of Cottonwood Valley at Sanborn.

VESTA LINE

Wand.—154 miles from St. Paul; Alt. 1,093 feet. Wabasso.—160 miles; Alt. 1,080 feet. Seaforth.—167 miles; Alt. 1,054 feet. Vesta.—172 miles; Alt. 1,061 feet.

Seaforth is at the eastern end of an outwash glacial channel that extends for 50 miles, to Canby in western Yellow Medicine County, along the southwest border of a large moraine which extends northwest of Lac qui Parle County, beyond the State line. Redwood River, Three Mile Creek, and Yellow Medicine River each meander for a time on the sandy plain of this ancient water course.

MARSHALL-REDFIELD LINE

Amiret.—180 miles from St. Paul; Alt. 1,282 feet.

Till-plain, on east slope of Coteau des Prairies.

Heckman.—186 miles; Alt. 1,170 feet. **Marshall.**—190 miles; Alt. 1,167 feet. (Lyon County.)

An outwash glacial channel extends from Heckman southeast to and beyond Sanborn, along which meanders the Cottonwood River. A prominent moraine extends from beyond the South Dakota line southeast for 125 miles. The outwash channel referred to was formed by waters from the melting ice sheet at the time of formation of this moraine. Marshall stands on this moraine.

Minneota.—203 miles; Alt. 1,168 feet. Taunton.—208 miles; Alt. 1,178 feet. Porter.—213 miles; Alt. 1,211 feet. Canby.—221 miles; Alt. 1,240 feet. Burr.—225 miles; Alt. 1,327 feet. Gary.—231 miles; Alt. 1,483 feet.

The railroad runs on or near this moraine to Taunton. Between Taunton and Porter a small outwash plain is crossed. At Canby another outwash plain is crossed, related to the same moraine. Canby is located at the east side of a moraine, that to the west and parallel with the one just referred to. Burr is on rolling till-plain. Gary is on the edge of the great moraine which marks the second halting place of the western edge of the great Keewatin ice sheet. This moraine has been called by Professor Warren Upham the Gary moraine. It is well developed here. This moraine extends beyond Gary in South and North Dakota, and southeastward across Minnesota to Jackson County and beyond in Iowa.

ASTORIA LINE

Arco.—208 miles from St. Paul; Alt. 1,657 feet.

Rolling till-plain with frequent lakes, Tyler to Arco.

Ivanhoe.—215 miles; Alt. 1,655 feet. (Lincoln County.) Hendricks.—225 miles; Alt. 1,783 feet.

Moraine crossed north from Arco, then on border of rolling till-plain, to Ivanhoe. West from Ivanhoe cross moraine again, and on to rolling till-plain to Hendricks. Many lakes both in the moraine and on the till-plain.

THE CHICAGO, ST. PAUL, MINNEAPOLIS & OMAHA RAILWAY

SIOUX CITY AND OMAHA LINE

St. Paul.—0 miles; Alt. 706 feet. (Ramsey County.)

Leaving Union Depot the railroad follows the Mississippi Valley to Mendota, where the Minnesota Valley joins the Mississippi. Fort Snelling stands on the high terrace of the glacial Mississippi, which lies to the west. The St. Peter sandstone outcrops in the valley sides, and overlying this formation is the harder and more enduring Trenton limestone. The sandstone is very soft and friable, and the limestone overlying protects the softer sandstone layers, resulting in steep walls as sides of the valley.

Mendota.—6 miles from St. Paul; Alt. 735 feet. Savage.—19 miles.

On the alluvial plain of the glacial Minnesota River. St. Peter sandstone and Trenton limestone outcroppings along sides of valley. On the bluffs above and bordering the valley a clayey terminal moraine extends from St. Paul to Mendota and west beyond Savage.

Shakopee.—28 miles; Alt. 758 feet. (Crossing C., M. & St. P. Ry.) (Scott County.)

Broad alluvial plain on south side of valley, Savage to Shakopee. The Paleozoic formations, St. Peter sandstone, and Trenton limestone outcrop along valley sides.

Mudbaden.—37 miles. Jordan.—39 miles; Alt. 755 feet. (Crossing M. & St. L. Ry.)

On alluvial flood-plain or terrace of glacial Minnesota River. An "island" of Paleozoic rock (Trenton limestone) surrounded by alluvial plain west of Jordan.

Belle Plaine.—46 miles; Alt. 731 feet. Henderson.—58 miles; Alt. 741 feet. LeSueur.—62 miles; Alt. 760 feet.

From Belle Plaine to Ottawa the railroad runs upon the alluvial plain of the valley bottom. This broad valley is filled in with drift borne by the later glacial Minnesota River.

Ottawa.—68 miles.

Valley is here narrow, a headland of limestone jutting out into the valley. Rolling till-plain above on either side of the valley.

St. Peter.—75 miles; Alt. 754 feet.

The Minnesota Valley is here about 250 feet in depth. Glacial terraces border the valley, the highest about 150 feet above the present river. The city stands upon glacial gravel terraces. Rock ledges appear in the valley sides up to heights of 50 and 75 feet.

Kasota.—77 miles; Alt. 807 feet.

A fine building stone, known as Kasota sandstone, of Cambrian age, is quarried here.

Mankato.—86 miles; Alt. 783 feet. (Blue Earth County.)

Blue Earth River enters the Minnesota from the south. Both valleys are deeply eroded into the Paleozoic formations. Glacial terraces occur on the side of the valley opposite the city.

Lake Crystal.—99 miles; Alt. 987 feet.

The railroad leaves the deep valley of the Minnesota after crossing the Blue Earth, and ascends to the rolling till-plain. Crystal Lake is a good example of a morainic lake. The town stands at the east end of a moraine, which extends south of the railroad to Madelia. Two small moraines rise from the till-plain, one south the other north of the track, between Lake Crystal and Madelia. (Winnebago and Blue Earth Line see p. 294.)

Madelia.—110 miles; Alt. 1,028 feet.

Moraine one mile in width; group of morainic lakes east. Outwash plain crossed west.

Grogan.—116 miles; Alt. 1,049 feet.

On rolling till-plain, clayey in character. (Fairmont Line see p. 294.)

St. James.—122 miles; Alt. 1,084 feet. (Crossing M. & St. L. Ry.)

Moraine 3 miles in width. This moraine extends almost unbroken in a northwest-southeast direction across the State, a distance of nearly 150 miles, varying in width from less than 1 mile to 3 miles.

Butterfield.—130 miles; Alt. 1,191 feet. (Crossing C. & N. W. Ry.)
Mountain Lake.—134 miles; Alt. 1,306 feet.

Rolling till-plain or ground moraine east. West cross terminal moraine. Mountain Lake on gently rolling till-plain.

Bingham Lake.—143 miles; Alt. 1,425 feet.

Rolling till-plain, with morainic lakes and sloughs. Terminal moraine one-half mile in width crossed 3 miles east. (For Currie Line see p. 295.)

Windom.—148 miles; Alt. 1,359 feet. (Cottonwood County.)

Cross moraine 2 miles wide. Windom stands on outwash filling in Des Moines Valley. Blue Mounds, 3 miles northwest, are drift hills that rise 100 feet or more above their bases.

Wilder.—154 miles; Alt. 1,456 feet. Heron Lake.—160 miles; Alt. 1,424 feet. (For Pipestone Line see p. 294.)

Rolling moraine at Wilder, followed by undulating till-plain west. Morainic lakes. Gently rolling till-plain continues to Worthington.

Heron Lake was once one of the most famous lakes for wild fowl in Minnesota. It is bordered by extensive marshes, once the home of vast numbers of Blue-winged Teal, Mallard, and Gadwell. In early times this was the nesting place of a considerable number of Trumpeter swans, one pair breeding there as late as 1883. Heron Lake is remarkable for the many varieties of water-fowl frequenting its waters, practically all kinds common to inland waters being found here. A day's shooting often consists of 10 to 15 different species.

Miloma.—164 miles; Alt. 1,433 feet. (Crossing C., M. & St. P. Ry.) Brewster.—170 miles; Alt. 1,493 feet. **Worthington.**—178 miles; Alt. 1,595 feet. (Nobles County.) (Crossing C., R. I. & P. Ry.) Org.—182 miles. Bigelow.—187 miles; Alt. 1,637 feet.

Lakes on till-plain represent old valleys partially filled with drift. Two moraines crossed between Org and Bigelow. Outwash plain west of Bigelow.

SIOUX FALLS AND MITCHELL LINE

Rushmore.—190 miles from St. Paul; Alt. 1,683 feet.

Two moraines are crossed between Worthington and Rushmore, separated by a belt of till-plain varying from 1 to 5 miles in width. These moraines are the outermost of those formed at the west side of the Keewatin glacier, and lie along the high plain of the Coteau des Prairies.

Adrian.—197 miles; Alt. 1,565 feet.

A thin covering of drift from the Keewatin ice sheet (Wisconsin) extends westward from the moraine to the east. This drift forms a thin veneer over the old Kansan drift. Drainage is along lines established before the last ice invasion, and is southwestward to the Big Sioux and the Missouri. The valleys are broad with sluggish streams meandering on gravelly outwash. Two miles west of Adrian the landscape is that of the Old Gray drift (Kansan).

Magnolia.—204 miles; Alt. 1,530 feet. **Luverne.**—211 miles; Alt. 1,469 feet. (Rock County.) (Crossing C., R. I. & P. Ry.)

Magnolia is on the Old Gray drift plain, between two valleys having outwash filling. Luverne is on the sandy and gravelly outwash that forms the broad glacial floodplain of Rock River valley. Ash Creek is on the outwash filling of this valley on the branch that runs south.

About 2 miles north of Luverne a hill of ancient quartzite rock rises 150 to 200 feet above the surrounding landscape. It is 10 to 12 miles in length north and south, and about 2 miles in width. Another outcropping of this ancient rock about 3 miles north and south by 1 mile in width lies 1 to 2 miles west of the larger hill just described. These are outlying remnants of the primitive formations of Minnesota. (See Chap. X.)

Beaver Creek.—219 miles; Alt. 1,461 feet. Manley.—220 miles.

From Luverne west the plain is loess-covered. (See Chapters I & XXVI.) A characteristic broad sweep in the surface lines distinguishes this district from the more abruptly rolling drift deposits farther east. The topography here is that of preglacial time, modified by deposits of loess over the thin veneer of Old Gray drift.

WINNEBAGO AND BLUE EARTH LINE

Garden City.—104 miles from St. Paul; Alt. 969 feet.

In valley of Watonwan River. Sandy moraine north, 2 miles in width. Rolling till-plain south.

Vernon Center.—100 miles; Alt. 1,026 feet. Amboy.—115 miles; Alt. 1,046 feet.

In valley of Blue Earth River. Clayey till-plain, splendid soil, gently rolling, south to Amboy, Winnebago, and the State line.

Winnebago.—123 miles; Alt. 1,098 feet. (Crossing C., M. & S. P. Ry.) **Blue Earth.**—133 miles; Alt. 1,086 feet. (Faribault County.) (Crossing C. & N. W. Ry.) Elmore.—143 miles; Alt. 1,130 feet.

Gently rolling or undulating till-plain continues to the State line. Blue Earth River meanders over the bottom of a valley that becomes deep and broad northward.

FAIRMONT LINE

Lewisville.—119 miles from St. Paul; Alt. 1,065 feet. Truman.—126 miles; Alt. 1,112 feet. Northrop.—132 miles; Alt. 1,144 feet. **Fairmont.**—138 miles; Alt. 1,160 feet. (Martin County.)

Madelia south to Truman is gently rolling till-plain, with morainic lakes and undrained depressions. Moraine crossed south of Truman. Elm Creek, which is crossed south of the moraine. This creek meanders over a broad outwash valley bottom northwest of Northrop, and before it enters the Chain of Lakes. The outwash is related to a moraine which lies north. Elm Creek ''drains'' the Middle Chain of Lakes, if indeed they may be said to be drained. Farther south Center Creek is crossed, which also ''drains'' part of this Chain of Lakes. A moraine is crossed north of Fairmont, and this moraine extends south of Fairmont east of the Middle Chain of Lakes to the State line.

The Middle Chain of Lakes, like the other two chains which lie east and west of this, are remnants of valleys by which the land was drained before the invasion of ice by which the drainage systems were destroyed. (See Chap. XXIII.)

PIPESTONE LINE

Dundee.—168 miles from St. Paul; Alt. 1,453 feet. Lime Creek.—174 miles; Alt. 1,492 feet. Avoca.—180 miles; Alt. 1,541 feet. **Slayton.**—186 miles; Alt. 1,611 feet. (Murray County.)

All on undulating or gently rolling till-plain. Pooling streams occur, but these can hardly be said to drain the landscape. The landscape is young, the original drainage systems having been destroyed by the invasion of the great ice sheet. Lakes occupying depressions in the till-plain, when connected, form a line of "drainage" in name, but the land is essentially without drainage systems. Local drainage from the slopes gives good character to the soil, which is very fertile.

Hadley.—191 miles; Alt. 1,696 feet.

At north edge of a rolling, hilly moraine. Till-plain south.

Lake Wilson.—196 miles; Alt. 1,662 feet.

Near boundary between till-plain and rolling sandy moraine, 4 miles in width. Glacial outwash channel west of this moraine.

Woodstock.—204 miles; Alt. 1,829 feet.

On rolling till-plain. Three miles west cross outwash plain in valley of upper Rock River. Till-plain, gently undulating to rolling to Eton and Pipestone.

Pipestone.—215 miles; Alt. 1,732 feet. (Pipestone County.)

Hard quartzite rock outcrops at Pipestone over an area about 3 miles north and south and 1 to 2 miles in width. The western margin of the later drift (Wisconsin) is along the west side of the townsite. Glacial striæ or markings on the hard quartzite rock surfaces have a trend south by southwest. About a mile north of the city, on the Indian reservation, is the famous pipestone quarry. This rock is an indurated clay (decomposed quartzite leached and compressed into a definite layer), the deposit having a thickness of about 1½ feet, and overlain by several feet of hard rock. West of Pipestone the land surface is that of the Old Gray drift. This old drift plain is cut across between Pipestone and Airlee by an outwash filled valley.

CURRIE LINE

Delft.—149 miles from St. Paul; Alt. 1,443 feet.

North from Bingham Lake the railroad runs amongst rolling morainic hills to and beyond Delft.

Jeffers.—157 miles; Alt. 1,479 feet.

On rolling till-plain. A belt of morainic hills lies east, same as that at Delft. North about 3 miles is the west end of a low quartzite hill which extends eastward about 15 miles, and having a width of 1 to 2 miles. Glacial striæ on surfaces of this rock have a south-southeasterly trend. West the railroad crosses a hilly moraine, clayey in character.

Storden.—164 miles; Alt. 1,394 feet. Westbrook.—169 miles; Alt 1,422 feet.

On rolling till-plain.

Dovray.—175 miles; Alt. 1,520 feet.

On sandy moraine 3 miles in width.

Currie.—182 miles; Alt. 1,483 feet.

On rolling till-plain. Sandy moraine north and east. Clayey moraine west and south. Lakes Sarah and Shetek, morainic lakes, sources of the Des Moines River, north.

ST. PAUL-STILLWATER LINE

Lake Elmo.—12 miles from St. Paul; Alt. 935 feet. **Stillwater.**—18 miles. (Washington County.)

From Union Depot, St. Paul, the railroad climbs out of the Mississippi Valley by a partially filled preglacial valley, and crosses the rolling moraine to Lake Elmo, which is at the north end of an outwash plain which fills an old valley. (See Chap. XVII.) East of Lake Elmo to Stillwater Junction a moraine is crossed, then the railroad follows a terrace of the St. Croix to Stillwater. Stillwater is built on glacial terraces of the St. Croix. (See Chap. XVII.)

CHAPTER XXX

GEOLOGY FROM A CAR WINDOW

THE CHICAGO GREAT WESTERN RAILWAY

MINNEAPOLIS & ST. PAUL-CHICAGO LINE

Minneapolis to St. Paul runs over tracks of Great Northern Railway. (See p. 316.)

St. Paul.—10 miles from Minneapolis; Alt. 708 feet. (Ramsey County.)

Leaving Union Depot the railroad crosses the Mississippi River and follows the west bank to South St. Paul. At South Park an outwash of red gravel from the red drift moraine on the higher upland is passed.

South St. Paul.—15 miles from Minneapolis; Alt. 705 feet.

Stock yards and packing plants are on the alluvial flats, or modern river deposits. The residence part of South St. Paul is on the high glacial terrace.

Inver Grove.—18 miles from Minneapolis; Alt. 720 feet.

From South St. Paul to 2 miles beyond Inver Grove the railroad runs on a low terrace of Oneota dolomite (limestone), the glacial terrace lying at a level about 100 feet higher. About 3 miles south of Inver Grove the railroad cuts across the red drift moraine. Before reaching Rich Valley an ancient waterway is crossed, this being an old, partly filled valley which was once the course of the Mississippi from Mendota to Pine Bend. (See Chap. XVI.)

Rich Valley.—26 miles; Alt. 865 feet. Coates.—29 miles; Alt. 923 feet. Empire.—33 miles; Alt. 859 feet. (Crossing C., M. & St. P. Ry.)

Large sandy outwash plain from the moraine south and east of St. Paul. Tree-covered morainic hills west in near distance beyond outwash plain southwest of Coates.

Hampton.—37 miles; Alt. 983 feet.

South of Empire the outwash plain gives way to a rolling plain of the Old Red drift. At Hampton a terminal moraine marks the southermost limit in Minnesota of the Old Red drift. (See Chap. IV.) South and west of Hampton is a rolling plain of Old Gray drift. The St. Peter sandstone is exposed in ridges which are cut by the railroad south of Hampton. A ridge of this sandstone rises above the Old Gray drift plain to the west.

Randolph.—43 miles; Alt. 885 feet. (Red Wing-Rochester Line see p. 299. Randolph-Mankato Line see p. 303.)

About half way between Hampton and Randolph a sandy outwash plain is entered upon which extends to the east. To the east about 3 miles approaching Randolph an "island" or mound of St. Peter sandstone is a conspicuous landscape feature rising above the surrounding outwash plain. Cannon River is crossed, bordered on either side by the sandy outwash plain. (See Chap. XXV.)

Stanton.—47 miles; Alt. 925 feet.

Sandy plain of glacial deposit in old valley now occupied by Prairie Creek. Outcropping ledges of rock in bluffs of ancient valley both east and west, Trenton limestone above, St. Peter sandstone below. Gently rolling plain of Old Gray drift both east and west of the ancient watercourse in which Prairie Creek now flows.

Dennison.—52 miles; Alt. 972 feet.

Outcropping limestone and sandstone on east side of valley. Leave ancient watercourse to south and cross Old Gray drift plain; then about 3 miles across a loess covered area to Nerstrand.

Nerstrand.—57 miles; Alt. 1,186 feet.

On boundary between the loess covered area (to the north) and the Old Gray drift plain to the south.

Kenyon.—63 miles; Alt. 1,145 feet.

The gently rolling and undulating plain of Old Gray drift is cut through by the valley of North Branch of Zumbro River, crossed north of Kenyon. The steep banks are beautifully wooded.

Skyberg.—68 miles; Alt. 1,195 feet. West Concord.—73 miles; Alt. 1,232 feet.

Eden.—77 miles; Alt. 1,220 feet.

Dodge Center.—82 miles; Alt. 1,295 feet. (Crossing C. & N. W. Ry.) Vlasaty.—86 miles; Alt. 1,334 feet. Hayfield.—91 miles. (Omaha Line see p. 299.) Sargeant.—98 miles; Alt. 1,385 feet. Renova.—103 miles; Alt. 1,390 feet. (Crossing C. M. & St. P. Ry.) Elkton.—109 miles; Alt. 1,382 feet. Taopi.—117 miles; Alt. 1,344 feet. (Crossing C., M. & St. P. Ry.)

Gently undulating plain of Old Gray drift. Splendid farming region. (See Chapters IV & XXVI.) Small streams head on this plain which flow east into the Mississippi River. East of Hayfield, but scarcely visible from the car window, are several gravelly hills known as kames. These are deposits of moraine-like character of the Old Gray drift.

MANTORVILLE BRANCH

Wassioji.—4 miles from Eden.

Valley of South Middle Fork of Zumbro River cuts deeply into the plain of the Old Gray drift.

Mantorville.—7 miles. (Dodge County.)

At this point the river has cut deeper, the Trenton limestone being exposed in the deeper banks below the mantle of Old Gray drift.

THE OMAHA LINE

Waltham.—96 miles from Minneapolis; Alt. 1,328 feet.

Gently undulating Old Gray drift plain.

Mayville.—101 miles; Alt. 1,257 feet.

At Mayville a small stream is crossed which flows westward into the Cedar. The divide or "watershed" on this plain is imperceptible to the eye.

Austin.—108 miles; Alt 1,200 feet. (Crossing C. M. & St. P. Ry.) (Mower County.)

Austin is on the western edge of the Old Gray drift in the ancient glacial channel in which the Cedar now flows.

Varco.—112 miles; Alt. 1,020 feet.

Rose Creek enters the ancient watercourse of the Cedar Valley from the east.

Lyle.—120 miles; Alt. 1,205 feet.

Near the State line, on the undulating plain of the Old Gray drift, where another small creek flows west to Cedar Valley.

RED WING-ROCHESTER LINE

Randolph.—43 miles; Alt. 885 feet. Cannon Falls.—50 miles; Alt. 816 feet. Welch.—59 miles; Alt. 718 feet. **Red Wing.**—71 miles; Alt. 712 feet. (Goodhue County.)

Broad gravelly outwash plain Randolph to Cannon Falls. Cannon River south. The course of the river was originally north of the two broad flat-topped mesas that lie to the north. (See Chap. XXV.) From Cannon Falls to Red Wing the deep canyon-like valley is followed. Walls of rock rise 400 feet on either side. This is a picturesque ride. The great valley was cut in preglacial times. The river now meanders over gravelly filling that was not entirely removed by the glacial flood waters. Red Wing is built on gravelly terraces of the glacial Mississippi.

Hay Creek.—78 miles; Alt. 807 feet.

From Red Wing the railroad ascends the valley of Hay Creek. The flat valley bottom is alluvium. The bluffs overlooking the valley are capped with loess. The St. Croix sandstone outcrops in the valley sides and forms many hummocks and knobs on the valley bottom.

Goodhue.—87 miles; Alt. 1,121 feet.

Goodhue is fully 300 feet higher than Red Wing. Here an area of Cretaceous rock overlies the St. Peter sandstone, and is itself thinly covered with loess. In the Cretaceous deposits valuable commercial clays occur, and extensive pits have been opened for clay for manufacturing of clay products at Red Wing.

Zumbrota.—97 miles; Alt. 984 feet. (Crossing C. M. & St. P. Ry.)

The railroad passes off the Cretaceous formation to the south of Zumbrota, onto the lower St. Peter sandstone and Richmond sandstone, then ascends again upon the Trenton limestone. Approaching Zumbrota, where the South Branch of Zumbro River is crossed, the St. Peter sandstone outcrops in the valley sides. The uplands are overlain with loess.

Pine Island.—106 miles; Alt. 998 feet. Oronoco.—109 miles; Alt. 1,042 feet.

From Zumbrota south the C. G. W. and C. & N. W. railroads run nearly parallel to Rochester. The St. Peter sandstone forms the valley slope south and east of Zumbrota, being thinly covered with Old Gray drift and loess. The Trenton limestone underlies the loess north of Pine Island. The limestone is harder and protects the soft and friable sandstone beneath, thus causing knobs and pinnacles to be formed. Pine Island is in the valley of the North Middle Branch of Zumbro River. Alluvial deposits form the valley floor below Pine Island. Running across the valley of South Middle Branch of the Zumbro the St. Peter sandstone forms the valley floor where the river is crossed. The sandstone is again covered by the Trenton limestone on the higher land southward. The bluffs are in many places rocky, and rise more than 100 feet in height. The valley is deep and its sides generally steep. The valley is naturally timbered and is such as to appeal to the nature lover.

Douglas.—114 miles; Alt. 1,080 feet.

The sandstone formation is covered by a thin mantle of Old Gray drift. North and east of Douglas are gravelly hills technically known as kames. Such hills are generally gravelly in character, and are associated with moraines. These hills are among the most eastern gravel deposits in the State. South of Douglas the formations are covered with loess. The railroad descends upon the alluvial valley bottom at Rochester, the floor of which valley is limestone (Trenton) with irregular bluffs and hummocks of sandstone (St. Peter) protected by the harder limestone.

Rochester.—122 miles; Alt. 998 feet. (Olmstead County.)

Rochester lies in the valley of South Branch of the Zumbro. The Trenton limestone caps the bluffs which surround the city. The bluffs are generally flat on top and covered with a mantle of loess. The city is in the center of an amphitheatre of limestone capped bluffs, the limestone at one time forming a continuous plain 200 feet above the present site of the city, the friable St. Peter sandstone lying underneath. The numerous tributaries of South Branch of Zumbro River which meet in the arena about Rochester give to the city a unique location.

Simpson.—130 miles; Alt. 1,062 feet.

South from Rochester the plain is that of the Old Gray drift, deeply cut into by streams. Simpson is on the high prairie, and is on a tract of loess-covered drift.

Stewartville.—137 miles; Alt. 1,240 feet.

The valley of Root River is here 75 to 100 feet below the plain of the Old Gray drift which forms the prairie bordering the valley. Limestone cliffs form the valley sides in many places, and hardwood forests add beauty to the rugged valley.

Racine.—142 miles; Alt. 1,296 feet.

Racine is on the gently undulating prairie of Old Gray drift. To the south Bear Creek and Deer Creek are crossed. These valleys are here cut through the mantle of Old Gray drift to a depth of 75 feet, into the limestone.

Spring Valley.—149 miles; Alt. 1,317 feet. (Crossing C. M. & St. P. Ry.)

A thin veneer of Old Gray drift covers the limestone formation (Galena.) Sink-holes are common on this mantled limestone plain. These sometimes occur in series, indicating that a preglacial valley had been eroded into the limestone and later filled with drift. Sometimes a small surface stream leads to a sink-hole and abruptly disappears. The Galena and Trenton limestones erode into fantastic forms, and frequently form caverns. Underground dissolving of the rock and caving in of the surface frequently results in a sink-hole being developed.

Ostrander—156 miles; Alt. 1,343 feet.

South of Ostrander the South Branch of Root River is crossed. Here the valley is cut into the Old Gray drift, but it soon becomes deeper and is entrenched in the Galena and Trenton limestone formations. Ostrander is on the plain of Old Gray drift, which extends to the State line near Le Roy.

Le Roy.—164 miles; Alt. 1,243 feet. (Crossing C. M. & St. P. Ry.)

The valley of Iowa River has cut 50 to 75 feet through the clayey drift mantle into the limestone.

THE WINONA-ROCHESTER LINE

Winona.—296 miles from Chicago; Alt. 444 feet. (Winona County.)

Winona is located on the broad alluvial plain of the Old Mississippi Valley. The bluffs rise 550 to 600 feet above the river. The many streams that enter the great valley descend through deep gorge-like valleys whose bottoms merge into that of the main valley. Up stream these valleys become narrower and their sides more rugged, often terminating in rugged cliffs over which small rivulets fall. Sugar Loaf Bluff is a splendid monument carved in the great process of valley-making, which rises about 600 feet above its base. (For description of the Mississippi Valley see Chap. XVI.)

Minnesota City.—11 miles from Winona; Alt. 513 feet.

Minnesota City is located at the mouth of Rolling Stone Creek. The high gravel terrace of this valley joins with the great terrace of the Mississippi. This terrace is more than 50 feet above the bottom of Rolling Stone Valley. The terrace was the valley bottom during the time when the glacial waters were carrying drift down the preglacial valleys. Later erosion removed part of the filled-in material cutting the valley down to the lower floodplain. If all the drift and alluvium were removed the valley would be probably 100 feet deeper than it is now, that is, the bottom would be 100 feet lower than the present river and sandstone and limestone rocks would be exposed along the valley bottom and sides.

Rolling Stone.—14 miles; Alt. 547 feet.

The railroad climbs up Rolling Stone Valley following up the terrace plain. The valley narrows upstream, and becomes more gorge-like. Sandstone and limestone rock ledges form steep walls and promontories. Rolling Stone Valley is a fine valley. It is wide, and extends smoothly from the river toward the bluffs which border it. The main flat is the same terrace which extends up another creek to Stockton, and is continuous with the great terrace of the Mississippi.

Bear Creek.—21 miles; Alt. 727 feet. Altura.—23 miles; Alt. 965 feet.

The railroad winds along the tortuous course of a small tributary stream, climbing up to the loess covered plain at Altura. A short distance west is the deep valley of the Whitewater.

Bethany.—27 miles; Alt. 904 feet. Utica.—32 miles; Alt. 968 feet.

At Altura the railroad turns south and follows the high loess covered plain to Bethany, keeping on the divide between Rolling Stone and Whitewater Valleys. The railroad crosses a tributary of the Whitewater south of Bethany. The valley of the Whitewater, which flows north through Elba township, is a beautiful valley, with its many tributaries. The tributaries are narrow and gorge-like in their upper courses, the main valley from Elba down being a magnificent broad and fertile valley.

St. Charles.—37 miles; Alt. 922 feet.

The city is on the undulating plain of Old Gray drift. One of the head streams of the Whitewater passes north of the city, and in the valley ledges of Shakopee limestone are exposed. A plateau of Trenton limestone lies to the south. This rises abruptly nearly 100 feet above the loess covered plain along the railroad. This limestone resists erosion and thus steep bluffs are formed along the edge of the plateau, the soft and friable St. Peter sandstone crumbling away underneath it as the limestone ledges are weathered and broken off. South of St. Charles about 2 miles is a tributary of Root River, which has eroded into the St. Peter sandstone. St. Charles is thus on a narrow divide between the Whitewater and Root Rivers.

Dover.—41 miles; Alt. 937 feet. (Crossing C. & N. W. Ry.)

A small valley of a tributary of the Whitewater has been cut into the St. Peter sandstone. A thin mantle of Old Gray drift overlies the sandstone outside the valley.

Laird.—45 miles; Alt. 1,104 feet.

Laird is on the gently rolling or undulating plain of Old Gray drift.

Predmore.—51 miles; Alt. 1,023 feet.

A narrow belt of loess borders the Old Gray drift and caps the bluffs overlooking the valley of the Root. The station is on the ridge which forms the divide between the Root and the Zumbro, the distance between the head valleys being barely more than 1 or 2 miles.

RANDOLPH-MANKATO LINE

Randolph.—43 miles from Minneapolis; Alt. 885 feet. Waterford.—7 miles from Randolph; Alt. 908 feet. Northfield.—9 miles; Alt. 913 feet.

Gravelly outwash plain up Cannon River. The boundary between the Old Gray drift (Kansan) east and the Young (Keewatin) Gray drift west is a little east of Waterford and Northfield. When the edge of the Keewatin glacier was about where Northfield and Waterford are now floods of water from the melting ice sheet were forced across an old divide at Northfield and thus the present course of Cannon River was established. The rapids at Northfield were caused by the water being forced over a rocky divide. The drainage had formerly been in the opposite direction, to the Minnesota. (See Chap. XXV.)

Dundas.—12 miles; Alt. 929 feet. Bridgewater.—16 miles; Alt. 1,013 feet. **Faribault.**—23 miles; Alt. 982 feet. (Rice County.)

South of Northfield the valley is comparatively narrow. Morainic hills cap the bluffs on the east. St. Peter sandstone capped with Trenton limestone is exposed in the valley sides. A gravel deposit known as an esker is crossed near Bridgewater. At Faribault the gravel filling of the valley of the glacial Cannon River is reached. The upper Cannon at one time discharged southward by the valley now occupied by Straight

River, before the present course by Dundas and Northfield was established.

Warsaw.—32 miles; Alt. 1,013 feet. Morristown.—35 miles; Alt. 1,013 feet. Waterville.—41 miles; Alt. 1,011 feet.

West of Faribault the railroad follows the plain of gravel filling that forms the floor of the broad glacial valley. Beautiful Cannon Lake is skirted on the south. Morainic hills border the valley. The valley is a most beautiful one. The lakes at Waterville are gems.

Elysian.—47 miles; Alt. 1,051 feet. Madison Lake.—54 miles; Alt. 1,051 feet. Watters.—61 miles; Alt. 1,011 feet. Benning.—66 miles; Alt. 829 feet. **Mankato.**—70 miles; Alt. 782 feet. (Blue Earth County.)

The moraine continues west of Waterville to Elysian. Madison Lake is on rolling till-plain. Fine lakes are on every hand. The soil of the till-plains and the moraines is a splendid type of loam. South of Benning the gravelly terraces of the glacial Minnesota River are crossed, with outcropping ledges of rock appearing in the bluffs to Mankato.

THE CHICAGO, ROCK ISLAND & PACIFIC RAILWAY.

Minneapolis to St. Paul runs over C., M. & St. P. tracks. (See p. 265.)

St. Paul.—10 miles. Newport.—18 miles from Minneapolis. Inver Grove.—20 miles. Rosemount.—31 miles.

From Union Depot, St. Paul, the line skirts the bluffs on the east side of the river, St. Peter sandstone with Trenton limestone above outcropping in the bluffs. A flat terrace of Shakopee dolomite (limestone) lies along the river to Newport. Crossing the river to Inver Grove the railroad climbs to the high bluffs, which are covered with roughly rolling red drift morainic hills. Between Inver Grove and Rosemount the old valley (preglacial) of the Mississippi is crossed west of Pine Bend. (See Chap. XVI.)

Rosemount to Northfield runs over tracks of C., M. & St. P. Ry. (See p. 269.)

Northfield.—51 miles from Minneapolis. Dundas.—54 miles. **Faribault.**—64 miles; Alt. 972 feet. (Rice County.) (Crossing C. G. W. Ry., C., M. & St. P. Ry.)

From Northfield to Faribault the railroad follows the Cannon Valley. Till-plain borders the valley west, and morainic hills cap the river bluffs east. St. Peter sandstone capped by Platteville limestone is exposed below the drift in the valley sides. South of Dundas an esker is crossed in which a gravel pit has been opened. South of this a rolling moraine to which the esker is related. A mound of St. Peter sandstone is cut through, then glacial outwash plain of valley of Straight River is followed to Faribault.

Medford.—73 miles; Alt. 1,102 feet. **Owatonna.**—80 miles; Alt. 1,129 feet. (Crossing C. & N. W. Ry.) (Steele County.)

From Faribault to Medford the railroad follows the valley of Straight River, at times crossing glacial outwash in the large ancient valley, and again cutting through moraines which crowd close upon the valley at Medford and Owatonna. Tracts of flat till-plain west of valley, north and south of Medford.

Hope.—89 miles; Alt. 1,260 feet. Ellendale.—95 miles. Clark Grove.—103 miles.

From Owatonna south for a short distance a morainic ridge is followed, a part of the moraine which extends to and beyond the State line. Straight River occupies an old glacial channel of gravelly and sandy outwash. This outwash channel is crossed three times between Owatonna and Ellendale. Straight River flows north, but the ancient glacial river flowed south past Blooming Prairie and Austin by the valley now occupied by Cedar River. Straight River is crossed north of Hope, and south of Hope an outwash channel is crossed that carried glacial waters from the edge of the melting glacier eastward into the valley now occupied by the Straight-Cedar ancient channel. Ellendale stands on the moraine formed at this time. The moraine at Ellendale continues south beyond the State line. (See Chap. XXII.) South of Clark Grove and extending to Albert Lea is an outwash plain of gravel and sand formed after the glacier had melted back from the position at which the moraine east of Albert Lea was formed.

Albert Lea.—111 miles; Alt. 1,235 feet. (Freeborn County.) (Crossing C. M. & St. P. Ry., M. & St. L. Ry.)

Belt undulating till-plain Clark's Grove to Albert Lea. Moraine east, and high gravelly plain of outwash west. The narrows connecting Albert Lea Lakes is crossed, and the clayey bottom of glacial Lake Albert Lea. (See Chap. XXII.)

Glenville.—126 miles.

The town is located on the outwash plain of the old channel that extends south from Albert Lea Lakes. (See Chap. XXII.)

Gordonsville.—131 miles; Alt. 1,213 feet.

The outwash plain of gravel and sand continues south from Glenville and the Albert Lea Lakes. Distinct morainic ridge east.

Myrtle.—13 miles from Albert Lea (on Illinois Central Railway); Alt. 1,254 feet. London.—19 miles; Alt. 1,199 feet.

Between Glenville and Myrtle a moraine about 1 mile in width marks the halting place of the great Keewatin glacier. Myrtle is on a till-plain or ground moraine of this glacier, the eastern edge of the deposit made by this glacier, that is, the boundary between the Young Gray drift (Keewatin) and the Old Gray drift (Kansan) being about half way between Myrtle and London. London is on the plain of the Old Gray drift. (See Chap. IV.) About half way between London and Lyle is the ancient drainage channel which at one time carried water from Faribault, Owatonna, and Austin southward from the edge of the melting glacier. This part of the ancient channel is now occupied by the Cedar River.

Conger.—10 miles from Albert Lea; Alt. 1,290 feet. Walters.—17 miles; Alt. 1,235 feet.

Passing Albert Lea Lakes a till-plain lies south of Albert Lea city. A sandy outwash plain borders the moraine which lies west of Albert Lea. This was formed by the waters from the melting ice at the time the moraine was being formed. The railroad crosses the south side of this outwash plain onto the moraine. Conger is at the west edge of the moraine. West of Conger a till-plain is crossed and west of the till-plain another moraine extends to Walters. West of Walters the railroad lies close upon the edge of a sandy moraine to the south and east, then crosses the clayey plain of an ancient lake bottom to Bricelyn.

Bricelyn.—26 miles; Alt. 1,177 feet. (Crossing C. & N. W. Ry.)

Walnut, Swan, Goose, and Rice Lakes remain as remnants of a glacial lake which occupied the basin in which the lakes mentioned now lie, and through which basin the waters of East Fork of Blue Earth River now pass.

LAKE PARK-JASPER LINE

Round Lake.—10 miles from Lake Park, Ia.; Alt. 1,559 feet.

Round Lake is near the inner edge of the great Altamont or outer moraine formed on the west side of the Keewatin glacier. The railroad crosses this moraine as it enters the State. A group of morainic lakes lies east of Round Lake. State Line Lake and Indian Lake are on the moraine west of the railroad.

Worthington.—21 miles; Alt. 1,585 feet. (Nobles County.)

Worthington is on the undulating till-plain east of the Altamont moraine. East and West Okabena Lakes south and west of the city discharge to Lake Ocheeda and westward to the Missouri River. Oakabena Creek, which is crossed a mile west of Worthington, carries water east to the Des Moines River. Worthington is nearly on the crest of the Coteau des Prairies.

Reading.—27 miles; Alt. 1,722 feet. Wilmont.—31 miles; Alt. 1,735 feet. Linsmore.—41 miles; Alt. 1,689 feet.

The Altamont moraine between Reading and Wilmont is separated into two belts by an intervening tract of till-plain or ground moraine. Reading is on the eastern belt. Wilmont is on the western edge of the till-plain. West of Wilmont the western belt of the great moraine is crossed. A broad channel of glacial drainage is crossed before Linsmore is reached. Linsmore is on the undulating till-plain which borders the moraine on the west. This till-plain shows that the ice advanced beyond the Altamont moraine, but its edge was not stationary for long as far west as Linsmore, as no moraine was deposited.

Kenneth.—48 miles; Alt. 1,588 feet.

About 2 miles west of Linsmore is the western edge of the drift deposited by the Keewatin glacier, the Young Gray drift. (See Chap. IV.) From the edge of this drift deposit outwash drainage channels lead south and west across the plain of Old Gray drift. An outwash plain between Linsmore and Kenneth is crossed by the railroad, this outwash leading to several distinct ancient channels to the south, all of which lead to the valley of Rock River. Kenneth stands on the edge of one of these channels.

Hardwick.—55 miles; Alt. 1,608 feet.

Between Kenneth and Hardwick two ancient channels are crossed, and two intervening tracts of Old Gray drift. Hardwick is located on a ridge of pre-Cambrian rock (the Sioux quartzite). (See Chap. X.) The Old Gray or Kansan drift probably once covered this rock, but it has been removed by erosion of wind and water.

Trosky.—64 miles; Alt. 1,705 feet.

The railroad follows the quartzite ridge for 5 miles north from Hardwick, then passes onto the Kansan or Old Gray drift plain.

Jasper.—73 miles; Alt. 1,560 feet.

From Trosky west nearly to Jasper the Kansan or Old Gray drift continues. Jasper is in the valley of Split Rock Creek, a deep gorge eroded into the hard quartzite rock. The names of the town and the creek are appropriate. Jasper is the particular variety of quartzite rock here exposed, and the term "split" fittingly describes the valley.

Pipestone.—40 miles from Ellsworth; Alt. 1,725 feet. (Pipestone County.)

A thin sheet of till that borders the Altamont moraine on the west extends to the western limits of the city. West of this is the Old Gray (Kansan) drift, a flat plain of drift that thinly covers the underlying rock. Pipestone is on an "island" of quartzite rock. Ledges of this rock outcrop in the northern part of the city. The railroad crosses the western edge of this "island," passing near the outcropping ledges.

Cazenovia.—45 miles from Ellsworth.

On the rolling till-plain outside (west) of the outer or Altamont moraine. About 1 mile west of Cazenovia is the margin of the Young Gray drift. The undulating plain of the Old Gray drift extends westward into South Dakota.

Cresson.—51 miles.

Cresson is near the western border of the Young Gray drift. Between Cazenovia and Cresson an ancient glacial river course is crossed, which is now occupied by Flandreau River.

Luverne.—13 miles from Ellsworth; Alt. 1,452 feet. (Rock County.) (Crossing C., St. P., M. & O. Ry.)

Luverne is located at the west edge of the broad ancient watercourse which is now occupied by Rock River. West of this ancient channel the Old Gray drift is covered with loess. East of Luverne the prairie is that of the Old Gray drift.

Kanaranzi.—5 miles from Ellsworth; Alt. 1,505 feet. Ellsworth.—532 miles from Chicago; Alt. 1,445 ft.

Between Luverne and Kanaranzi three outwash channels are crossed, all of which lead to the valley of Rock River. Another of these channels of glacial drainage is crossed between Kanaranzi and Ellsworth. The Old Gray drift plain is intersected by these ancient channels. Ellsworth, near the State line, is also near the boundary between the Old Gray drift and the Young Gray drift, but is on the former.

Bruce.—18 miles from Sioux Falls (on Illinois Central Railway); Alt. 1,492 feet. Hills.—20 miles; Alt. 1,451 feet. Steen.—25 miles; Alt. 1,485 feet.

The Illinois Central Railway between Rock Rapids, Iowa, and Sioux Falls, S. Dak., crosses southern Rock County. The three places named are in the district that is covered with loess. This part of the State was very thinly covered with drift of the Old or Kansan ice sheet. So little drift was deposited that the topography is essentially that of a nonglaciated region. (See Chap. IV.)

THE MINNEAPOLIS & ST. LOUIS RAILWAY

St. Paul to Minneapolis runs over N. P. tracks. (See p. 339.)

Minneapolis.—10 miles from St. Paul. (Hennepin County.)

Leaving Minneapolis the M. & St. L. line crosses rolling morainic hills and level sandy, alluvial deposits to Cedar Lake, where a sandy outwash plain lies between Cedar Lake on the right (west) and Lake of the Isles and Lake Calhoun on the left (east). A belt of morainic hills lies west of Lake Calhoun. Bass Lake lies at the left (south). St. Louis Park is on a gravelly outwash plain, which extends halfway to Hopkins.

Hopkins.—20 miles from St. Paul; Alt. 919 feet. (Watertown Line see p. 312.)

Rolling morainic hills about Hopkins. Minnehaha Creek is crossed west of St. Louis Park. This is a pretty stream which follows an old glacial channel, and carries water from Minnetonka Lake to the Mississippi River.

Eden Prairie.—26 miles; Alt. 878 feet.

The rolling morainic hills continue from Hopkins nearly to Eden Prairie with many small lakes, and hollows containing muck deposits. The town is built on an outwash plain formed when the great moraine which has just been crossed, was being deposited by the glacier. This plain merges into the high glacial terrace of the Minnesota Valley. The smoother and more even character of the gravelly plain, and the lack of trees, give the name "prairie" as distinguished from the rolling morainic hills, which are naturally wooded.

Chaska.—34 miles; Alt. 725 feet. (Carver County.) (Crossing C. M. & St. P. Ry.) Carver.—36 miles; Alt. 720 feet.

West of Eden Prairie the railroad again crosses the rolling hills of the moraine, which here crowds close upon the Minnesota Valley, then descends upon the outwash plain east of Chaska to the high terrace or ancient floodplain of the glacial Minnesota.

Merriam.—39 miles; Alt. 754 feet. (Crossing C., St. P., M. & O. Ry.) Jordan.—44 miles; Alt. 755 feet.

After passing Carver the railroad descends further to the alluvial river bottom and crosses to Merriam. Merriam stands on a limestone terrace cut by the glacial flood waters of the Minnesota. This is the Shakopee dolomite, a limestone of Paleozoic age. Fragments of this rock lie upon the terrace. (See Chap. X.) From Merriam the railroad follows the glacial terrace to Jordan, where it climbs out of the Minnesota Valley by the valley of Sand Creek to the prairie upland. At Chaska and Jordan springs issuing from the valley sides, or bursting out on the terrace plain, have developed hillside bogs, which have become famous as mud baths. (See Chap. VIII.)

Helena.—48 miles; Alt. 863 feet.

Helena is situated in the deep glacial valley of Sand Creek. Out from the valley morainic hills with many lakes occur. The valley of Sand Creek was eroded when the glacial waters flooded the valley.

New Prague.—54 miles; Alt. 973 feet. Montgomery.—61 miles; Alt. 1,064 feet. (Crossing C., M. & St. P. Ry.)

At Hilltop south of Helena the moraine merges into rolling till-plain which continues south to Montgomery. The soil is generally loam, there being considerable silt, and is fine farming land. The hills are beautifully rolling. A group of morainic lakes north of Montgomery are "drained" by Sand Creek. Sand Creek is really not a drainage stream at all. It was established by waters from the melting ice which flowed away from the glacier between the hills where best it could. The modern stream follows the ancient channel, a small pooling stream meandering over the broad valley bottom. Water overflows from the lakes by this creek, but the land a few rods distant is not drained.

Kilkenny.—70 miles; Alt. 1,058 feet. Waterville.—77 miles; Alt. 1,010 feet. (Crossing C. G. W. Ry.)

From Montgomery the railroad runs south through clayey morainic hills having a fertile loam soil. Beautiful lakes, large and small, and pooling streams carry water between the hills. The "drainage" of the region is into the valley of Cannon River, entering Lake Tetonka west of Waterville and discharging east into Lake Sakata. Waterville is on the rolling moraine just south of the Cannon Valley. The beautiful morainic topography continues south to Palmer and Waseca. The lakes between Waterville and Palmer "drain" northward. Lake Elysrian discharges its overflow waters westward by the LeSueur and the Blue Earth to the Minnesota at Mankato. The lakes west and northwest of Waterville "drain" eastward by the Cannon.

Palmer.—81 miles; Alt. 1,147 feet. **Waseca.**—88 miles; Alt. 1,150 feet. (Waseca County.) (Crossing C. & N. W. Ry.)

Waseca is located at the western edge of the moraine. A beautiful group of morainic lakes lies east, north, and south. The "drainage" of these lakes is in part eastward to Straight River, and in part westward to the LeSueur. There is no definite "divide" between these lakes, nor between these and those north of Palmer, which discharge to the Cannon.

Otisco.—94 miles; Alt. 1,146 feet. Richland.—100 miles; Alt. 1,182 feet. Hartland.—106 miles; Alt. 1,252 feet. Manchester.—112 miles; Alt. 1,282 feet.

From Waseca to Albert Lea the railroad runs nearly south, Otisco and Richland being at the junction of the moraine on the east and the till-plain on the west. Between Richland and Albert Lea alternating belts of terminal moraine and gently rolling till-plain are crossed. Richland, Hartland, and Manchester each stand on till-plain, but east of each of these places the rolling terminal moraines are seen.

The great moraine which is traversed by the Minneapolis and St. Louis Railway from Minneapolis to Albert Lea was formed at the eastern edge of the great Keewatin glacier. (See Chap. IV.) To the work done by this great ice-plow is due much of the fertility as well as the topography of a large area of central and southern Minnesota.

Albert Lea.—119 miles; Alt. 1,227 feet. (Crossing C., M, & St. P. Ry. and C.. R. I. & P. Ry.)

Moraine north of city, and gravelly outwash plain. City mostly built on sediments of glacial Lake Albert Lea. Rolling morainic hills south. (See Chap. XXII.)

Twin Lakes.—126 miles; Alt. 1,256 feet.

The town is named from Upper and Lower Twin Lakes, which are located on the west, on the gently rolling till-plain. The railroad runs on the boundary between the moraine on the east and the till-plain on the west from Albert Lea to the State line at Emmons.

Emmons.—132 miles; Alt. 1,281 feet.

Bear Lake is on the west, on the edge of a flat, sandy, and gravelly outwash plain. State Line Lake lies among the morainic hills east of the railroad near the State line.

THE WATERTOWN AND ABERDEEN LINE

Minnetonka Mills.—23 miles from St. Paul; Alt. 936 feet. Deephaven.—27 miles; Alt. 935 feet. Excelsior.—30 miles; Alt. 946 feet.

Terminal moraine all the way, with many small morainic lakes and muck-bottomed hollows. Hills tree covered. Excelsior is on southern arm of Minnetonka Lake.

Victoria.—36 miles; Alt. 964 feet. Waconia.—43 miles; Alt. 984 feet. Young America.—51 miles; Alt. 993 feet.

Morainic hills and lakes, with intervening tracts of muck. The region is undrained so far as the development of streams is concerned. The soil is clayey in character and very productive. There are many fine fruit, vegetable, and dairy farms.

Norwood.—52 miles; Alt. 976 feet. (Crossing C., M. & St. P. Ry.) Hamburg.—55 miles; Alt. 999 feet. Green Isle.—60 miles; Alt. 999 feet. Arlington.—66 miles; Alt. 995 feet. **Gaylord.**—74 miles; Alt. 998 feet. (Sibley County.)

Gently rolling ground moraine or till-plain, with many lakes, becoming more broadly rolling and undulating west. Lake Erin near Green Isle and Lake Titlow near Gaylord are large fine lakes. New Auburn Lakes, north and west of Arlington, comprise an interesting chain. The positions of these lakes indicate that they lie in a partially filled valley, that is, a valley that had been cut into the old Kansan drift, and partially filled by the deposits of the later Keewatin glacier. These lakes overflow by High Island Creek, which is crossed near Arlington, to the Minnesota. Buffalo Creek passes within a few rods of this chain of lakes, carrying water to the Mississippi by way of the Crow, above Anoka.

Winthrop.—81 miles; Alt. 1,015 feet. (For Line to Storm Lake, see p. 314.) Gibbon.—89 miles; Alt. 1,048 feet. Fairfax.—99 miles; Alt. 1,041 feet. Franklin.—107 miles; Alt. 1,004 feet.

Broadly rolling till-plain or ground moraine, with occasional lakes. A narrow morainic belt is crossed between Gibbon and Fairfax and another east of Franklin. These moraines were deposited on the west side of the Keewatin glacier, or on the opposite edge of the great ice lobe or glacier from the great moraine that extends from Minneapolis to Albert Lea. Franklin is located on the rolling prairie overlooking the deep valley of the Minnesota. West of Franklin the railroad descends to the high terrace or ancient floodplain of the glacial Minnesota River.

Morton.—112 miles; Alt. 840 feet.

Here is seen the eroded and partially decomposed granite rocks, the ancient floor of the Continent, into which the glacial Minnesota cut its valley to a depth of 125 to 150 feet. West of Morton the river is crossed, the railroad continuing on the granite valley bottom to North Redwood. The valley is alluvium deposited by overflow of the modern river, but granite knobs stand out in picturesque forms. The great valley was, at one time, crowded by the rushing waters that came from the melting ice, and thus the deep and broad valley was carved into the hard rock. Deep channels, some of them gorge-like in character, have been eroded by tributary streams plunging down the sides of the valley. (See Chap. X.)

North Redwood.—118 miles; Alt. 855 feet.

North Redwood is on the broad valley bottom of the Minnesota where Redwood River enters the Minnesota. The Redwood has cut a deep gorge into the granitic rocks. Redwood River descends 100 feet within a distance of a mile in a succession of picturesque cascades and rapids. Granitic cliffs tower on either side 100 to 150 feet. This gorge extends 1½ miles before it opens into the broad bottom land of the Minnesota Valley.

Delhi.—124 miles; Alt. 1,022 feet.

Delhi is on ground moraine or till-plain, overlooking the broad valley of the Minnesota.

Belview.—130 miles; Alt. 1,071 feet.

A small terminal moraine lies just north of Belview, surrounded by till-plain. Small lakes of morainic type south.

Echo.—135 miles; Alt. 1,080 feet. Wood Lake.—141 miles; Alt. 1,059 feet.

Undulating or gently rolling till-plain with occasional lakes occupying generally broad flat depressions.

Hanley Falls.—146 miles; Alt. 1,047 feet. (Crossing Great Northern Railway.)

Yellow Medicine River here meanders across the till-plain in northeasterly direction to the Minnesota.

Hazel Run.—152 miles; Alt. 1,057 feet. Clarkfield.—151 miles; Alt. 1,087 feet. Boyd.—164 miles; Alt. 1,050 feet.

From Hanley Falls to Boyd the railroad runs on or parallel with a narrow moraine. Gently rolling till-plain extends away into the distance.

Dawson.—173 miles; Alt. 1,054 feet. **Madison.**—182 miles; Alt. 1,095 feet. (Lac Qui Parle County.)

Till-plain Boyd to Madison. A moraine extends parallel with the railroad on the left (southwest). Cross Lac Qui Parle River approaching Dawson. Madison is at the north side of a narrow moraine, and a larger moraine lies a mile north.

Marietta.—193 miles; Alt. 1,128 feet.

Between Madison and Marietta 4 definite moraines or morainic belts are crossed, with intervening tracts of undulating till-plain. A glacial channel fully 1 mile in width is crossed 3 miles east of Marietta, this channel extending in a north-northwest south-southeast direction between parallel terminal moraines. This was a channel of glacial drainage at the time when the ice of the Keewatin glacier had its western edge flanking the highland of the Coteau des Prairies, and the southern end of the glacier was far south toward the present city of Des Moines.

STORM LAKE LINE

Lafayette.—88 miles; Alt. 1,010 feet. Klossner.—94 miles; Alt. 1,006 feet. **New Ulm.**—100 miles; Alt. 833 feet. (Brown County.)

From Winthrop south to Lafayette gently rolling till-plain, then two belts of terminal moraine are crossed between Lafayette and Klossner. Turning away from this moraine the railroad swings into the valley of the Minnesota at New Ulm. New Ulm is built on terraces of glacial Minnesota River. (See Chap. XV.) After crossing Cottonwood River south of New Ulm, Old Redstone can be seen a mile to the east. (See Chap. XI.)

Searles.—106 miles; Alt. 989 feet. Hanska.—113 miles; Alt. 1,007 feet. LaSalle.—119 miles; Alt. 1,028 feet.

After crossing the Minnesota the Cottonwood is crossed a little above its mouth, then rolling till-plain is crossed to Searles and Hanska and beyond. The deep valley of the Little Cottonwood is crossed north of Searles. On this plain are numerous large and small lakes. West of Hanska is Lake Hanska which lies in a long channel extending from the Cottonwood Valley to that of the Watonwan at Madelia. This ancient channel is crossed a mile north of LaSalle. Bordering this channel on the north is a terminal moraine which marks the position of the edge of the ice at the time when this channel was being formed. It was by this channel the ice waters were carried to the Minnesota at the present Big Bend at Mankato. South of LaSalle two moraines and two other glacial channels are crossed, marking two other positions of the edge of the ice and two channels of discharge of the ice waters, all leading eastward via the valley of the Watonwan. The North Branch of the North Fork and the South Branch of the North Fork of Watonwan River occupy the two channels.

St. James.—126 miles; Alt. 1,076 feet. (Watonwan County.) (Crossing C., St. P., M. & O. Ry.) Ormsby.—137 miles; Alt. 1,201 feet.

South of the moraines and ancient channels referred to above a till-plain is crossed. St. James is on a moraine that extends in a northwest and southeast direction for many miles. South a till-plain extends beyond Ormsby. South Fork Watonwan River is crossed north of Ormsby.

Monterey.—143 miles; Alt. 1,233 feet. (Crossing C. & N. W. Ry. north.)

Monterey is on another moraine which lies generally parallel with the one on which St. James is located. West of Ormsby and Monterey is the West Chain of Lakes. (See Chap. XXIII.)

Sherburne.—150 miles; Alt. 1,288 feet. (Crossing C., M. & St. P. Ry.)

Sherburne is on a gently rolling till-plain on which are many lakes. South 2 miles is another moraine, in general parallel with those at Monterey and St. James, and south and west of this moraine is a broad, ancient channel of glacial drainage now occupied by the East Fork of Des Moines River.

Dunnell.—157 miles; Alt. 1,310 feet.

Three small moraines lie southeast of Dunnell, with intervening tracts of till-plain or ground moraine. From Dunnell south to the State line the railroad crosses a broad till-plain. This is bordered on the west by another moraine which extends continuously in a northwesterly direction past Windom, Tracy, and Gary across the South Dakota State line, and across South Dakota into and across North Dakota into Canada. It extends southeast into Iowa. It is bordered on the west by the great ancient glacial channel which is now occupied by Des Moines River.

CHAPTER XXXI

GEOLOGY FROM A CAR WINDOW

GREAT NORTHERN RAILWAY

St. Paul.—0 miles; Alt. 706 feet. (Ramsey County.)

Leaving Union Depot the railroad turns away from the valley of the Mississippi, following a preglacial valley which was partially filled with drift. Passing from this old valley a gravelly outwash plain of red drift is crossed. Opposite the State Fair Grounds a moraine of red drift is crossed. The State Agricultural College buildings, seen to the north, are on gray drift hills, the gray drift here overlapping upon the earlier red drift. The red drift outwash plain is overlaid by an outwash of gray drift to the east and north of the Fair Grounds. The gray drift was deposited over the red by the later Keewatin ice sheet. (See Chap. IV.) The boundary marking the limit of the later ice invasion is through St. Anthony Park and north of Prospect Park, Minneapolis. The red drift moraine is more roughly rolling and contains more "hardheads" or boulders of granite and quartzite. The hills in Prospect Park are red drift, and those in the southern part of St. Anthony Park. Immediately north of Prospect Park and the northern and western part of St. Anthony Park the gray drift topography is less rolling. To the west the railroad crosses peat and sand dune tracts and presently enters upon the glacial sand and gravel terraces of the Mississippi. The gorge of the Mississippi is crossed south of St. Anthony Falls.

Minneapolis.—10 miles from St. Paul; Alt. 815 feet. (Hennepin County.) (For Willmar-Breckenridge Line see p. 320.)

The railroad crosses the deep gorge of the Mississippi immediately below St. Anthony Falls, a fine view of which is obtained from the north window. Trenton limestone outcrops in the sides of the gorge, with St. Peter sandstone below. West of Minneapolis the railroad crosses through morainic hills of gray drift, and enters upon the sandy outwash plain approaching Robbinsdale.

Robbinsdale.—17 miles from St. Paul; Alt. 884 feet.

Morainic hills, clayey in character from Minneapolis westward. Robbinsdale on edge of outwash plain which lies west of the Mississippi River and extends north beyond Anoka. The railroad crosses this plain to Osseo.

Osseo.—24 miles; Alt. 893 feet. Rogers.—33 miles; Alt. 965 feet.

Leave outwash plain west of Osseo, and cross moraine 4 miles. Rogers on rolling till-plain.

Monticello.—47 miles; Alt. 936 feet.

Two miles west of Rogers cross Crow River which meanders on a flat plain of outwash 1 mile wide. This broad, deep valley was cut through the great moraine between Dayton on the Mississippi and Rockford and Delano by a stream which flowed in the opposite direction from that in which the Crow now flows. This was the glacial Upper St. Croix. (See Chap. XVII.) A till-plain 6 miles, then cross another moraine 3 miles, entering upon the great outwash plain that borders the Mississippi River.

Enfield.—55 miles; Alt. 1,016 feet. Clearwater.—62 miles; Alt. 963 feet. The railroad lies close to the Mississippi River on outwash plain. Enfield is on the north end of a moraine which broadens southward and may be seen bordering the outwash plain to the west for several miles. Clearwater is on the outwash plain which the railroad follows to St. Cloud, except a rolling till-plain is crossed 2 miles west of Clearwater. This till-plain is of gray (Keewatin) drift. The moraine to the west which can be seen from the west (left) window is red (Patrician) drift.

St. Cloud.—75 miles; Alt. 1,040 feet. (Stearns County.) (Crossing Soo Line.)

Important granite quarries are operated here. This granite rock is the ancient Archæan formation, the oldest rock of the earth, the original back-bone of the continent. The ice sheets passed over these rocks and broke off and removed fragments, and polished the hard surface. Large and small fragments torn from these ledges are scattered on and in the drift deposits to the southward. (See Chap. X & XXIV.)

St. Joseph.—82 miles; Alt. 1,088 feet. On the outwash plain which borders the Mississippi River. A small clayey moraine north which forms an "island" in the sandy plain.

Avon.—90 miles.

Railroad follows glacial floodplain of Watab River. Sandy terminal moraine to the south (left) window.

Albany.—96 miles; Alt. 1,201 feet. Freeport.—103 miles; Alt. 1,241 feet.

Cross hilly, sandy moraine 6 miles to Albany. Rolling till-plain at Albany and 3 miles west of Freeport. Boundary between red (Patrician) drift and gray (Keewatin) drift, at Albany.

Melrose.—109 miles; Alt. 1,211 feet.

Outwash plain. Rolling till-plain north; clayey moraine south.

Sauk Center.—117 miles; Alt. 1,254 feet.

Crossing Morris branch N. P. Ry. on outwash plain. Moraine west and north. Sauk Lake in old glacial channel in which Sauk River now meanders. West of Sauk Center cross moraine, then again cross outwash channel in which Sauk River flows. The ancient channel was cut through the moraine by the waters from the melting ice.

West Union.—125 miles; Alt. 1,337 feet.

Railroad runs on moraine 1 mile wide to Osakis.

Osakis.—130 miles; Alt. 1,345 feet.

On Osakis Lake. Rolling till-plain to Nelson.

Alexandria.—142 miles; Alt. 1,389 feet. (Douglas County.) Garfield.—148 miles. Brandon.—154 miles; Alt. 1,389 feet. Evansville.—159 miles; Alt. 1,354 feet. Ashby.—168 miles; Alt. 1,275 feet. Dalton.—176 miles; Alt. 1,352 feet.

West of Nelson cross sandy moraine with morainic lakes 4 miles to crossing Soo Line. Alexandria on sandy undulating outwash plain on which are many beautiful lakes. This is a beautiful group of lakes and the sandy plain makes fine shores and splendid outing and camping sites. West of Alexandria the railroad passes onto the great Fergus Falls moraine and continues amid the hills and lakes of this moraine 45 miles to Fergus Falls.

This is a trip unique in its picturesque scenery. No journey of like distance in Minnesota or the United States, or indeed, probably in the world, carries the traveller through a more typical region of terminal morainic topography. Hundreds of lakes with every variety of rolling knob-like hills, the so-called ''pots and kettles'' of every size. Tiny streams having no definite course or direction of flow give the impression of the wildest confusion of topographic order. This is the ''Lake Park Region'' of Minnesota. Here is the field where the titanic struggle between glacial cold represented by advancing ice, struggled against the contending warmth, which finally vanquished the great Keewatin lobe of the continental ice sheet. On this geologically historic battle ground, the struggle between heat and cold left its tremendous record. How long the struggle lasted we do not know, but the countless millions of tons of earth,—boulders, gravel, clay, and sand,—that were dumped in the wildest confusion as the great ice mass advanced and was melted, tell of the vastness of the great work done during this closing epoch of the Ice Age.

Fergus Falls.—187 miles; Alt. 1,196 feet. (Crossing N. P. Ry.) (Otter Tail County.)

The moraine just passed through was named for the city that stands amidst its hills. An outwash plain lies immediately east, formed when the great moraine was being deposited. The moraine west is clayey in character. Northeast of the city is a sandy moraine about 7 miles in length which forms an ''island'' surrounded by outwash sand.

Across the ancient channel that lies east of the island the Otter Tail or Red River meanders, passing through the city to the westward, cutting through the moraine. This river drains Height of Land Lake in Becker County, and pools its meandering course through outwash plains and lakes, finally entering upon the plain of the bottom of Lake Agassiz where it joins the Bois des Sioux and becomes the Red River of the North.

It is interesting to observe that an ancient watercourse, which is crossed by the railroad at Carlisle 8 miles west, extends south for more than 40 miles, varying in width from one-half mile to a mile. The Otter Tail or Red enters this ancient channel 3 miles west of Fergus Falls and flows over its bottom about 4 miles, after being joined by Pelican River, then turns abruptly west and crosses the bottom of Lake Agassiz. A few rods south of the point in the ancient channel where the Otter Tail turns westward the Mustinka River takes its beginning. An imperceptible "divide" on the flat bottom of this ancient channel separates the Mustinka from the Otter Tail or Red. The Mustinka follows this ancient channel southward about 24 miles, then turns abruptly westward upon the bottom of Lake Agassiz and enters Lake Traverse from the north.

Carlisle.—195 miles; Alt. 1,230 feet. Rothsay.—204 miles; Alt. 1,194 feet.

Rothsay is near the west side of the moraine and is about 2 miles east of the highest or Herman Beach of Lake Agassiz.

Lawndale.—210 miles; Alt. 1,074 feet. The railroad crosses the upper Herman Beach 3 miles west of Rothsay, then passes onto the lower Herman Beach approaching Lawndale. (See Chap. XIII.)

Barnesville.—218 miles; Alt. 1,025 feet. (Winnipeg Line p. 328.)

Barnesville is on the Tintah Beach. A belt of gently undulating plain crossed at Barnesville is a moraine which was deposited in Lake Agassiz and leveled by its waves. One and two miles west of Barnesville, the Campbell and McCauleyville Beaches are crossed.

Baker.—226 miles; Alt. 939 feet. Sabin.—232 miles; Alt. 930 feet.

From Barnesville to Baker is a sandy plain of the ancient Lake Agassiz bottom. From Baker to Moorhead is the fine lacustrine silt of the bottom of Lake Agassiz. Sabin is on a narrow belt of undulating topography which represents a leveled moraine deposited in the waters of Lake Agassiz.

Moorhead.—241 miles; Alt. 904 feet. (Clay County.)

At the time of the formation of the Herman Beach the water of Lake Agassiz was about 200 feet deep where Moorhead is now. The soil on this axial portion of the ancient lake bottom is that of the finest water-assorted sediments, and is exceedingly fine-grained. The heaviest of these soils have been classified by the U. S. Bureau of Soils as Fargo clay, and pronounced the finest in texture known to the Bureau laboratories at the time the soil survey was made.

For Great Northern Lines in North Dakota, see "The Story of the Prairies," Willard, page 326.

WILLMAR-BRECKENRIDGE LINE

Wayzata.—24 miles from St. Paul; Alt. 938 feet. Long Lake.—27 miles. (For Hutchinson Line see p. 333.) Maple Plain.—31 miles; Alt. 1,014 feet. Delano.—38 miles; Alt. 947 feet.

Wayzata is at east end of Minnetonka Lake amongst morainic hills. Typical terminal moraine Wayzata to Maple Plain. Rolling till-plain west. Cross Crow River at Delano amid morainic hills.

The large valley now occupied by Crow River was made by the glacial St. Croix River when that stream flowed in the opposite direction to that in which the Crow now flows. The glacial St. Croix entered the valley of the old Mississippi where Delano is now. The Crow above Delano follows the old course of the Mississippi. After the last glacier had melted and the Mississippi had become established in its present course the Crow took the old channel of the St. Croix from Delano to the Mississippi at Dayton.

Montrose.—45 miles; Alt. 984 feet. Waverly.—48 miles; Alt. 1,000 feet. Howard Lake.—53 miles; Alt. 1,050 feet.

Morainic hills, with many small lakes and basins. Outwash plain north of Montrose. Howard Lake to Cokato rolling till-plain.

Cokato.—59 miles; Alt. 1,055 feet. Dassel.—65 miles; Alt. 1,089 feet. Darwin.—70 miles; Alt. 1,135 feet.

Cokato to Darwin typical morainic hills, with many small lakes.

Litchfield.—76 miles; Alt. 1,133 feet. (Meeker County.)

Outwash plain Darwin to Litchfield and Grove City. North of Litchfield 4 miles is a glacial lake bed about 6 by 12 miles in extent.

Atwater.—89 miles; Alt. 1,221 feet. Kandiyohi.—96 miles; Alt. 1,227 feet. **Willmar.**—102 miles; Alt. 1,133 feet. (Kandiyohi County.)

Ancient glacial river channels east of Grove City and Atwater. Moraine west to Kandiyohi. Then rolling till-plain to Willmar. Pass Foot Lake along south shore. Moraine north with typical group of morainic lakes.

Pennock.—109 miles; Alt. 1,126 feet. Kerkhoven.—116 miles; Alt. 1,113 feet. Murdock.—120 miles; Alt. 1,092 feet. DeGraff.—125 miles; Alt. 1,064 feet. **Benson.**—132 miles; Alt. 1,050 feet. (Swift County.) (Watertown-Huron Line see p. 335.)

Rolling till-plain Willmar to Benson. Hills of the great Fergus Falls moraine 2 to 4 miles north. Benson is on a broad outwash plain which is traversed by Chippewa River. This outwash plain extends north 20 miles and has a width of 2 to 15 miles. It was formed by the glacial waters flowing away from the melting ice at the time of the formation of the bordering moraines.

Clontarf.—140 miles; Alt. 1,048 feet. Hancock.—148 miles; Alt. 1,152 feet. **Morris.**—157 miles; Alt. 1,140 feet. (Stevens County.)

Outwash plain extends nearly to Hancock. Hancock is on the terminal moraine which lies between the Chippewa Valley outwash plain and the outwash of the Pomme de Terre Valley. The latter is crossed east of Morris. The Pomme de Terre was a large glacial river which carried waters from the melting ice sheet from the vicinity of Fergus Falls almost due south nearly 80 miles to the glacial River Warren. (See Chap. XV.)

Donnelly.—165 miles; Alt. 1,129 feet. Moose Island.—171 miles; Alt. 1,090 feet.

On rolling till-plain. Here is the Continental Divide which separates the waters tributary to the Red River of the North and Hudson Bay from the Minnesota and the Gulf of Mexico. This is the continental highland that hemmed in the waters of glacial Lake Agassiz. (See Chapters XII & XIII.)

Herman.—176 miles; Alt. 1,074 feet. Norcross.—181 miles ; Alt. 1,043 feet. Tintah.—192 miles; Alt. 1,001 feet. Campbell.—199 miles; Alt. 988 feet. Doran.—207 miles; Alt. 978 feet.

Herman is on the outer margin of the bottom of glacial Lake Agassiz. Two miles west of Herman is the Herman Beach, the highest shore-line of Lake Agassiz.

The Norcross Beach lies about 3 miles west of the Herman Beach, a tract of wave-washed sandy lake bottom lying between. From Norcross to Tintah is the flat plain of the bottom of Lake Agassiz. Near Tintah, 1 and 2 miles east, are 2 Tintah Beaches separated by a tract of wave-washed sand. Seven miles farther across the flat wave-washed till-plain is Campbell located on the Campbell Beach. Eight miles farther is Doran, on the McCauleyville Beach. The McCauleyville Beach marks the lowest level of Lake Agassiz while its waters outflowed southward by the River Warren. (See Chaps. XII & XIV.)

Breckenridge.—214 miles; Alt. 966 feet. (Wilkin County.)

From Doran to Breckenridge the plain is that of the fine lacustrine silt of the ancient lake bottom. The elevation of Herman is 1,074 feet; that of Breckenridge is 966 feet. Thus the water of Lake Agassiz at Breckenridge was more than 100 feet deep at the time when the shore line of the lake was at its highest level, that of the Herman Beach. (For Geology from a Car Window in North Dakota see "The Story of the Prairies," Willard, p. 326-328.)

BRECKENRIDGE-MOORHEAD LINE

Kent.—228 miles from St. Paul; Alt. 947 feet. Wolverton.—237 miles; Alt. 934 feet. Comstock.—244 miles; Alt. 925 feet. **Moorhead.**—260 miles; Alt. 904 feet. (Clay County.)

The railroad from Breckenridge to Moorhead crosses into North Dakota a distance of 6 miles, then follows the axis of the bed of the ancient Lake Agassiz from 1 to 3 miles east of the Red River of the North northward to Moorhead. The journey from Breckenridge to Moorhead is in most marked contrast with a journey from St. Paul to Breckenridge. Contrast in particular the scenery from Alexandria to Fergus Falls. (P. 318.) The two districts each owe their characteristics of surface to the great ice sheet. Both landscapes are young—they are today essentially as they were left after the great ice sheet melted. The Red River Valley is a nearly level plain whose surface owes its form to the work of the water which came from the melting ice sheet. The Lake Park Region owes its rough and tumultuous topography to the dumping of the earth burden of the glacier directly from the melting ice. From Breckenridge to Moorhead the railroad traverses the low axial portion of the floor of the ancient lake bottom. Here were deposited the finer sediments which were washed and assorted and laid down systematically in comparatively still water. The towns and villages along the line are primary shipping points for an important part of the world's bread supply.

MOORHEAD-CROOKSTON LINE

Kragnes.—9 miles from Moorhead; Alt. 892 feet. Georgetown.—15 miles. Perley.—22 miles; Alt. 877 feet. Hendrum.—28 miles; Alt. 875 feet. Halstad.—34 miles; Alt. 870 feet. Shelley.—42 miles. Nelsville.—46 miles. Climax.—52 miles. Eldred.—58 miles. **Crookston.**—68 miles; Alt. 871 feet. (Polk County.)

The railroad runs throughout the distance to Crookston mostly within 1 to 2 miles of the Red River of the North. The plain is the flat floor of the axial portion of the bottom of Lake Agassiz. The soil is possessed of great fertility, and the region has long been famous for its hard wheat. The landscape is like the surface of the sea for evenness. Vision is limited by the curvature of the earth.

DULUTH LINE

St. Paul to Minneapolis, see p. 316. Fridley.—19 miles from St. Paul; Alt. 847 feet. Coon Creek.—23 miles; Alt. 873 feet. Andover.—29 miles; Alt. 889 feet.

Passing to the east side of the Misssisippi after leaving the station at Minneapolis, the railroad follows the Mississippi across a sandy plain to Fridley and Coon Creek, the sandy plain becoming more broad at Andover.

Bethel.—41 miles; Alt. 931 feet. Isanti.—47 miles; Alt. 939 feet.

Extending northward is the largest sand-plain in Minnesota. Many lakes occupy depressions in the plain. The sand was probably derived from sandstone formations to the north and east, and was ground up by the great ice sheets. With the melting of the ice the sand was thrown down and was carried by the winds and widely spread. The sand was carried over lands that are naturally clayey in character, and thus the sandy plain appears larger than it really is. Much land over which a surface veneer of sand has been deposited is underlaid with clay and the soil is therefore of good quality. There are some tracts of active dune sand.

Cambridge.—53 miles; Alt. 964 feet. (Isanti County.) Grandy.—57 miles; Alt. 934 feet. Stanchfield.—59 miles; Alt. 945 feet.

East of Isanti and Cambridge, and extending north by Grandy and Stanchfield low ranges of morainic hills alternate with tracts of undulating ground moraine or till-plain. The water-table is near enough to the surface to give good support to growing crops even where sand has been blown over the surface. At Cambridge and Isanti Rum River meanders over the plain in a deep valley. (See Chap. XVI.) It carries water from Mille Lacs Lake.

Braham.—63 miles; Alt. 956 feet. Grasston.—69 miles; Alt. 961 feet. Henriette.—74 miles; Alt. 996 feet.

Braham is on the boundary between the gray drift (south) and the red drift (north). When the ice of the Keewatin glacier covered the region south of Braham the Mississippi River had its course around the edge of the glacier from St. Cloud, north of Princeton, near Braham and Grasston, to Pine City and the St. Croix. (See Chap. XVII.) Grass Lake, now a clayey plain, was a lake when the ice waters from the melting glacier were here. An outwash sandy plain is crossed by the Snake east of Grasston. Pokegama Lake lies in a long trough north of this, extending to a moraine at its north end. The lake trough was probably formed by a glacial river which came from the melting ice to the north when the moraine was being formed. The flat marshy tract south of Brook Park was a lake during the time when the melting ice was flooding its waters here, and the moraine to the south acted as a dam, as it still does, preventing the drainage of the swamp.

Brook Park.—79 miles; Alt. 1,030 feet. Hinckley.—88 miles; Alt. 1,032 feet. (Crossing N. P. Ry.) Sandstone.—97 miles; Alt. 1,082 feet. Askov.—103 miles; Alt. 1,163 feet. Bruno.—111 miles; Alt. 1,154 feet.

Swampy flat till-plain between Brook Park and Hinckley. About Hinckley gently undulating till-plain. South of Sandstone a narrow moraine is crossed, and this continues parallel with the railroad to Bruno. Another larger moraine lies east parallel with the railroad beyond Bruno. Kettle River is crossed near Sandstone, a broad and deep valley formed by the waters of glacial St. Louis River, which at one time passed down this valley to the Mississippi. (See Chap. XX.) Sandstone of Keeweenawan age outcrops in the side of Kettle Valley at Sandstone, and is extensively quarried.

Kerrick.—117 miles; Alt. 1,183 feet. Nickerson.—123 miles; Alt. 1,161 feet.

Swamp and undulating till-plain about Bruno. A moraine is crossed between Bruno and Kerrick, and outwash channels are crossed both north and south of the moraine. A swampy outwash channel also lies east of and parallel with the railroad. A moraine is seen east of this swampy channel. Willow Creek crosses the outwash at Kerrick. Nickerson is in the midst of rolling morainic hills. North from Kerrick the great moraine that was formed by the Labradorian glacier around the head of Lake Superior is crossed.

Holyoke.—130 miles; Alt. 1,039 feet.

The highest beach of glacial Lake Duluth is crossed a little south of Holyoke. This highest shore-line of the ancient lake is 400 feet higher than the present level of the lake. Above this highest beach the railroad crosses a sandy plain which was the bottom of a pond of ice water that gathered in front of the ice and behind the moraine, and became a temporary lake and received the sand deposits.

Four miles east of Holyoke the railroad crosses the State line into Wisconsin. Its course winds over the flat plain of clayey deposits of glacial Lake Duluth, the Superior red clay, to the city of Superior. The St. Louis River is crossed to the city of Duluth.

DULUTH-CROOKSTON LINE

Carlton.—35 miles from Duluth; Alt. 1,084 feet. (Carlton County.)

The railroad runs via Superior across the ancient bottom of Lake Duluth. The plain is that of the Superior red clay. Before reaching Carlton a leveled moraine is crossed which was deposited in the waters of Lake Duluth. The St. Louis River has cut an opening through the ancient beach of the lake, and through this opening the railroad approaches Carlton. The great moraine which lies all around the west end of Lake Superior was cut through at Carlton by the glacial floodwaters of the St. Lôuis River. In this passage through the moraine is now the city of Carlton, the river, and the railroads. Pre-Cambrian rocks are exposed in high embossments. These were overridden by the ice sheets and their surfaces smoothed and polished.

Scanlon.—38 miles; Alt. 1,146 feet. Cloquet.—41 miles; Alt. 1,195 feet.

A gravelly outwash was made at Scanlon by the glacial floodwaters of St. Louis River. Hard knobs and promontories of pre-Cambrian rocks give a picturesque appearance to the valley, Carlton to Cloquet. These outcropping ledges show many smooth surfaces polished by the ice. Glacial striæ on these smoothed surfaces show the direction of ice movement. Their general trend is north of west, showing that the Labradorian glacier moved out westward through the basin of Lake Superior. When the edge of the glacier was at Carlton the St. Louis River was turned southward along the edge of the ice. It was then that the great gravelly outwash plain from Scanlon southwest to Iverson and Atkinson was formed. At this time the waters of the St. Louis flowed past Moose Lake and down the Kettle River valley to the St. Croix. (See Chap. XX.)

Draco.—49 miles; Alt. 1,215 feet. Brookston.—58 miles; Alt. 1,229 feet.

A hilly moraine 2 miles in width is cut through by the river at Draco. West of this is rolling till-plain. Three miles west of Brevator, another moraine is entered upon. West of Brookston is another moraine, which is crossed, or run through, to Paupori and Mirbat. The glacial flood waters of the river cut a large valley and the railroad follows the west bank from Carlton to Mirbat.

Mirbat.—70 miles; Alt. 1,249 feet.

At Mirbat the boundary between the Labradorian (red) drift and the Keewatin (gray) drift is crossed. A lobe of the Keewatin glacier crossed the Iron Ranges and moved south as far as Mirbat, McGregor, and Moose Lake. The Patrician glacier had passed over the country to the north a little earlier, and its moraines were overridden by the ice of the Keewatin glacier. (See Chap. IV.) Glacial Lake Upham was formed from the ponded waters of the melting Keewatin glacier west and north of Mirbat. (See Chap. XXI.) About a mile west of Mirbat a beach of Lake Upham can be seen from the south window.

Floodwood.—75 miles; Alt. 1,257 feet. Island.—81 miles; Alt. 1,274 feet. Wawina.—88 miles; Alt. 1,269 feet.

About Floodwood is a clayey plain, sediment deposited by the waters of Lake Upham. This plain is crossed by St. Louis River. The plain continues up Floodwood River from Floodwood. These clayey tracts lie along the river courses, and the intervening areas are marshes. Island is on an island of clay, surrounded by marsh. Wawina is on a larger island, which is sandy in character.

Swan River.—92 miles; Alt. 1,294 feet. (For Kelly Lake Line see p. 337. For Hill City Line see p. 373.)

Sandy plain near western shore of Lake Upham. To the west is a moraine of Patrician red drift overridden by gray Keewatin drift.

Warba.—97 miles; Alt. 1,277 feet. Blackberry.—101 miles; Alt. 1,304 feet. **Grand Rapids.**—111 miles; Alt. 1,289 feet. (Itasca County.) (For Hibbing-Virginia Line see p. 337.)

Warba and Blackberry are on gently rolling till-plain. About Grand Rapids red drift moraines overridden by Keewatin ice and veneered with gray drift. A few miles southwest of Grand Rapids is Pokegama Lake, a large lake with exceedingly irregular outline, in depressions in the overridden moraine.

Cohasset.—116 miles; Alt. 1,287 feet. Deer River.—126 miles; Alt. 1,294 feet. Bena.—146 miles; Alt. 1,311 feet.

Marshy undulating till-plain. The railroad runs between Ball Club Lake and the Mississippi River. The Mississippi passes within a few rods of Ball Club Lake but does not tap it. From Ball Club Lake the railroad runs along the south side of a large sandy outwash plain for a distance of 50 miles.

Cass Lake.—165 miles; Alt. 1,331 feet. (Park Rapids-Cass Lake Line see p. 332.)

Cass Lake is between Cass Lake and Pike Bay, on the southern side of the great outwash plain. Lakes Winnibigoshish and Bemidji are on this sandy plain, across which from west to east meanders the Mississippi River. The Soo and Great Northern run side by side for 30 miles. North of this sandy plain is the large clayey moraine from which it was formed. Good clayey land lies south. Many beautiful smaller lakes lie in depressions in the sandy plain, showing that the water table is not far below the surface.

Bemidji.—180 miles; Alt. 1,351 feet. (Beltrami County.) (Crossing M. & I. Ry.)

The railroad runs between Bemidji Lake and Lake Irving, crossing the Mississippi River by which the two lakes are connected. East of Nymore and Bemidji is an ''island'' of clayey till-plain in the sandy outwash plain. Good clayey land lies a few miles south.

Wilton.—186 miles; Alt. 1,391 feet.

On a sandy moraine which forms an "island" in the outwash plain. This morainic island is about 2 miles in width and 5 miles long, north and south.

Solway.—192 miles; Alt. 1,454 feet.

On rolling clayey till-plain. The outwash plain of sand which has been traversed for 50 miles has its western margin 3 miles east.

Shevlin.—198 miles; Alt. 1,457 feet. **Bagley.**—205 miles; Alt. 1,446 feet. (Clearwater County.) Ebro.—213 miles; Alt. 1,458 feet.

These three places are on a long narrow outwash plain which borders an extensive clayey moraine to the north. This outwash plain extends south from Bagley and Ebro more than 30 miles through the great moraine. The moraine continues southward and becomes merged with the great Fergus Falls moraine.

Lengby.—219 miles; Alt. 1,395 feet.

Lengby is in the midst of this great moraine. Many small lakes occupy basins amongst the hills. This great moraine extends across the continental Height of Land. Height of Land Lake is in this moraine 40 miles south. Lake Itasca, the source of the Mississippi River, is 25 miles southeast. Many rivers that discharge into the Red River of the North take their beginning among the hills of this moraine, as Clearwater, Lost, Hill, Poplar, Sand Hill, Wild Rice, White Earth, and Buffalo.

Fosston.—226 miles; Alt. 1,298 feet. McIntosh.—233 miles; Alt. 1,228 feet.

Fosston at west edge of moraine. McIntosh is on rolling till-plain.

Erskine.—239 miles; Alt. 1,201 feet.

Sandy moraine 3 miles east. Herman Beach, highest shore-line of Lake Agassiz, crossed 1 mile east. Group of morainic lakes south and west, the largest of which is Maple Lake.

Mentor.—246 miles; Alt. 1,177 feet.

Mentor is on the second Herman Beach. The first or highest lies parallel with the railroad and the second beach 1 mile south. West of Maple Lake the beaches turn abruptly south. Four miles west of Mentor the second Herman Beach is crossed by the railroad, and a mile farther west another, the third Herman Beach, is crossed. The beaches are here multiple, and represent changes in the level of the crust of the earth. (See Chap. XIV.)

Dugdale.—251 miles; Alt. 1,143 feet. Tilden.—253 miles; Alt. 1,120 feet. (Crossing N. P. Ry.) Benoit.—257 miles; Alt. 1,030 feet.

Between Dugdale and Benoit 8 beaches are crossed, and 2 more are crossed west of Benoit. There is a difference in elevation between the highest and lowest Herman Beaches here of 98 feet. Yet these beaches all merge into one beach at Lake Traverse. These differences in level show that the crust of the earth was rising during the time the beaches were being formed. (See Chap. XIV.)

Crookston.—272 miles; Alt. 871 feet. (Polk County.)

Crookston is on the flat plain of the ancient bottom of Lake Agassiz.

Fisher.—283 miles; Alt. 856 feet. Mallory.—291 miles; Alt. 841 feet. East Grand Forks.—297 miles; Alt. 835 feet.

The line west is upon the lacustrine silt deposited on the deeper bottom of Lake Agassiz. The Red River of the North, the boundary of the State, is crossed at East Grand Forks.

(For North Dakota see "The Story of the Prairies," Willard, p. 315.)

WINNIPEG LINE

Barnesville.—218 miles from St. Paul; Alt. 1,025 feet. Downer.—226 miles; Alt. 968 feet.

Barnesville is on the Tintah Beach. A belt of leveled moraine half a mile to 1 mile in width lies west of Barnesville, and is crossed by the railroad immediately west of the city. The Campbell Beach is crossed at west side of the leveled moraine, and the McCauleyville Beach is crossed approaching Downer.

Glyndon.—235 miles; Alt. 926 feet. (Crossing N. P. Ry.) Averill.—242 miles; Alt. 921 feet.

Glyndon is on the fine-grained lacustrine plain. Averill is near the edge of the wave-washed sandy shore plain.

Felton.—250 miles; Alt. 919 feet. Borup.—257 miles; Alt. 915 feet. Wheatville.—260 miles; Alt. 910 feet. Ada.—265 miles; Alt. 910 feet. Lockhart.—275 miles; Alt. 898 feet. Beltrami.—282 miles; Alt. 905 feet.

Felton is on the sandy littoral zone,—wave-washed sand covering the deeper clayey subsoil. Beaches to the east. Toward the west the soil grades into the fine lacustrine silt. North to Ada and Crookston the plain is that of fine lacustrine sediment. The soil is famous for its fertility. The plain is nearly flat, and artificial drainage is required in places to assist nature in carrying away the waters. The Wild Rice River, after dropping down from the Height of Land to the east, divides east of Ada and enters the Red River of the North by two distinct channels, the northern one, which joins the Red near Shelley, being known as Marsh River. At Beltrami is a sandy plain having much the aspect of a delta. It is a sandy plain at the point where Sand Hill River discharged into Lake Agassiz. After crossing its own sand-plain Sand Hill River spreads out into a marsh west of Beltrami, then sluggishly meanders across the flat lake bottom plain to the Red River of the North.

Crookston.—299 miles; Alt. 871 feet. (Polk County.) (Crossing N. P. Ry.) (For Duluth Line see p. 323. For Warroad Line see p. 329.) Shirley.—306 miles; Alt. 905 feet. Euclid.—313 miles; Alt. 895 feet. Angus.—321 miles; Alt. 875 feet.

Shirley is on sandy littoral zone. McCauleyville Beach crossed 3 miles south, and lies parallel with the railroad north. Euclid is on lake-washed till-plain, the town being at the boundary between the fine-grained lacustrine silt west and the lake-washed till east.

Warren.—329 miles; Alt. 858 feet. (Marshall County.) (Crossing Soo Line.) Argyle.—339 miles; Alt. 850 feet. Stephen.—348 miles; Alt. 833 feet. Donaldson.—356 miles. Kennedy.—361 miles. Hallock.—370 miles; Alt. 820 feet. Northcote.—376 miles; Alt. 807 feet. Humboldt.—383 miles. St. Vincent.—390 miles; Alt. 790 feet. Winnipeg.—458 miles; Alt. 757 feet..

The sandy littoral zone approaches Warren on the east, and extends near the railroad north to Argyle. Thence on the broad flat plain extends as far as the eye can reach, save for interruption of lines of trees along the stream courses. The plain presents the monotonous level like that of the sea. The fertility of the soil formed from this fine-grained lake sediment is world renowned. Here has long been one of the great sources of the world's bread supply. Probably nowhere else in the world is there a plain so great in extent, so nearly level in surface, and so fertile in those elements which are needed for the growth of cereal crops.

WARROAD BRANCH

Red Lake Falls.—32 miles from Crookston; Alt. 1,001 feet. (Red Lake County.) St. Hilaire.—42 miles; Alt. 1,083 feet.

The surrounding nearly level plain is that of lake-washed till, the drift deposits being leveled to a gently undulating surface by the waves of Lake Agassiz. The Campbell Beach is 3 miles west. Several fragments of beaches are on the sandy plain 4 to 6 miles east. Lake-washed sand lies along the Red Lake River and its tributaries.

Thief River Falls.—50 miles; Alt. 1,135 feet. (Pennington County.) (Crossing Soo Line.)

Lake-washed till with marshy depressions surrounding. A moraine deposited in Lake Agassiz and leveled by its waves, and overstrewn with sand, lies 3 miles west. Sandy and gravelly beaches border this leveled moraine on the west.

Holt.—62 miles; Alt. 1,161 feet.

On wave-washed moraine. A sandy beach lies on either side of this moraine.

Middle River.—72 miles; Alt. 1,149 feet.

West of lake-washed moraine on tract of littoral sand. Beaches crossed north, then an arm of the great Beltrami swamp, to Strathcona.

Strathcona.—81 miles.

Sandy beaches crossed south of Strathcona. On lake-washed sandy till-plain.

Greenbush.—91 miles; Alt. 1,078 feet.

Lake-washed sandy till-plain. Town on sandy Campbell Beach. Marsh bordering beach on south is caused by the beach holding back the waters from draining away.

Badger.—100 miles; Alt. 1,076 feet. Fox.—107 miles. **Roseau.**—113 miles; Alt. 1,056 feet. (Roseau County.)

The railroad runs on the Campbell Beach 4 miles beyond Fox. The plain on either side of the beach is lake-washed clayey till.

Mandus.—118 miles. Salol.—123 miles. Warroad.—135 miles; Alt. 1,073 feet.

Salol is on an island of lake-washed sandy till surrounded by the Beltrami Swamp. Warroad stands on the lake-washed till-plain 1 mile from the shore of Lake of the Woods. A fragment of beach is passed west, and another lies 1 mile south.

DULUTH-WILLMAR LINE

Brook Park.—80 miles from Duluth; Alt. 1,030 feet.

Gently rolling or flat till-plain. Many undrained depressions. Boulders abundant, from the Lake Superior region.

Quamba.—85 miles.

Flat marshy till-plain east. Low-rolling clayey moraine immediately east of station, about 2 miles in width.

Mora.—91 miles; Alt. 1,010 feet. (Kanabec County.) Ogilvie.—98 miles. Bock.—105 miles; Alt. 1,084 feet.

A gravelly esker 10 miles in length is cut through by Snake River at Mora. This has been extensively used as a source of gravel. Mora is on a gravelly outwash plain which is related to the moraine north. Snake River and the streams crossed to the west are small streams flowing over the bottoms of large valleys,—valleys cut by the larger glacial flood streams that coursed down them. Mora to Milaca and beyond is a splendid tract of rolling till-plain having excellent soil. Hard wood forests have grown extensively since the cutting of the original pine.

Milaca.—110 miles; Alt. 1,073 feet. (Mille Lacs County.) (For Princeton Line see p. 331.)

Rum River is a small stream which meanders over the broad bottom of a large glacial valley. It carries water from Mille Lacs Lake to the

Mississippi. A clayey moraine a quarter of a mile in width lies parallel with the railroad Milaca to Foreston.

Foreston.—3 miles from Milaca. Ronneby.—12 miles. **Foley.**—14 miles; Alt. 1,798 feet. (Benton County.)

Rolling till-plain or ground moraine. An esker 4 miles in length lies south of Foley 1 mile.

St. Cloud.—29 miles; Alt. 1,040 feet. (Stearns County.) (Crossing N. P. Ry.)

One mile west of St. Cloud outcropping of granitic rock where extensive quarries are operated.

Rockville.—39 miles; Alt. 1,077 feet.

On outwash plain in valley of Sauk River. Till-plains north and south approaching Rockville. Moraine west bordering outwash plain both north and south. Three miles west cross boundary between Patrician (red) drift (east) and Keewatin (gray) drift (west).

Richmond.—48 miles.

On broad undulating outwash plain of Sauk Valley. This was the old valley of the Mississippi. (Chap. XVI.) Many lakes and sloughs in depressions. Moraine north, and in distance south.

Roscoe.—54 miles. Paynesville.—59 miles. Hawick.—64 miles.

On sandy outwash plain which extends 40 miles northward. Crossing Soo Line at Paynesville.

New London.—71 miles; Alt. 1,218 feet.

At southern point of outwash plain amidst the hills and lakes of the Fergus Falls moraine. Railroad runs south across moraine, passing west of Green Lake and many small lakes. Gently rolling till-plain about Willmar.

PRINCETON LINE

Pease.—115 miles from Duluth; Alt. 1,030 feet.

Rolling or undulating till-plain. Three miles south cross sandy moraine one-half mile in width, then across flat clayey plain, the bottom of a glacial lake which was formed by the hemming in of the water from the melting ice sheet by the moraine which is crossed 1 mile north of Princeton. The outlet of the lake was 3 miles west of Princeton, across a sandy outwash plain that joins the great outwash plain along the Mississippi.

Princeton.—124 miles; Alt. 976 feet.

Princeton is on an extensive undulating sandy plain, in part windblown. (See Chaps. III and XXVI.) Rum River valley is a large glacial valley, with broad flat bottom over which the river meanders.

Zimmerman.—133 miles; Alt. 977 feet.

From Zimmerman south the topography is that of typical terminal moraine, very decidedly rolling in character. The moraine is sandy in character, and forested to a large extent. Four miles north of Elk River the sandy outwash plain of the Mississippi is reached.

PARK RAPIDS-CASS LAKE LINE

Sauk Center.—117 miles from St. Paul. Little Sauk.—10 miles; Alt. 1,261 feet.

The old course of the Mississippi was where the Sauk Valley is now from Sauk Center to Richmond. (See Chap. XVI.) Sauk Lake lies in the old valley, the water being ponded by the outwash in the valley. The railroad runs on the drift hills that block the old valley to Little Sauk.

Round Prairie.—131 miles; Alt. 1,334 feet. **Long Prairie.**—136 miles; Alt. 1,298 feet. (Todd County.) Browerville.—143 miles; Alt. 1,284 feet.

Round Prairie is on the glacial gravel filling which was deposited when the ice waters were carrying their burden of earth southward. The outwash plain is broad here, hence it is called "round" prairie. Long Prairie River now flows in the opposite direction to that of the glacial river which built up the sandy bottom. The sandy plain of the valley is narrow and long, and hence the name "long" prairie. The railroad follows **down** Long Prairie River, but **up** the old glacial river course, to Browerville. Here it turns up Eagle Creek, which also is in a large glacial stream channel. Rolling till-plain borders the old glacial valley on either side. The till-plain was formerly forested, but the sandy and gravelly valley bottoms were not naturally forested. This was therefore a "long prairie" in a forested country, and hence came to be called "Long Prairie."

Clarissa.—149 miles; Alt. 1,331 feet. Eagle Bend.—154 miles; Alt. 1,367 feet. Bertha.—161 miles; Alt. 1,406 feet. Hewitt.—165 miles.

At Eagle Bend the railroad turns away from the ancient water-course and crosses rolling till-plain past Bertha to Hewitt. An outwash channel now followed by Wing River is crossed at Hewitt. A clayey till-plain and small moraine are west. Then sandy outwash to Wadena.

Wadena.—173 miles; Alt. 1,334 feet. (Wadena County.) Sebeka.—187 miles. Menahga.—198 miles; Alt. 1,403 feet. **Park Rapids.**—108 miles; Alt. 1,434 feet. (Hubbard County.)

A broad sandy plain about Wadena consists of glacial deposits overlaid with fine sand and silt which were partially water-assorted by waters from the melting ice sheet. Six miles north of Wadena a gently rolling clayey till-plain extends to and beyond Sebeka. North from Sebeka to Park Rapids is the western edge of a great sandy outwash plain formed from the large moraine which embraces the southern half of Hubbard County and extends for many miles both east and west.

Dorset.—215 miles. Nevis.—220 miles; Alt. 1,473 feet. Akeley.—226 miles; Alt. 1,430 feet. **Walker.**—236 miles; Alt. 1,342 feet. (Cass County.) (Crossing M. & I. Ry.)

Park Rapids to Dorset and Nevis the sandy morainic hills have been washed and leveled by the waters escaping from the great melting ice sheet. Many beautiful lakes lie in depressions on this modified outwash tract, and along the morainic hills to the north. Lake Itasca and many beautiful lakes are within a few miles. At Akeley the morainic hills were somewhat subdued by the outwashing glacial waters but the hills north and south of Akeley and on to Walker are typically roughly-rolling. Walker is on the west shore of Leech Lake amidst the most beautiful of morainic hills.

Wilkinson.—248 miles. Cass Lake.—257 miles; Alt. 1,331 feet. **Bemidji.**—272 miles; Alt. 1,351 feet. (Beltrami County.)

The railroad runs for 10 miles north from Walker through rolling morainic hills, forested except where the forests have been destroyed by axe or fire. Wilkinson is on a till-plain, with marsh to the east. This till-plain continues north till the great sandy outwash plain is reached, which extends to and beyond Cass Lake.

HUTCHINSON LINE

Minnetonka Beach.—29 miles from St. Paul; Alt. 961 feet.

On north shore of Lake Minnetonka amid the rolling hills of this morainic region. The many bays of the lake, and the islands, which are morainic hills surrounded by water, with the setting of morainic hills and hollows all about, make a picturesque example of morainic topography.

St. Bonifacius.—37 miles; Alt. 945 feet.

The great terminal moraine continues, passing Clearwater Lake, and many small lakes.

Mayer.—45 miles.

On rolling till-plain, which borders the moraine on the west. Buffalo Lake crossed 1 mile west.

Lester Prairie.—52 miles; Alt. 983 feet.

On rolling till-plain.

Silver Lake.—60 miles.

Silver Lake is one of a group of beautiful morainic lakes that occupy depressions in the rolling till-plain. These lakes are morainic in character, and the till-plain differs from terminal moraine only in the degree of irregularity of the surface.

Hutchinson.—68 miles; Alt. 1,044 feet.

Hutchinson is at the southern point of a prominent moraine that extends away to the north. This moraine is thickly set with typical morainic lakes, with many small basins often called "pots and kettles," many of these lakes having beautiful shores. Most of the lakes are without outlets, being typical dump moraine basins. This is the southern part of the Lake Park Region of Minnesota. This great moraine extends continuously though with much irregularity to and beyond Fergus Falls, and is included in the Fergus Falls moraine.

WILLMAR-YANKTON LINE

Raymond.—114 miles from St. Paul; Alt. 1,082 feet.

Rolling till-plain Willmar to Raymond. Small lake at Raymond, an enlargement of Hawk Creek. This creek is deflected towards the northwest from its course southward by a narrow moraine which lies west of Raymond.

Clara City.—122 miles; Alt. 1,057 feet.

At west end of a moraine which extends 15 miles east.

Maynard.—128 miles.

Till-plain from Clara City. Cross moraine 1 mile west. The railroad crosses outwash plain and moraine before entering the valley of Minnesota River.

Granite Falls.—137 miles; Alt. 931 feet. (Yellow Medicine County.)

South of the station is a large natural "park" of granite crags and knobs. Many polished surfaces show the effect of the passing of the ice sheets over these hard rocks. Many granite boulders were carried from here southward and deposited with other drift materials. Glacial gravels form the valley bottom, filled in after the glacial floods had eroded the deep valley.

Hanley Falls.—146 miles. Cottonwood.—152 miles.

Cross moraine 2 miles in width after leaving Minnesota Valley. Rolling till-plain or ground moraine continues beyond Cottonwood. Lakes occupy many depressions in till-plain.

Green Valley.—160 miles.

Four moraines lying in parallel belts between Cottonwood and Green Valley merge into one broad morainic belt east. Bordering this moraine is an outwash plain or glacial channel which borders the moraine on the south and west for 50 miles.

Marshall.—165 miles; Alt. 1,165 feet. (Lincoln County.)

Gently rolling till-plain north. The city is on a low-rolling moraine, which extends many miles northwest and southeast. The moraine is here about a mile wide.

Lynd.—178 miles; Alt. 1,329 feet. Russell.—178 miles; Alt. 1,517 feet. Florence.—186 miles; Alt. 1,724 feet.

After crossing the ancient waterway at Green Valley the railroad follows the course of Redwood River 25 miles to Florence, up the east slope of the Coteau des Prairies. The rise from Marshall to Florence is 556 feet in 21 miles. Lynd is on rolling till-plain. West a roughly rolling moraine is crossed to Russell. The C. & N. W. Ry. is crossed east of Florence amidst the rolling hills of another moraine.

Ruthton.—191 miles; Alt. 1,730 feet.

On rolling till-plain. Two miles west the great Altamont moraine. This moraine forms the crest of the Coteau des Prairies. The hills are picturesque in their irregular tumbling character, and fittingly mark the limit reached by the great ice sheet.

Holland.—199 miles; Alt. 1,778 feet.

Holland is on the west slope of the Coteau des Prairies. Ancient watercourses extend away from the moraine, avenues by which the waters from the melting glacier escaped to the Missouri Valley. One of these ancient channels is crossed before reaching Holland. Small streams meander on many of the flat bottoms of these ancient courses.

Pipestone.—207 miles; Alt. 1,732 feet. (Pipestone County.)

Holland to Pipestone is undulating or rolling till-plain, which lies west of the great Altamont moraine. The boundary of the drift deposited by the Keewatin glacier lies in the western limits of the city of Pipestone.

Ihlen.—214 miles; Alt. 1,649 feet. Jasper.—219 miles; Alt. 1,544 feet.

West from Pipestone the railroad follows the valley of Split Rock Creek. This valley has been eroded deeply into the hard rocks that underlie the old Kansan drift.

WATERTOWN-HURON LINE

Benson.—132 miles from St. Paul; Alt. 1,050 feet. (Swift County.) Danvers.—140 miles. Holloway.—148 miles.

Sandy outwash plain from Benson 6 miles. Danvers is on a narrow moraine, clayey in character, then another outwash plain. Holloway is on rolling till-plain. Holloway to Appleton the railroad runs on sandy outwash past the ends of 4 moraines which were islands in the great glacial River Warren.

Appleton.—154 miles; Alt. 1,016 feet. (Crossing C., M. & St. P. Ry.) Louisburg.—163 miles. Bellingham.—169 miles. Nassau.—178 miles; Alt. 1,122 feet.

The railroad continues west across the sandy outwash plain, and crosses the Minnesota Valley. Louisburg is on an island of clayey till, a channel of the flood stage of River Warren lying to the west. Rolling till-plain to Bellingham. Large moraine west, nearly to Nassau. Outwash plain east of Nassau, bordered by narrow moraine on which Nassau stands.

BROWN'S VALLEY LINE

Morris.—157 miles from St. Paul; Alt. 1,140 feet. (Stevens County.) Chokio.—171 miles. Johnson.—177 miles. Graceville.—184 miles; Alt. 1,109 feet. (Crossing C., M. & St. P. Ry.)

The line west from Morris is through a rolling ground moraine or till-plain. The character of the drift is clayey rather than sandy, and the texture of the soil is excellent. Many of the hills or ground swells approach the dignity of morainic hills, and again the topography has a broad sweeping horizon of the gently and broadly rolling prairie. Many lakes occupy depressions in the till-plain, and these are mostly without outlets, showing the "young" character of the landscape. Northwest of Graceville is a moraine which marks the halting place of the margin of the glacier immediately preceding the beginning of Lake Agassiz.

Beardsley.—197 miles; Alt. 1,098 feet.

Three miles east the railroad enters upon a moraine at the west edge of which Beardsley is located. An outwash plain 1 to 2 miles wide extends south along the west side of this moraine to Big Stone Lake. This was the avenue of escape for the waters from the melting ice sheet to glacial River Minnesota.

Brown's Valley.—204 miles; Alt. 981 feet.

Crossing a till-plain about 4 miles the deep valley of Traverse Gap is reached. Brown's Valley stands on the glacial outwash or sandy filling of this ancient channel, and is the technical source of Minnesota River. The city is built on the sandy filling which is the "divide" between the northward flowing Red River of the North and the Minnesota. It was across this divide and through this gap that River Warren carried the waters of Lake Agassiz southward. (See Chap. XII.)

EVANSVILLE-TINTAH LINE

Elbow Lake.—17 miles from Evansville; Alt. 1,199 feet. (Grant County.) Hereford.—24 miles. Tintah.—33 miles; Alt. 1,001 feet.

Evansville is amongst the hills of the great Fergus Falls moraine. The line runs through the hills west about 7 miles, then till-plain. West of the till-plain an outwash channel is crossed, over the broad flat bottom of which Pomme de Terre River meanders for a distance of 70 miles, past Morris and Appleton, till it enters the Minnesota. This valley is broad, and its bottom filled with glacial gravel and sand. A large river flowed down this valley when the ice was melting near Fergus Falls. West of this ancient channel is a narrow moraine, followed by till-plain. Elbow Lake is on another moraine, in the midst of a group of beautiful morainic lakes. West is another belt of undulating till-plain, between which and another long narrow moraine is an ancient watercourse on the sandy bottom of which Mustinka River now meanders. West of this moraine is till-plain, up to the sandy and gravelly shore-line of Lake Agassiz, the Herman Beach. A mile west the Norcross Beach is crossed, and after crossing wave-washed till for several miles the Tintah Beach is crossed. Tintah is on the wave-washed till-plain near this beach.

PELICAN RAPIDS BRANCH

Elizabeth.—196 miles from St. Paul. Erharts.—203 miles. Pelican Rapids.—209 miles; Alt. 1,302 feet.

This branch of the railroad runs on the outwash plain that extends to Detroit. It becomes broader toward the north. Ruggedly rolling morainic hills lie on either side of the great outwash plain. This is an interesting part of the Lake Park Region. Lakes Lida and Lizzie lie to the east, and Pelican and Cormorant to the north. Countless smaller lakes of great beauty are on every hand. A clayey lake bottom plain lies east of Pelican Rapids. Around beautiful Lakes Lida and Lizzie there are gravelly beaches which are 7 to 10 feet higher than the present lakes showing that the two lakes were once included in a larger body of water. Pelican River drains Pelican, Lizzie, Lida, and Prairie, and flows down across the sandy plain of the ancient glacial watercourse past Elizabeth to a point 4 miles north of Fergus Falls, where it crosses the moraine to the westward and enters upon the sandy plain of another outwash channel, and flows south in this channel till it joins the Otter Tail or Red.

KELLY LAKE & VIRGINIA LINE

Goodland.—98 miles from Duluth; Alt. 1,420 feet. Acropolis.—101 miles. Bengal.—107 miles. (Crossing D., M. & N. Ry.)

Railroad runs near shore of glacial Lake Upham, on overridden moraine of red drift.

Kelly Lake.—118 miles; Alt. 1,511 feet.

On rolling till-plain. Overridden moraine north.

Hibbing.—122 miles; Alt. 1,542 feet. Chisholm.—127 miles; Alt. 1,502 feet. Buhl.—132 miles. Virginia.—144 miles; Alt. 1,434 feet.

The line from Kelly Lake to Virginia is over a drift covered area, stony and rolling hilly. The great Mesabi Iron Range lies to the north and parallel with the course of the railroad. East of Virginia the primitive Archæan rocks outcrop. The Archæan and other pre-Cambrian formations north of the Range were swept bare of soil by the ice sheets. The drift covering in this part of the State varies from none or a few feet to 50 or more. The rock formations are pre-Cambrian in age. They are very hard, and from this fact arises the great number of "hardheads" or boulders of granite and quartzite and other hard rocks in the drift deposits to the south.

COLERAINE LINE

Coleraine.—9 miles from Grand Rapids; Alt. 1,343 feet. Bovey.—10 miles.

Overridden moraine, red drift veneered by gray drift. Trout Lake south.

Nashwauk.—24 miles; Alt. 1,430 feet.

Overridden moraine. Pass Swan Lake and other small morainic lakes.

Keewatin.—29 miles; Alt. 1,472 feet.

On rolling till-plain.

CHAPTER XXXII

GEOLOGY FROM A CAR WINDOW

NORTHERN PACIFIC RAILWAY

St. Paul.—0 miles; Alt. 732 feet. (Ramsey County.)

(For trains running St. Paul to Minneapolis over Great Northern tracks, see p. 316.)

Leaving Union Depot the railroad ascends an old preglacial valley which was partially filled with drift. At Soo Junction morainic hills of red drift are encountered. These morainic hills continue to Como Lake, then a red drift outwash plain is crossed as far as the State Fair Grounds. The State Fair Grounds and the buildings of the State Agricultural College are on hills of gray drift. The boundary between the red drift morainic hills and the veneer of gray drift deposited by the later Keewatin glacier passes through St. Anthony Park. The roughly rolling hills east and south are red drift. The more undulating surface westward is that of the gray drift. The railroad thence crosses tracts of peat and dune sand to the glacial gravel terraces of the Mississippi, and crosses the rocky gorge of the Mississippi below St. Anthony Falls.

Minneapolis.—10 miles from St. Paul; Alt. 854 feet. (Hennepin County.)

Fine view of the head of the gorge of the Mississippi and of St. Anthony Falls. St. Peter sandstone exposed below; Trenton limestone above. North of the city the railroad again crosses the river to the east bank. Northward dune sand and glacial gravel terraces border the river. At Northtown a gray drift moraine is cut through by the river. St. Peter sandstone overlaid by Trenton limestone is exposed above Northtown.

Fridley is on an island of outwash gravel, with glacial gravel terrace between it and the river. Dune sand and peaty marshes to Coon Creek. Gray outwash gravel to Anoka.

Anoka.—29 miles from St. Paul; Alt. 904 feet. (Anoka County.)

Sandy outwash plain, nearly level. Moraine at Dayton west of river.

Elk River.—41 miles; Alt. 924 feet. (Sherburne County.)

On edge of outwash plain. Terminal moraine east and north. Rolling hills and lakes characteristic of terminal moraines. Mississippi River seen from west window. Morainic hills seen from east window (north).

Big Lake.—49 miles; Alt. 960 feet. Becker.—57 miles; Alt. 996 feet.

Outwash plain of gray drift, related to moraine across river at Enfield, 1 mile west of Becker.

Clear Lake.—64 miles; Alt. 1,016 feet.

Outwash plain; gently undulating, with hollows occupied by lakes. These basins mark places where pieces of glacier ice were buried, and later melted leaving the hollows.

St. Cloud.—76 miles; Alt. 1,049 feet. (Stearns County. Railroad station is in Benton County.) (Crossing G. N. Ry.)

State Reform School, west window, before reaching St. Cloud. Sandy and gravelly soil of the outwash plain with tract of wind-blown dune sand east. Rolling clayey till-plain outside the valley. Two areas of granitic rock occur, one northeast and another southwest of St. Cloud; extensive granite quarries are operated. The Mississippi River is crossed in going from the station to city of St. Cloud.

Sauk Rapids.—77 miles; Alt. 1,034 feet.

Sauk Rapids is located on a sloping hill of granitic rock. The outwash plain lies on either side of the Mississippi River. The river was diverted from its old course by the glacier and forced to flow across the rocky ledge which forms the rapids. (Chap. XVI.) The granite which here appears at the surface is part of the ancient rock foundation of Minnesota. (See Chap. X.)

Sartell.—80 miles; Alt. 1,044 feet. Watab.—84 miles; Alt. 1,080 feet.

Rapids caused by river passing over ledge of granite rock. Railroad traverses glacial river terraces. Hills east are dune sand upon granite rock, or upon drift (till).

Rice.—90 miles; Alt. 1,086 feet. Royalton.—97 miles; Alt. 1,103 feet.

Gently undulating red drift outwash plain. Soil sandy. Dune sand over moraine north and east, wooded. One mile east of Royalton clayey till-plain, with soil of excellent quality.

Little Falls.—107 miles; Alt. 1,134 feet. (Morrison County.)

Pass under Soo Line 4 miles north of Royalton. Near crossing the character of the outwash plain changes to sand deposited by glacial flood waters of the Mississippi. This continues 2 miles north of Little Falls. Two miles east the surface is that of a rolling till-plain, with mixed sandy and clayey soils. Many lakes and sloughs in depressions. Fine quality of farming land. Railroad crosses the Mississippi River at this point. Large paper manufacturing plant. Power furnished by falls, which are formed by the river passing over ledge of granite rock. (See Chap. XVI.)

Darling.—112 miles; Alt. 1,176 feet.

The railroad leaves the Mississippi Valley at Little Falls, going up Little Elk Valley, and passes upon the rolling wooded clayey till-plain of the Patrician ice sheet. At Darling the railroad crosses a gravelly ridge known as an esker, from which gravel is obtained for railroad ballasting and other purposes. (See Chap. IV.)

Randall.—118 miles; Alt. 1,201 feet.

Randall is located near the edge of the till-plain. A roughly rolling moraine is seen about a mile to the east.

Cushing.—123 miles; Alt. 1,288 feet. Lincoln.—129 miles; Alt. 1,304 feet.

Cushing and Lincoln are situated amongst typical wooded morainic hills of red drift, sandy in character. Beautiful lakes. These rolling lands are very productive when improved. (See Chap. XXVI.)

Philbrook.—135 miles; Alt. 1,269 feet.

Cross Long Prairie River. Extensive sandy outwash plain.

Staples.—141 miles; Alt. 1,298 feet. (For Line to Duluth see p. 346.)

Staples is located on the edge of a flat plain of red drift sandy outwash which was later overridden by the Keewatin glacier and a deposit of clayey gray drift overspread. To the southwest is a rolling or gently undulating till-plain of gray drift.

Aldrich.—148 miles; Alt. 1,351 feet.

On the undulating till-plain of gray drift that covers the red outwash plain to the north. Partridge River, at Aldrich, crosses the outwash plain in a broad flat-bottomed valley. Rolling till-plain south.

Verndale.—152 miles; Alt. 1,369 feet.

Outwash plain continues. Wing River crossed west. Valley broad with flat bottom, across outwash plain.

Wadena.—159 miles; Alt. 1,372 feet. (Wadena County.) (Crossing G. N. Ry.)

Outwash plain of red drift overlaid by gray drift continues. Low morainic hills west.

Bluffton.—164 miles; Alt. 1,344 feet.

Bluffton on edge of clayey till-plain. Cross Leaf River. Broad valley with flat bottom.

New York Mills.—172 miles; Alt. 1,433 feet.

Till-plain continues 1 mile west, then moraine crossed to Richdale.

Richdale.—177 miles; Alt. 1,417 feet.

Edge of till-plain. Moraine north. Flat outwash plain south. Toad River crossed west.

Perham.—182 miles; Alt. 1,390 feet. Luce.—188 miles; Alt. 1,396 feet. Frazee.—194 miles; Alt. 1,410 feet.

Railroad follows the flat outwash plain rather than the rolling morainic plain to the north or south. Easier grade. Esker 2 miles south of Perham. Another east of Pine Lake. (Not seen from railroad.) Rolling wooded morainic hills at Luce. Also at Frazee. Large glacial valley of Otter Tail River crossing outwash plain at Frazee.

Detroit.—203 miles; Alt. 1,386 feet. (Becker County.) (Crossing Soo Line.)

Detroit Lake in full view to the left approaching Detroit. Important summer resort. City and lakes on rolling gravelly pitted outwash plain. The depressions were caused by melting of blocks of ice which had become isolated from the parent glacier, and more or less completely buried. Lakes Melissa, Big Cormorant, Little Cormorant, Sally, and others, are within easy distance. Moraine west to Audubon.

Audubon.—210 miles; Alt. 1,332 feet.

On edge of clayey till-plain. Moraine south (left).

Lake Park.—216 miles; Alt. 1,341 feet.

In the midst of morainic hills; soil clayey; good farming lands. Big and Little Cormorant Lakes and many smaller lakes with fine boating and fishing a few miles south amid beautiful morainic hills.

Manitoba Junction.—224 miles; Alt. 1,228 feet. (Winnipeg Line see p. 352.)

Rolling till-plain crosses deep glacial channel of Buffalo River.

Hawley.—228 miles; Alt. 1,174 feet.

Hawley is on the edge of a till-plain; terminal moraine west toward Muskoda.

Muskoda.—234 miles; Alt. 1,087 feet.

Here is reached the eastern edge of the Red River Valley—the shore-line of glacial Lake Agassiz. The station is on the gravelly Herman Beach. Many thousands of tons of gravel have been hauled from this beach for railroad filling and ballasting. From the crest of the Herman Beach to Glyndon, 10 miles west, the natural surface falls 150 feet, and to reduce this grade the fill west of Muskoda was made. The mounds or ridges that lie on either side of this railroad fill were caused by the settling of the earth used in making the fill, the great pressure due to the weight of the materials in the fill caused creep or swelling of the ground on either side.

Glyndon.—242 miles; Alt. 946 feet. **Moorhead.**—251 miles; Alt. 929 feet. (Clay County.)

Glyndon and Moorhead are on the bottom of what was once the great glacial Lake Agassiz. The water, where the city of Moorhead now stands, was 250 feet deep. The soil between Glyndon and Moorhead is that of the finer lacustrine silt of the ancient lake. It is one of the most productive soils in the world, when wisely handled. The soil types are the Fargo clay loam, and Fargo clay. The Fargo clay type was stated by the U. S. Bureau of Soils, when surveyed, to be one of the finest textured soils ever analyzed in the Bureau Laboratories. By finest texture is meant that the rock particles of which the soil is composed are the finest. The sediment in this axial part of the lake is composed of the finest rock flour which was carried into the lake from the melting ice. (Chap. XIII.)

(For Geology from a Car Window in North Dakota see, "The Story of the Prairies," p. 335.)

DULUTH LINE

White Bear.—12 miles from St. Paul; Alt. 961 feet. Bald Eagle.—13 miles; Alt. 955 feet.

Pulling out from Union Depot two engines are required to lift the train up the steep grade through a narrow ravine cut in the soft earth of an outwash plain by waters falling into the deep valley of the Mississippi. A moraine of red drift extends beyond Phalen Lake, then the red drift is overlaid with gray drift, and the hills become less sharply rolling, to White Bear Lake. Between White Bear and Bald Eagle Lakes and northward about 3 miles is an outwash plain lying between terminal moraines both east and west.

Hugo.—17 miles; Alt. 960 feet.

South of Hugo a belt of terminal moraine is crossed. Hugo is on an outwash plain about 4 miles in length north and south. A moraine lies to the east, and a wind blown mixed sand and dust plain west.

Forest Lake.—25 miles; Alt. 937 feet.

The town stands at the west end of a beautiful lake from which it gets its name. This is a morainic lake. The undulating till-plain graduates into the more roughly rolling moraine to the east. To the west the till-plain is covered with ancient dune sands. (See Chap. II.)

Wyoming.—30 miles; Alt. 925 feet.

On the eastern edge of the broad sandy plain which covers portions of four counties west of the railroad. (Chap. XXVI.) The gray till-plain to the east reaches to the great red drift moraine which lies along the valley of the St. Croix River.

Stacy.—34 miles; Alt. 922 feet. North Branch.—42 miles; Alt. 921 feet.

From Wyoming to Harris the railroad runs nearly due north across the eastern portion of the sandy plain which has been referred to. The soft and fine character of the soil has proven an important factor in making this district famous for the excellent quality of potatoes grown.

Harris.—47 miles; Alt. 924 feet.

Harris is on a gently undulating till-plain. North 1 mile a terminal moraine of gray drift is crossed. The gray drift moraines are not as rough and stony as the red drift moraines.

Rush City.—54 miles; Alt. 942 feet.

Broadly rolling till-plain. Three miles east the flat valley of St. Croix River. St. Croix River at one time passed where Rush City is now, by the course of Rum River to Dayton and the old Mississippi at Delano. (See Chap. XVII.)

Grantsburg (Wis.).—71 miles; Alt. 922 feet.

Grantsburg is at the terminus of the Grantsburg Branch of the Northern Pacific Railway, which leaves the main line at Rush City. Grantsburg is located across the St. Croix River, on an extensive sandy outwash plain.

Rock Creek.—59 miles; Alt. 965 feet.

On terminal moraine, about 1 mile in width. Gently rolling clayey till-plain north to Pine City.

Pine City.—64 miles; Alt. 975 feet. (Pine County.)

Pine City is at the boundary between the gray drift of the Keewatin glacier (south) and the red drift of the Patrician glacier (north). When the edge of the Keewatin glacier lay on the land south of Pine City the Mississippi River was forced to go around this tongue of ice. Its course was eastward by Snake River north of Princeton, by Grasston and Pine City to the St. Croix. (See Chap. XVI.)

Terminal moraine, with beautiful morainic lakes. Topography softens to a rolling till-plain 1 mile north, then graduates into a red terminal moraine 2 miles south of Beroun.

Beroun.—70 miles; Alt. 1,000 feet. Mission Creek.—73 miles; Alt. 1,020 feet. Hinckley.—77 miles; Alt. 1,057 feet.

Swampy till-plain between Beroun and Mission. Several townships to the north and west are bordered by a terminal moraine so that drainage is retarded. The streams attempt to flow southward but are blocked by the moraine. Drainage is ultimately by Pine River to the St. Croix. Power dam on Grindstone River, west. The sandstone or "grindstone" rock is seen in a quarry on the east.

Friesland.—81 miles; Alt. 1,144 feet. Groenigen.—86 miles; Alt. 1,155 feet.

Rolling till-plain, with lakes and sloughs without outlets.

Finlayson.—90 miles; Alt. 1,154 feet.

A long sharp morainic ridge is cut through 1 mile north. Morainic hills toward Rutledge.

Rutledge.—95 miles; Alt. 1,056 feet. Willow River.—99 miles; Alt. 1,063 feet. Sturgeon Lake.—103 miles; Alt. 1,100 feet.

Kettle River is crossed near Rutledge. This was at one time a large glacial river. The St. Louis River came around the western end of the glacier that filled the basin of Lake Superior, down by Moose Lake. Outwash sand and gravel partially fill the valley, and the large channel now occupied by Kettle River was made by the flood of ice water. (See Chap. XX.) Moraines having clayey soil are seen to the west, and clayey till-plains lie farther away to the east.

Moose Lake.—109 miles; Alt. 1,085 feet.

The town is in the valley of glacial St. Louis River. Moose Head Lake, in the east part of town, is in the old outlet channel of glacial Lake Nemadji, which was the earliest stage of glacial Lake Duluth. The western part of the town is built on a terrace of the glacial St. Louis River. The Soo depot stands on this terrace. Outside the old glacial river bottom and above it on either side of the valley are the moraines which were formed by the Superior glacier as it pushed its way out of the Superior Basin. (See Chap. XX.)

Barnum.—114 miles; Alt. 1,122 feet. Mahtowa.—120 miles; Alt. 1,172 feet. Atkinson.—124 miles; Alt. 1,168 feet.

These places are in the large valley cut by the great glacial St. Louis River during the time that the basin of Lake Superior was filled with ice. To the west 2 or 3 miles extends a belt with some outcropping ledges of ancient slate rock. (See Chap. X.) The rock outcrops are partially obscured by drift and by forest growth.

Carlton.—131 miles; Alt. 1,102 feet. (Carlton County.)

Carlton is in the valley of glacial St. Louis River. To the west is a large outwash plain of gravel, from the Superior glacier. A channel one-half mile wide was cut through this by the glacial river. Knobs of slate rock, smoothed and polished by the passage of glacier ice over them, and left bare by the glacial river, are conspicuous features. Glacial striæ on the hard rocks show the direction of ice movement westward. A terminal moraine, extending northeast and southwest, was cut through by the St. Louis River. Beaches of glacial Lake Duluth occur east. River gorge, falls, and dam, at Thompson, 1 mile east of Carlton.

Duluth.—164 miles; Alt. 626 feet. (St. Louis County.)

One line of Northern Pacific Railway runs via Wrenshall and Superior, crossing the red clay deposits of glacial Lake Duluth. The "Short Line" runs via Thompson and West Duluth, following the edge of glacial Lake Duluth. The railroad runs on the beach of Lake Duluth east of Thompson for about 2 miles, then cuts through the moraine which is spread upon the highland to the north. At Brownell the rail road crosses the beach, then follows the ancient lake bottom to Duluth, the beaches at Duluth being 100 feet to 400 feet above the present lake.

TAYLOR'S FALLS BRANCH

Chisago.—37 miles from St. Paul; Alt. 945 feet. Lindstrom.—39 miles; Alt. 960 feet. **Center City.**—41 miles; Alt. 929 feet. (Chisago County.) Shafers.—44 miles; Alt. 964 feet.

This is a most beautiful rolling till-plain, graduating into the terminal moraines which surround this district. The drift is clayey in character, and very productive. Some of the finest dairy farms in the State are in this district. The group of lakes in southern Chisago County is a most beautiful one. They represent a preglacial valley partially filled with drift, blocked by moraines above and below. This is a popular resort for tourists for camping, boating, fishing, and picnicking.

Taylor's Falls.—50 miles; Alt. 818 feet.

The approach to the town is along a steep cliff of the St. Croix River, with a splendid panoramic view of the river and valley below. The cut-bank overhanging the railroad shows 3 successive deposits of drift made by glaciers which covered this district at different times. (Chap. IV.) The history of this, one of the most interesting scenic spots in the Northwest, is given in Chapters XVII and XVIII.

After passing Shafers about 2 miles the whole panorama suddenly changes from that of rolling prairie with fine farms to a precipitous rocky gorge of most striking grandeur. It is as though translated suddenly, as in a dream, from the monotonous undulating prairie to the Grand Canyon itself. The ice sheets formed the prairies. The water from the melting ice sheets formed this most remarkable gorge, known as The Dalles.

DULUTH-STAPLES LINE

(For Duluth to Carlton see p. 345.)

Iverson.—32 miles from Duluth; Alt. 1,259 feet.

Terminal moraine of Labradorian glacier. Outwash plain west to Zebulon.

Zebulon.—37 miles.

Terminal moraine crossed west, 5 miles in width.

Corona.—44 miles; Alt. 1,322 feet.

Swamp hemmed in by moraine. Cross rolling till-plain 5 miles, to terminal moraine 1 mile east of Cromwell.

Cromwell.—49 miles; Alt. 1,330 feet.

Terminal moraine 2 miles in width, with fine morainic lakes. Outwash plain south of railroad between Cromwell and Wright. Swamp to the north hemmed in by moraine.

Wright.—55 miles; Alt. 1,322 feet.

Terminal moraine. This and moraines east deposited by the Labradorian glacier. Boulders from the Lake Superior region are scattered over this region.

Tamarack.—61 miles; Alt. 1,290 feet.

Swamp, hemmed in by moraine. One mile east is the boundary between the red drift of the Labradorian glacier and the gray drift of the Keewatin glacier. (Chap. IV.) The greater frequency of granitic boulders in the red drift is noticeable.

Grayling.—65 miles; Alt. 1,255 feet.

Grayling is on the beach which marks the eastern shore of glacial Lake Aitkin. (Chap. XXI.) West to McGregor the sandy plain is the bottom of this extinct lake.

McGregor.—70 miles; Alt. 1,254 feet. (Crossing Soo Line.)

On lake-washed sand-plain, the bottom of glacial Lake Aitkin. (Chap. XXI.) Three miles west a beach is crossed. This beach runs all around an irregular shaped island, a moraine, embracing an area about equivalent to a township. The railroad crosses this island.

Kimberly.—79 miles; Alt. 1,259 feet.

Kimberly stands on the beach at the southern end of this island. Rice River Valley lies between the island and the ''mainland'' to the south, the river running between the island beach and the main lake beach. The railroad crosses Rice River and the main beach west of Kimberly, and runs on high land parallel with the beach to Rossburg.

Rossburg.—85 miles; Alt. 1,260 feet.

The beach lies along the margin of a swamp,—the old lake bed,—with a roughly rolling terminal moraine to the south.

Aitkin.—91 miles; Alt. 1,230 feet. (Aitkin County.)

Aitkin is on a sandy part of the lake plain, the beach lying one-half mile south. The Mississippi River meanders across the ancient lake bottom, passing 1 mile north of Aitkin.

Cedar Lake.—96 miles; Alt. 1,245 feet.

The beach lies along the north shore of Cedar Lake. Two miles west the railroad crosses the ancient lake beach, into the rough terminal moraine of red drift.

Deerwood.—101 miles; Alt. 1,310 feet.

Deerwood is located amongst the beautifully rolling morainic hills. Many beautiful lakes occur. This is typical terminal moraine. West of Deerwood an outwash plain is crossed, then another portion of the moraine extends to Loerch.

Loerch.—111 miles; Alt. 1,259 feet.

Sandy outwash plain to Brainerd.

Brainerd.—118 miles; Alt. 1,231 feet. (Crow Wing County.)

Outwash plain of fine sand, wind-blown. Mississippi River crossed.

Baxter.—123 miles; Alt. 1,228 feet.

Dune sand, on outwash plain. Lakes hemmed in among sand hills.

Sylvan.—128 miles; Alt. 1,230 feet. Pillager.—132 miles; Alt. 1,232 feet. Motley.—140 miles; Alt. 1,250 feet.

The railroad traverses the valley of Crow Wing River, which occupies a glacial stream valley the bottom of which is from 2 to 6 miles in width. Terminal moraines both north and south of this broad outwash channel, the channel being cut through by the ice waters when the moraines north and south were being formed. The soil of the outwash is sandy. That of the moraines and near-by till-plains is clayey, and the soil is a fine quality of loam. (For line Staples to Fargo see p. 341.)

LITTLE FALLS TO BRAINERD AND INTERNATIONAL FALLS

Belle Prairie.—113 miles; Alt. 1,155 feet.

From Little Falls north to Brainerd, the railroad traverses the sandy plain or terrace of the glacial Mississippi River. The soil is sandy, as viewed from the car window. This condition, however, applies only to this plain, which varies from 3 to 6 miles in width. Undulating till-plains, having good soil for agricultural purposes, lie east and west of Belle Prairie.

Fort Ripley.—122 miles; Alt. 1,190 feet.

Going north to Fort Ripley, two eskers on the east and one on the west are passed. The eskers were formed in, on, or under the ice, probably at the time these moraines were being formed. Terminal moraines border the large valley on either side. The sand forming the broad valley floor is glacial outwash modified by the floodwaters of the glacial Mississippi River. Sand blown from the glacial river terraces covers some of the slopes and hills on the east.

Barrows.—133 miles; Alt. 1,227 feet.

Iron mines of the Cayuna Range. (See Chap. XXIV.)

Brainerd.—139 miles; Alt. 1,231 feet. (Crow Wing County.) (Crossing Duluth-Staples Line.)

To the east, approaching Brainerd, the landscape is that of a gently rolling till-plain. The city is located on the sandy alluvial floodplain of the glacial Mississippi. West of Brainerd the sand is blown by the wind, forming dunes. The railroad crosses the deep gorge of the Mississippi River, then turns northward.

Merrifield.—149 miles; Alt. 1,243 feet. Hubert.—154 miles; Alt. 1,230 feet. Nisswa.—156 miles; Alt. 1,255 feet.

North from Brainerd the railroad traverses a rolling sandy outwash plain. Beautiful lakes, with the finest of fishing and boating.

Pequot.—162 miles; Alt. 1,303 feet. Jenkins.—166 miles; Alt. 1,293 feet.

Pequot and Jenkins are located on the outwash plain; the edge of the glacier at one time stood at Pequot, as is shown by the terminal moraine, which extends northeast from this place. This moraine occurs interruptedly for many miles across the State. It extends south to the west of Gull Lake and beyond Whitefish Lake to the northeast.

Pine River.—172 miles; Alt. 1,319 feet. Mildred.—175 miles; Alt. 1,370 feet. Backus.—180 miles; Alt. 1,363 feet.

Pine River and Mildred are on an outwash plain that was formed when the ice had melted back till its front was south of Backus. Many beautiful lakes are in this vicinity.

Hackensack.—189 miles; Alt. 1,413 feet. Cyphers.—197 miles; Alt. 1,411 feet. **Walker.**—202 miles; Alt. 1,341 feet. (Cass County.) Laporte.—214 miles; Alt. 1,352 feet.

After passing a small outwash plain which lies north of Backus,—seen from the right (east) window, for 5 miles after leaving Backus,—the course of the railroad is through roughly rolling terminal moraine for 25 miles till Laporte is passed. Magnificent lakes abound throughout this moraine, offering splendid camping and fishing opportunities.

Approaching Walker, the State Tuberculosis Sanitarium may be seen at the left on a high, forest covered hill overlooking the western arm of Leach Lake. About 3 miles north of Walker, the railroad follows a valley out through the moraine on the bottom of which is a sandy deposit of glacial outwash.

Laporte lies at the north end of this outwash plain. Garfield Lake lies in the north end of this glacial valley. The sand and gravel deposit referred to serves as a dam holding the waters of Garfield Lake from draining away.

Guthrie.—218 miles; Alt. 1,443 feet. Nary.—225 miles; Alt. 1,448 feet.

Guthrie and Nary lie on a broadly rolling clayey till-plain. With the removal of the mixed hardwood forests that grew on these lands after the removal of the original pine forests, splendid farms are being developed. The soil is well adapted to agriculture.

Bemidji.—234 miles; Alt. 1,371 feet. (Crossing G. N. and Soo Rys.) (Beltrami County.).

Bemidji is located on an outwash plain which was formed when the edge of the continental glacier stood at Turtle River, Buena Vista, and Pinewood. The soil on which the town is built is sandy and gravelly, characteristic of outwash deposits. Lake Bemidji is a magnificant sheet of water 6 miles in length and 3 to 4 miles in width. The Mississippi River is crossed (flowing north) just before reaching the Union Station. Lake Plantagenet lies to the south, being drained into Lake Bemidji by the Mississippi. The railroad follows the east shore of the lake, crossing the Mississippi again as it leaves the lake from the east side.

Lavinia.—238 miles; Alt. 1,394 feet.

This is a beautiful summer resort station, there being fine opportunities for boating and fishing, and first-class hotel accommodations.

Turtle River.—245 miles; Alt. 1,366 feet.

A marked change in the character of the soil is observed after crossing Turtle River. The river marks almost the exact boundary between the outwash plain on which Bemidji is located and the terminal moraine to the north. The soil of the moraine is a splendid quality of loam. Typical morainic lakes occur among the hills both east and west of Turtle River. The moraine, where crossed by the railroad, is about 3 miles in width.

Tenstrike.—251 miles; Alt. 1,422 feet. Black Duck.—259 miles; Alt. 1,404 feet.

After leaving the moraine, going north from Turtle River, a till-plain is crossing about 3 miles in width, coming to Tenstrike. At Tenstrike another moraine is reached, which extends beyond Black Duck. The topography is the characteristic rolling landscape which marks the deposits made at the edge of the great Continental ice sheet. Many beautiful lakes occur among the hills. The soil is somewhat clayey in character, and splendid farms are being developed as the timbered lands are cleared.

Funkley.—266 miles; Alt. 1,416 feet. Kelliher.—277 miles; Alt. 1,388 feet.

Here is crossed a broad tract of undulating till-plain. This was originally covered with forests of pine. Since the removal of the pine a hardwood forest has succeeded. The character of the timber growth indicates a strong productive soil. Good farms are being developed as the forests are cleared away.

Northome.—275 miles; Alt. 1,451 feet.

Northome stands on a well-defined terminal moraine. The steeply rolling hills and many lakes are characteristic of terminal morainic topography. The soil is a loam of splendid texture for cultivation, and very productive.

Mizpah.—280 miles; Alt. 1,409 feet.

On a continuation of the till-plain on which Funkley and Kelliher are located. This plain extends to the west around the moraine on which Northome stands.

Gemmell.—285 miles; Alt. 1,364 feet.

Another small terminal moraine occurs at Gemmell. This moraine marks the boundary of the great Beltrami Swamp, which is a part of the bottom of glacial Lake Agassiz. About 4 miles north of Gemmell a gravelly and sandy beach ridge is crossed,—the highest or Herman Beach of Lake Agassiz. Lake Agassiz during its highest stage extended 70 miles east to Vermilion Lake.

Margie.—298 miles; Alt. 1,286 feet.

North of the Herman Beach a tract of marsh is crossed, and this marsh continues in irregular patches throughout the distance to International Falls. Margie stands on an "island" of sandy, lake-washed till 10 miles in length. This island in the swamp represents a low, broad morainic hill that was deposited in Lake Agassiz and was leveled down by its waves. Several well-defined sandy beaches occur east of Margie, facing the swamp. Outcropping ledges of granite rock near Margie bear glacial scratches or "striæ" having an east-southeast direction, showing the direction in which the ice moved in this locality.

Big Falls.—306 miles; Alt. 1,240 feet.

A clayey lake-washed till-plain is crossed at Big Falls. This is part of an extensive till-plain that was covered by the waters of Lake Agassiz and the hills leveled by the waves. After crossing the Big Fork River a terminal moraine is crossed 4 miles. A moraine was first deposited here by the Patrician glacier (see Chap. IV.), and this moraine was later overridden by the Keewatin glacier. The formation therefore consists of the pinkish-red drift of the northern rocky highlands, covered by the gray-limestone drift from the northwest, and all finally over-strewn with the lake-washed sediments of Lake Agassiz. This moraine extends east to Vermilion Lake. Big Fork River strikes the south side of this moraine as it flows northward, and is turned east by it and forced to cross a ledge of hard granite rock. This is the cause of the cascade or falls, seen from the car window between Big Falls and Grand Falls.

Little Fork.—325 miles; Alt. 1,153 feet.

On a clayey, wave-washed till-plain of the bottom of glacial Lake Agassiz which embraces a wide area extending to the east and west and northward to Rainy River. Irregular tracts of swamp occur. Little Fork River meanders across the plain parallel in a general way with Big Fork River. Four miles south of Little Fork a small terminal moraine is crossed which was deposited by the ice from the north and later overridden by the ice sheet from the northwest. At the north side of this moraine a beach of sand and gravel was formed by the waters of Lake Agassiz. This beach is crossed about 2 miles south of Little Fork Station.

International Falls.—341 miles; Alt. 1,140 feet. (Koochiching County.)

North of Little Fork another tract of swamp is crossed. At Nakoda the railroad runs along the edge of another overridden moraine, then crosses this moraine and follows its western border and that of the lake-washed till-plain to International Falls. Here is located one of the largest paper manufacturing plants on the North American continent. The falls of Rainy River furnish an extensive water power. The old Canadian town of Fort Frances is located across the river. Rainy River and Rainy Lake, to the east, with many hundreds of beautiful rocky isles, is a region of great interest to the tourist.

WINNIPEG LINE

Hitterdahl.—229 miles from St. Paul. Ulen.—236 miles; Alt. 1,181 feet.

The railroad runs due north across a terminal moraine for about 5 miles. This moraine grades into the clayey till-plain to the north, about Ulen.

Syre.—243 miles; Alt. 1,148 feet.

North of Ulen the railroad lies along the border of the till-plain. The Herman Beach lies parallel with the railroad and can be seen from the west window (left) for 3 miles, then this beach, which is here double, is crossed 2 miles south of Syre. Syre stands on a lower Herman Beach. (See Chap. XIII.)

Twin Valley.—249 miles; Alt. 1,117 feet. Gary.—256 miles; Alt. 1,123 feet. Flaming.—262 miles; Alt. 1,168 feet.

These places lie on the sandy eastern edge of the ancient lake bottom. The sandy and gravelly Herman Beaches lie at varying distances both east and west of the railroad. The beaches are here multiple in character. (See Chap. XIV.)

Fertile.—268 miles; Alt. 1,164 feet.

Fertile lies on the sandy off-shore plain. The highest Herman Beach lies to the east, 1 mile; the Tintah Beach lies west of Fertile 2 miles. Morainic hills east of the shore-line. Dunes have developed on the sandy plain since the disappearance of the lake. These are visible from the west (left) window. The Tintah Beach is crossed by the railroad 3 miles east of Melvin. West of Melvin, after crossing the Campbell and McCauleyville Beaches, the lake bottom becomes clayey.

Melvin.—276 miles; Alt. 1,056 feet.

Lower Herman Beaches lie west of Fertile, one of which is crossed by the railroad, 3 miles east of Melvin. West of Melvin, after crossing two beaches, the lake bottom becomes more clayey.

Crookston.—291 miles; Alt. 900 feet. (Polk County.)

Crookston is located on the fine grained lacustrine sediment of Lake Agassiz. In places, the soil is that technically known as Fargo clay. Much of the plain is clay loam, a splendid type of soil.

East Grand Forks.—318 miles; Alt. 855 feet.

From Crookston to East Grand Forks the traveler crosses the famous Red River Valley to its axis at the Red River of the North. The railroad crosses into North Dakota at Grand Forks and continues to Winnipeg, the remainder of the journey being entirely on the bottom of the ancient Lake Agassiz.

MORRIS BRANCH

Flensburg.—8 miles from Little Falls; Alt. 1,233 feet. Swanville.—15 miles; Alt. 1,195 feet.

Undulating clayey till-plain. Red drift. Numerous boulders from north of Lake Superior.

Burtrum.—20 miles; Alt. 1,290 feet.

Terminal moraine, about 4 miles across.

Grey Eagle.—24 miles; Alt. 1,245 feet.

Clayey till-plain. Many beautiful lakes, on till-plain and moraine to the east. These glacial soils are of splendid texture and highly productive.

Ward Springs.—28 miles; Alt. 1,246 feet.

On west side of till-plain, near beautiful Birch Lake. One mile west across sandy terminal moraine about 4 miles. Sauk Lake to the north is hemmed in by a clayey moraine. The line between the sandy and clayey moraines is the approximate boundary between the red (Labradorian) drift (east) and the gray (Keewatin) drift (west).

Sauk Center.—36 miles; Alt. 1,254 feet. (Crossing G. N. Ry.)

On sandy and gravelly outwash plain. Sandy moraine west of Sauk Center about 1 mile in width, followed by clayey moraine 2 miles, the latter followed by clayey till-plain.

Westport.—47 miles; Alt. 1,354 feet.

In valley of narrow outwash plain, with clayey till-plain north and south.

Villard.—52 miles; Alt. 1,380 feet.

On east side of extensive outwash plain, which extends south and east for more than 30 miles.

Glenwood.—59 miles; Alt. 1,420 feet. (Pope County.) (Crossing Soo Line.)

Located at west edge of outwash plain. Clayey terminal moraine north, sandy terminal moraine south. City at east end of beautiful Lake Minnewaska.

Starbuck.—68 miles; Alt. 1,181 feet.

Located at west end of Lake Minnewaska, in midst of rolling clayey terminal moraine. Small outwash plain west.

Cyrus.—78 miles; Alt. 1,156 feet.

Cross south end of moraine, and till-plain east. Town stands on clayey moraine. Fine group of morainic lakes west.

Morris.—87 miles; Alt. 1,148 feet. (Stevens County.) (Crossing G. N. Ry.)

Cross till-plain 4 miles. Outwash plain 1 to 2 miles in width occupies valley of Pomme de Terre River, crossed 1 mile east. This ancient glacial watercourse extends from the north boundary of Grant County almost due south through Stevens County to the valley of the glacial River Warren, at the southwest corner of Swift County.

Deer Creek.—10 miles from Staples; Alt. 1,415 feet.

On outwash plain. Clayey till-plain and moraine south. Cross sandy moraine west 4 miles.

Henning.—18 miles; Alt. 1,458 feet. (Crossing Soo Line.)

Clayey till-plain.

Vining.—24 miles; Alt. 1,408 feet.

On boundary between clayey till-plain and sandy outwash plain.

Clitheral.—29 miles; Alt. 1,369 feet. Battle Lake.—33 miles; Alt. 1,376 feet.

On sandy outwash plain amongst beautiful morainic lakes.

Underwood.—41 miles; Alt. 1,364 feet.

Clayey terminal moraine. Typical morainic pots and kettles, and many morainic lakes.

Fergus Falls.—52 miles; Alt. 1,214 feet. (Otter Tail County.) (Crossing G. N. Ry.)

City located amid the hills of the great Fergus Falls moraine, probably the most striking and majestic terminal moraine in the State. Typical morainic knobs, pots and kettles, and lakes abound. Narrow outwash plains, ancient watercourses, to the north and east. Alluvial outwash plain in valley of Otter Tail River 3 miles west.

French.—58 miles; Alt. 1,130 feet.

Cross outwash plain and moraine east. Till-plain 2 miles in width bordering basin of glacial Lake Agassiz. Herman Beach crossed 2 miles west of French. Norcross Beach crossed 2 miles west of Herman Beach.

Foxhome.—63 miles; Alt. 1,052 feet.

On the level plain of the bottom of glacial Lake Agassiz. The plain here consists of till leveled and washed by the waves of the ancient lake. Cross Tintah Beach 1 mile east.

Everdell.—68 miles; Alt. 1,015 feet.

Flat plain of bottom of Lake Agassiz. Town located on Campbell Beach.

Breckenridge.—77 miles; Alt. 982 feet. (Wilkin County.)

Four miles west of Everdell cross McCauleyville Beach. West of this beach is the fine lacustrine clayey sediment deposited from the deep waters of Lake Agassiz. Breckenridge is on the Red River of the North, the axial drainage of the Red River Valley.

CHAPTER XXXIII

GEOLOGY FROM A CAR WINDOW

THE SOO LINE

St. Paul.—0 miles; Alt. 732 feet. (Ramsey County.) Cardigan Junction.—7 miles; Alt. 903 feet. New Brighton (Bulwer Junction).—11 miles; Alt. 912 feet.

The line from the deep valley of the Mississippi is by an old valley partially filled with drift. The hills are red drift for 4 miles, then the red drift is overlaid with gray drift, and the topography becomes somewhat softened. The line west from Cardigan Junction to New Brighton and Minneapolis is through gray drift hills. A terrace of glacial sand and gravel a mile in width borders the Mississippi approaching Minneapolis. (For through trains between St. Paul and Minneapolis see Chap. XXVIII.)

Minneapolis.—11 miles; Local Station, Alt. 820 feet. (Hennepin County.)

Leaving Milwaukee station the railroad runs on a gravelly terrace of the glacial Mississippi River to Camden station. The Platteville limestone, underlaid by the soft and friable St. Peter sandstone, appears capping the cliff west of tracks. West from Camden a higher glacial terrace of the Mississippi is crossed about 1 mile. To about 1 mile west of Crystal (crossing G. N. Ry.) the course is across the southern end of an extensive gravelly outwash plain that extends far north along the Mississippi River. Twin Lakes and a tract of dune sand are crossed, included in the outwash plain. The outwash plain is bordered on the west by gently rolling (gray) drift, which is clayey in character, and in places the topography is hilly with lakes and sloughs, indicating terminal moraine.

Hamel.—28 miles; Alt. 987 feet.

The morainic till-plain east gives way to a more broadly rolling clayey till-plain.

Loretto.—34 miles; Alt. 989 feet.

At head of Sarah Lake, amid morainic hills, clayey in character.

Rockford.—39 miles; Alt. 957 feet.

Railroad skirts north side of Sarah Lake, through rolling morainic hills, crossing Crow River. The Crow Valley was cut through this moraine by the waters of the Upper St. Croix River when that stream discharged into the Mississippi at Delano, and the waters flowed in the opposite direction from that of the present stream. (See Chap. XVII.) The North Fork of the Crow now occupies the old valley of the Mississippi above Rockford to the Eden Valley. (See Chap. XVI.)

Buffalo.—49 miles; Alt. 975 feet. (Wright County.)

Buffalo Lake west, surrounded by morainic hills, and many small "pots and kettles." Rolling till-plain east.

Maple Lake.—57 miles; Alt. 1,047 feet.

Rolling till-plain, clayey. Maple Lake east. Moraine 3 miles in width crossed west.

Anandale.—63 miles; Alt. 1,059 feet. South Haven.—68 miles; Alt. 1,097 feet.

Three miles east of Anandale pass off from moraine onto undulating outwash sandy plain. Cedar Lake at right. Pleasant Lake and Clear Lake north (right). John Lake south (left). Lake Mary passed at right.

Kimball.—74 miles; Alt. 1,132 feet.

West of South Haven the railroad swings across a hilly, clayey moraine, and crosses the south edge of the west arm of the outwash plain which lies about Anandale and South Haven. This western arm of the sandy outwash plain is known as Kimball's Prairie.

Watkins.—79 miles; Alt. 1,157 feet.

A moraine 5 miles wide is crossed between Kimball and Watkins. Watkins is on the edge of a clayey rolling till-plain.

Eden Valley.—86 miles; Alt. 1,118 feet.

East of Eden Valley a broad glacial channel is crossed which was the outlet of a glacial lake which once occupied a considerable area in Meeker County now drained by the North Crow. The old channel was occupied by the Mississippi River before the glacier of the last ice invasion compelled it to take its present course. It then flowed south from Eden Valley by the present course of the Crow to Delano and the present Lake Minnetonka. (See Chap. XVI.)

Paynesville.—95 miles; Alt. 1,167 feet.

Rolling till-plain west of Eden Valley 3 miles, then cross clayey moraine 2 miles; Rice Lake north, Cedar Lake south. Sandy moraine 4 miles, to sandy outwash plain which lies along the moraine, and from which it was formed.

Georgeville.—106 miles; Alt. 1,238 feet. Belgrade.—110 miles; Alt. 1,268 feet. Brooten.—117 miles; Alt. 1,308 feet. Sedan.—125 miles; Alt. 1,330 feet.

Broadly undulating sandy outwash plain, with many lakes and sloughs in depressions. Crow Lake south of Belgrade. Skunk Lake south of Brooten. (Brooten-Duluth Line see p. 364.)

Glenwood.—133 miles; Alt. 1,388 feet. (Pope County.) (Crossing Morris Branch N. P. Ry.)

At head of Minnewaska Lake, on west margin of outwash plain. Sandy moraine south; clayey moraine west to Lowry. (Winnipeg Line, see p. 360.)

Lowry.—142 miles; Alt. 1,363 feet. Farwell.—148 miles; Alt. 1,335 feet. Kensington.—152 miles; Alt. 1,304 feet. Hoffman.—158 miles; Alt. 1,241 feet.

Cross Little Chippewa River at Lowry. Rolling till-plain to Farwell. Hilly moraine at Kensington, coming into the famous Lake Park region. Cross Chippewa River east of Hoffman. Rolling ground moraine or till-plain, with many small lakes.

Barrett.—165 miles; Alt. 1,161 feet.

Barrett is located in a glacial channel on sandy and gravelly outwash. At the time the edge of the ice sheet was about where Fergus Falls and Elbow Lake now are a large river of ice water laden with sand and gravel flowed down this valley, past Morris to the Minnesota Valley.

Elbow Lake.—172 miles; Alt. 1,206 feet.

A clayey moraine, quite hilly, lies about Elbow Lake. Long Lake lies 3 miles east in rolling till-plain. Worm and Round Lakes are among the morainic hills south. Elbow Lake, named for its elbow-like curve, lies at the right, west. At the Great Northern Railway crossing the glacial outwash channel in which Mustinka River runs is crossed.

Wendell.—179 miles; Alt. 1,118 feet.

A long narrow moraine borders the outwash channel of Mustinka River, which marks the edge of the ice sheet when this channel was formed. Wendell is on the boundary between the moraine and the rolling till-plain to the west.

Nashua.—189 miles; Alt. 1,000 feet. (Crossing G. N. Ry. west.)

The Herman Beach, the highest shore-line of Lake Agassiz, is crossed 4 miles west of Wendell. Two miles west of this beach and parallel with it is the Norcross Beach. Two Tintah Beaches are crossed before reaching Nashua. Lake-washed clayey till of the bottom of Lake Agassiz extends between these beaches. A tract of lake-washed sand lies east of Nashua.

Tenney.—196 miles; Alt. 988 feet.

Gently undulating lake-washed till, smoothed by the waves of Lake Agassiz. The Bois des Sioux River marks the axis of the ancient lake bottom. A mile west of Tenney the Campbell Beach is crossed and the McCauleyville Beach near the river. All these beaches converge into Traverse Gap at the south, which was the outlet of Lake Agassiz during the time of formation of these beaches.

Fairmount, N. D., is across the Bois des Sioux River.

(For Geology from a Car Window in North Dakota, see "The Story of the Prairies," p. 350.)

ST. PAUL-DULUTH LINE

St. Paul.—0 miles. (Ramsey County.)

From Union Depot the train pulls out through a valley having a filling of outwash gravel and sand, followed by rolling morainic hills. At the crossing of the Northern Pacific tracks east of Lake Wabasso northward to Cardigan Junction is outwash gravel, and to the north extends a tract of dune sand. Beyond the dune tract is rolling till-plain, and south of Bald Eagle Lake is a flat, sandy outwash plain.

Bald Eagle.—15 miles from St. Paul; Alt. 927 feet. (Crossing N. P. Ry.)

Bald Eagle Lake lies at the left and White Bear Lake a mile to the east (right). Rolling till-plain lies between.

Withrow.—20 miles; Alt. 978 feet.

On a small outwash plain, which is surrounded by rolling morainic hills.

Marine.—30 miles; Alt. 913 feet. Copas.—32 miles; Alt. 823 feet.

On the east edge of moraine, which is bordered by terraces of glacial St. Croix River. Broad terrace cut in limestone rock at Copas. Three miles north the deep valley of the St. Croix is crossed by a drawbridge into Wisconsin, and the line continues in that State for 50 miles recrossing St. Croix River near Danbury into Minnesota.

Danbury.—106 miles. Markville.—113 miles. Cloverton.—118 miles. Kingsdale.—123 miles. Belden.—128 miles. Harlis.—135 miles. Superior, Wis.—161 miles. Duluth.—167 miles.

At Danbury the St. Croix is crossed, a broad glacial channel. The railroad runs on the broad level terrace of the ancient glacial river 2 miles beyond Markville. The floodplain of the glacial valley, marked by the level terrace plains which border the deep valley in which the river now flows, is here 2 miles wide. About Cloverton is gently rolling till-plain, with low hills and swamps. At Kingsdale, Tamarack River is crossed, in a region of tamarack swamps, and tree-covered till-plains. Boulders from the Lake Superior country are common. At Belden and Harlis are moraines, sandy and gravelly in character, with bounders. The railroad re-enters Wisconsin north of Harlis, and crosses the great South Copper Range, descending from the Range to the great Red Clay Basin of Lake Duluth to Superior, then crosses the mouth of St. Louis River to Duluth. The entrance to Duluth is along the foot of the highland which lies north of Lake Superior. The approach to the station in Duluth was cut and tunneled through hard slaty rocks of Keweenawan age, the station being entered through a tunnel bored through the hard rock a distance of 1,031 feet.

WINNIPEG LINE

Forada.—143 miles from St. Paul; Alt. 1,413 feet.

From Glenwood to Forada the railroad runs on the western edge of the sandy outwash plain that has been followed from Paynesville. A hilly moraine lies to the west, clayey in character. Maple and Reno Lakes are among the morainic hills.

Alexandria.—150 miles; Alt. 1,424 feet. (Douglas County.) (Crossing G. N. Ry.)

Alexandria is located amidst a beautiful group of lakes which occupy depressions in sandy outwash plain. The outwash is related to the big sandy moraine which lies to the west. Lakes Winona and Agnes west of the city, and Geneva east (north of Great Northern tracks) are fine lakes. Sandy moraine east of Great Northern crossing. East point of Lake Le Homme Dieu 2 miles north. Carlos Lake lies to the west and north.

Carlos.—157 miles; Alt. 1,366 feet. Miltona.—162 miles; Alt. 1,401 feet.

Outwash plain of sand and gravel, across which meanders Long Prairie River draining the group of lakes, is crossed to Miltona, which is on the big sandy moraine referred to. Lake Miltona 2 miles west. Pass Lake Irene north.

Parker's Prairie.—170 miles; Alt. 1,464 feet.

Sandy moraine continues 4 miles north of Miltona, where broad undulating sandy outwash plain, known as Parker's Prairie, is crossed. Lake Adley west and Horsehead Lake east, and many small lakes. Four miles north a narrow sandy moraine is crossed, then sandy outwash in the valley in which Wing River flows. A mile north of Wing River another narrow moraine is crossed, beyond which is another outwash plain. The moraine from which the outwash was formed is now crossed, being roughly rolling hills with many pots and kettles. This is the same moraine that was crossed at Miltona. The range of strongly rolling hills extending from Lake Christina in northwestern Douglas County north and east to Deer Creek, 6 miles east of Henning, is locally known as Leaf Mountain. It has been called by Professor Warren Upham the Leaf Hills. Professor Upham says: "These are the most massive morainic accumulations in Minnesota. In their highest portions they rise 200 to 300 feet above the surrounding country and above their bases."

Henning.—183 miles; Alt. 1,434 feet. (Crossing Morris Branch N. P. Ry.)

On rolling till-plain. The rolling hills of the Leaf Hills moraine are seen 2 miles east.

Otter Tail.—192 miles; Alt. 1,354 feet.

On large outwash plain, formed from moraine to the west and north to be presently crossed. Otter Tail Lake 2 miles west, a large lake. Rush Lake east, with many small lakes north.

Richville.—199 miles; Alt. 1,353 feet. Dent.—205 miles; Alt. 1,358 feet. Vergas.—214 miles; Alt. 1,401 feet.

These towns are all in or "among" the great moraine named by Professor Upham the Fergus Falls moraine. Here is the Lake Park Region **par excellence.** Large lakes, small lakes, lakes deep, lakes shallow, hills high, hills low, the greatest topographic confusion that could well be conceived. An authority cited by N. H. Winchell places the number of lakes in Otter Tail County as 1,029 by actual count, not including small ponds and sloughs.

Detroit.—227 miles; Alt. 1,361 feet. (Becker County.)

The railroad passes upon the undulating surface of an outwash plain of sand and gravel 5 miles south of Detroit. The splendid lake east is Lake Detroit, occupying a large basin in the outwash plain. To the west are Lakes Melissa, Sallie, and St. Clair. This is one of the finest groups of lakes in the State or the United States. This group, like the group at Alexandria just passed, are said by travelers to vie in beauty and natural grandeur with the most famed European lakes.

Westbury.—234 miles; Alt. 1,454 feet.

Westbury is on the great moraine which continues many miles to the north and east. Floyd Lake and a group of small but beautiful lakes east of Westbury.

Callaway.—239 miles; Alt. 1,358 feet.

Callaway is on the rolling till-plain which merges into the moraine to the east. East of Callaway 4 miles is Rice Lake, which is drained by Pelican River. One-half mile north of Rice Lake is Buffalo Lake, which is drained by Buffalo River. It is interesting to observe that Pelican River carries water from Rice Lake in turn to Lakes Campbell, Floyd, Elsa, Detroit, Sallie, Melissa, Pelican, Lizzie, and Prairie, thence south by an ancient channel now occupied by Pelican River near to Fergus Falls, where it joins the Otter Tail or Red, its waters finally reaching the Red River of the North at Breckenridge. Buffalo River before entering Buffalo Lake carries water from a group of lakes to the east, one of which group is Height of Land Lake which is drained by the Otter Tail or Red. The Buffalo thus carries water from near

Height of Land Lake past Rice Lake whence it winds westward crossing the Herman Beach of Lake Agassiz at Muskoda, and finally reaching the Red River of the North at Georgetown, 15 miles below (north) of Moorhead, and 60 miles below Breckenridge where the Pelican enters. The Mississippi flows north 6 miles east of Upper Rice Lake, and Lake Itasca is 10 miles south of Upper Rice Lake, from which water goes to the Gulf of Mexico.

Ogema.—247 miles; Alt. 1,266 feet.

White Earth Indian agency is located 4 miles east amid a group of morainic lakes the largest of which is White Earth Lake. The morainic hills are strongly marked in character, rising 150 to 200 feet above their bases.

Waubun.—253 miles; Alt. 1,239 feet. **Mahnomen.**—262 miles; Alt. 1,213 feet. (Mahnomen County.) Bejou.—271 miles; Alt. 1,222 feet. Winger.—277 miles; Alt. 1,231 feet.

After leaving the moraine at Ogema the railroad traverses a rolling till-plain having a clayey character, the soil of which is excellent.

Erskine.—287 miles; Alt. 1,192 feet. (Crossing G. N. Ry.)

Four miles south the railroad passes upon a sandy moraine, marked by rolling hills and many lakes. The Herman Beach, or highest shore line of Lake Agassiz, is crossed 2 miles south of Erskine. The town stands on the clayey lake-washed till-plain which was the bottom of Lake Agassiz. Several small lakes, shore lagoons, lie west of town, and a flat marshy sand plain north, formed by waves upon a shallow bottom.

Cisco.—292 miles; Alt. 1,169 feet. Brooks.—297 miles; Alt. 1,129 feet. Plummer.—304 miles; Alt. 1,127 feet.

Cisco is on sandy wave-washed lake bottom. Beach 2 miles north. Brooks is on wave-washed till of Lake Agassiz bottom. North of a wave-washed sand plain, which is crossed by Hill and Lost Rivers, Plummer stands on the wave-washed till-plain.

Hazel.—312 miles; Alt. 1,114 feet. **Thief River Falls.**—319 miles; Alt. 1,127 feet. (Pennington County.)

After crossing Clearwater River at Plummer the lake-washed till continues to and beyond Thief River Falls, marshy depressions and sandy low swells marking imperfect leveling by the lake waves.

GOODRIDGE LINE

Silverton.—7 miles from Thief River Falls. Mavie.—13 miles. Goodridge.—19 miles.

This line runs east across the lake-washed till-plain. The plain was covered by shallow lake waters during the highest or Herman stage of Lake Agassiz. The irregular sandy patches and marshy depressions represent moraines that were leveled by the waves of the lake.

Anita.—328 miles; Alt. 1,152 feet.

Anita stands on a leveled moraine deposited in Lake Agassiz and leveled by its waves. A sandy beach lies on the east border of this moraine, and another beach on the west, near Anita. Five beaches are crossed in as many miles toward New Folden.

New Folden.—337 miles; Alt. 1,097 feet. Strandquist.—348 miles; Alt. 1,064 feet.

Middle River is crossed at New Folden, and north a tract of lake-washed sand, which grades into lake-washed sandy till to and beyond Strandquist.

Karlstad.—355 miles; Alt. 1,048 feet.

Karlstad stands on the Campbell Beach, which is here represented by 4 sandy shore-lines. Marshes are hemmed in between the beach ridges. Lake-washed sand west.

Halma.—362 miles; Alt. 998 feet. Bronson.—368 miles; Alt. 959 feet. Lancaster.—378 miles; Alt. 908 feet. Orleans.—386 miles; Alt. 835 feet.

Campbell Beach crossed west of Halma. The plain is mostly lake deposited sand, with tracts of lake-washed sandy till. Lancaster to Orleans mostly lake-washed clayey till. Sandy beach is crossed east of Orleans.

Noyes.—399 miles; Alt. 792 feet. Winnipeg.—465 miles.

From Orleans to Noyes the plain is that of fine lacustrine silt deposited in the axial or deeper part of Lake Agassiz. This fine lake sediment continues to Winnipeg.

THE WHEAT LINE

Rosewood.—8 miles from Thief River Falls; Alt. 1,133 feet.

Four beaches are crossed between Thief River Falls and Rosewood, with tracts of lake-washed sand between.

Viking.—14 miles; Alt. 1,070 feet.

Four beaches are crossed between Rosewood and Viking, with intervening marshy "lagoons" and clayey wave-washed till. Two miles west of Viking the large Campbell Beach is crossed. A belt 1 mile wide of clayey lake-washed till lies parallel with this beach, a narrow belt of lake-washed sand intervening. Lake-washed sand lies west.

Radium.—24 miles; Alt. 925 feet.

On an island of lake-washed till. A beach is crossed about a mile west.

Warren.—32 miles; Alt. 855 feet. (Marshall County.) (Crossing G. N. Ry.) March.—38 miles; Alt. 827 feet. Alvarado.—42 miles; Alt. 814 feet. Oslo (N. D.).—49 miles.

From Warren west to the Red River of the North at Oslo the flat plain is that of the deep bottom of Lake Agassiz. The sediment from which the soil is formed is fine grained compact silt and clay.

DULUTH-BROOTEN LINE

Duluth.—0 miles; Alt. 631 feet. (St. Louis County.)

Leaving Union Station, Duluth, the railroad is cut and tunneled through pre-Cambrian (volcanic) rocks, passing under Superior street, crossing the mouth of the St. Louis River by a swinging bridge to Superior, Wisconsin. From Superior to the point where the railroad re-enters Minnesota east of Frogner the red clay plain of the bottom of glacial Lake Duluth is crossed.

Frogner (Wis.).—26 miles from Duluth. Black Hoof (Minn.).—34 miles; Alt. 972 feet.

The Superior red clay continues to Black Hoof. A moraine a mile in width, which was leveled by the waves of Lake Duluth, lies west of Black Hoof. Another moraine, similarly leveled by wave action, lies east of Nemadji. Between these moraines is lake-washed till, sandy toward the north.

Nemadji.—42 miles; Alt. 1,060 feet.

The highest beach or shore-line of Lake Duluth lies both north and south of Nemadji, extending around the west end of Lake Duluth the western limit being at Moose Lake. This beach is 400 feet above the level of Lake Superior. (See Chap. XX.)

Moose Lake.—50 miles; Alt. 1,107 feet. (Crossing over N. P. Ry.)

The railroad station is on the high terrace of glacial St. Louis River. Moose Head Lake lies in the channel of the outlet of glacial Lake Nemadji.

Denham.—62 miles; Alt. 1,205 feet. (For Plummer-Winnipeg Line see p. 360.) Arthyde.—70 miles; Alt. 1,238 feet. Solana.—73 miles; Alt. 1,320 feet.

The railroad runs mostly through a moraine formed by the glacier which pushed westward from the basin of Lake Superior (Labradorian glacier). Rolling till-plains are both north and south. The railroad cuts through the drift into slate rock northeast of Denham. The soil is generally clayey. This is the red drift deposited by the Labradorian glacier of the Wisconsin stage. Boulders from the hard-rock region of Lake Superior are common. This is fertile agricultural land, well adapted to red clover. (See Chap. XXVI.)

McGrath.—81 miles; Alt. 1,241 feet. Redtop.—90 miles; Alt. 1,283 feet.

A large moraine lies south, and extends around the south and west sides of Mille Lacs Lake, hemming in the waters of this lake and preventing their escape southward. A small "island" of granitic rock projects up through the drift 2 miles west of McGrath. Another larger outcropping granitic ridge is cut through by Snake River 7 miles south. These are remnants of Old Minnesota which resisted the wearing action of the ice sheets that passed over them, and they stand as monuments of an ancient landscape.

Wahkon.—96 miles; Alt. 1,270 feet. Onamia.—104 miles; Alt. 1,260 feet.

Wahkon is at the south point of Mille Lacs Lake, in the midst of morainic hills. This moraine continues beyond Onamia. Here Rum River is crossed, a small pooling stream by which the waters of Mille Lacs Lake overflow to the Mississippi. Onamia, Nassawac, and Ogechie Lakes are entered and passed through by Rum River between its point of exit from Mille Lacs Lake and Onamia.

Hillman.—116 miles; Alt. 1,320 feet.

West from Onamia is rolling till-plain or ground moraine, clayey in character, with few lakes. The soil is good. Hillman stands on a moraine about 2 miles in width. West the rolling till-plain continues to Pierz (or Genola).

Genola.—127 miles; Alt. 1,162 feet.

Genola is on the east edge of an outwash plain. At the time when the Labradorian glacier lay over Mille Lacs Lake and the country west the ice waters from its melting passed this way to the Mississippi, and this and other sandy outwash plains were deposited from its waters.

Granite rocks are thinly covered with drift in places, and granite is quarried near Genola.

Vawter.—135 mile; Alt. 1,109 feet.

Vawter is farther down this ancient water-way. Platte River crosses this outwash plain from the north, descending by a narrower glacial channel past Royalton to the Mississippi. The Platte brings water from a group of lakes that lie in hollows in the moraine west of Mille Lacs Lake, one of which group is separated from Mille Lacs Lake by less than half a mile.

Bowlus.—145 miles; Alt. 1,109 feet. Holdingford.—152 miles; Alt. 1,143 feet.

A small till-plain intervenes between the ancient watercourse at Vawter and the great outwash plain which borders the Mississippi below Little Falls.

Crossing (over) Northern Pacific Ry. Mississippi River crossed west.

Bowlus and Holdingford are on rolling till-plain or ground moraine, clayey in character.

Albany.—160 miles; Alt. 1,244 feet. (Crossing Great Northern Ry.)

Strongly rolling moraine to Albany. Many hills rise 100 to 150 feet above their bases. ''Pots and kettles'' such as are characteristic of strong moraines. The boundary between the red (Labradorian) drift and the gray (Keewatin) drift is 1 mile east of Albany.

New Munich.—169 miles; Alt. 1,191 feet.

Rolling till-plain with many lakes and sloughs west from Albany. Town stands on sandy outwash plain, an ancient watercourse over the flat bottom of which Sauk River now meanders.

Greenwald.—175 miles; Alt. 1,263 feet. Elrosa.—180 miles; Alt. 1,313 feet.

Clayey rolling moraine crossed west of New Munich, which merges into rolling till-plain 10 miles in width. The great Paynesville-Glenwood outwash plain extends 4 miles east of Brooten.

MOOSE LAKE-PLUMMER LINE

Kettle River.—57 miles from Duluth; Alt. 1,181 feet.

Undulating till-plain. Cross Kettle River. Moraine 3 miles in width west of Moose Lake, many boulders. Outwash channel of glacial drainage runs through the moraine, now occupied by small tributary of Kettle River. Undulating till-plain west to Automba and Lawler.

Lawler.—71 miles; Alt. 1,313 feet.

Moraine 2 miles in width, with till-plain west. Four miles west of Lawler a hilly moraine 1 mile in width, west of till-plain, marks the western limit of the deposits of the Labradorian glacier (red drift), in this locality. Between Lawler and McGregor a beach ridge is crossed, which marks the eastern shore of glacial Lake Aitkin.

McGregor.—79 miles; Alt. 1,234 feet. (For Cayuna Range Line, see p. 368.)

Sandy plain, the bottom of glacial Lake Aitkin. Two miles west of McGregor another sandy beach is crossed. This beach runs entirely around a rolling tract of moraine which formed an island in Lake Aitkin. The railroad crosses the extreme east end of the island. Axtell stands on the beach at the east end of the island. The railroad follows the beach about a mile, then passing on to a marsh that extends to Palisade.

Palisade.—91 miles; Alt. 1,236 feet.

The town stands on a beach which runs entirely around another morainic island the west side of which extends northeast parallel with the Mississippi River to Libby, 7 miles.

Bain.—98 miles; Alt. 1,268 feet.

West of Palisade the railroad crosses the Mississippi and Willow Rivers, on a sandy plain of lake-washed materials. The western shore of Lake Aitkin is marked by a sandy beach, the end of which is passed toward Bain. East of Bain and north of Palisade are two islands each surrounded by sandy beaches.

Swatara.—106 miles; Alt. 1,297 feet. Shovel Lake.—112 miles; Alt. 1,340 feet.

The railroad runs on or near the east edge of a rolling hilly moraine. To the east and north the surface is gray drift overlying the red. To the west it is the red drift of the Patrician ice sheet.

Remer.—122 miles; Alt. 1,346 feet. Boy River.—135 miles; Alt. 1,310 feet.

Rolling till-plain or ground moraine, with marshy tracts and lakes intervening.

Crossing Leech Lake River. Leech Lake 2 miles west. The railroad runs around the north end of Leech Lake across till-plain along south edge of large outwash plain to Cass Lake.

Cass Lake.—164 miles; Alt. 1,334 feet. **Bemidji.**—180 miles; Alt. 1,354 feet. (Beltrami County.) Scribner.—187 miles. Pinewood.—195 miles; Alt. 1,424 feet.

For a distance of 40 miles the railroad traverses the great sandy outwash plain. Cass Lake lies to the north and Pike Bay to the south. Many smaller lakes occupy depressions in the sandy plain. Approaching Bemidji splendid clayey till-plains lie to the north and to the south, and these plains have excellent soil. The Mississippi River is crossed at Bemidji.

Leonard.—202 miles; Alt. 1,449 feet.

Leonard is on the moraine which extends to Lengby and to the Height of Land, and beyond, and eastward north of the great outwash plain which has just been crossed. When the great Keewatin ice sheet lay where Leonard now is, and southward and eastward, the great outwash plain was formed from the flood waters of its melting.

Clearbrook.—210 miles; Alt. 1,339 feet. Gonvick.—215 miles; Alt. 1,287 feet. Gully.—221 miles; Alt. 1,262 feet. Trail.—224 miles; Alt. 1,212 feet.

Rolling till-plain Gonvick to Gully. Gully and Trail are at the ancient shore-line of Lake Agassiz. A sandy beach lies north of Gully. Trail is on a marshy plain between two beach ridges. An arm of the great Beltrami Swamp is crossed west of Trail.

Oklee.—233 miles; Alt. 1,155 feet. Plummer.—243 miles; Alt. 1,127 feet.

Cross Lost River at Oklee. Two miles west of Trail a sandy beach ridge is crossed in the swamp. Lake-washed till to Plummer, sandy west of Oklee. Cross end of sandy beach 2 miles east of Plummer.

CAYUNA RANGE LINE

East Lake.—77 miles from Duluth; Alt. 1,251 feet.

West of Lawler a moraine 2 miles in width is crossed, with till-plain east and west. Moraine north, with beach of glacial Lake Aitkin bordering the moraine on its north side. A bay of Lake Aitkin extended to the town of East Lake, which stands on the beach. Westward the railroad runs a mile south of the beach on a moraine to Darina and Rossburg.

Darina.—86 miles; Alt. 1,252 feet. Rossburg.—91 miles; Alt. 1,228 feet. (Crossing Nor. Pac. Ry. east.)

Hilly moraine south, which extends west and north around the ancient lake. It was this moraine which caused the damming of the waters of the glacial upper Mississippi and forming Lake Aitkin.

Aitkin.—97 miles; Alt. 1,205 feet. (Aitkin County.)

Aitkin is on the southern edge of the sandy plain of the ancient lake bottom. The sandy beach ridge which marks the shore-line of the ancient lake is a few rods south of the city, bordering the moraine just referred to. The beach continues westward about 15 miles to the Mississippi River, where it turns on the north side of the river and extends 25 or 30 miles in a northeasterly direction forming the west shore of the ancient lake. The Mississippi River cuts through the moraine, and the cutting down of the river's channel allowed the waters of the lake to be drained away, and the lake ceased to be.

Iron Hub.—105 miles; Alt. 1,241 feet. Cayuna.—107 miles; Alt. 1,253 feet. Crosby.—110 miles; Alt. 1,265 feet. Ironton.—112 miles. Riverton.—115 miles; Alt. 1,224 feet.

Iron Hub is on the sandy plain of the ancient lake bottom, 1 mile from the shore-line. Cayuna and Deerwood are among the morainic hills and lakes. Cayuna is south of Rabbit Lake, and the ancient shore-line runs north of this lake. The outlet of the ancient lake, now the channel of the Mississippi, is 2 miles west of the western end of Rabbit Lake. Crosby is located on a sandy outwash plain, which was formed from the ice which built the moraine. Serpent Lake lies to the east.

CHAPTER XXXIV

GEOLOGY FROM A CAR WINDOW

The Iron Range Lines

DULUTH AND IRON RANGE RAILROAD

Duluth.—0 miles; Alt. 609 feet. (St. Louis County.) Knife River.—19 miles from Duluth; Alt. 626 feet. Two Harbors.—27 miles; Alt. 637 feet. Waldo.—30 miles; Alt. 1,058 feet. Alger.—37 miles; Alt. 1,452 feet. Drummond.—39 miles; Alt. 1,311 feet. Allen.—73 miles; Alt. 1,507 feet.

From Duluth to Two Harbors the railroad follows the shore of Lake Superior. At Two Harbors the steep ascent to the highland is begun. Waldo is on the lake-washed clayey till, the highest shore-line of glacial Lake Duluth being crossed a mile north. A moraine is crossed at Alger. North is a stony wooded till-plain. A still higher moraine lies northeast. It is a range of stony hills seen at Highland and Drummond. Volcanic rocks on which the moraine rests are seen at the northwest edge near Brimson. At Brimson is a sandy outwash plain, and north of this is till-plain to Norman. This plain is much cut by small stream valleys. Small lakes occupy depressions at Bassett. A sandy moraine is crossed at Norman, bordering which on the south is a gravelly glacial watercourse, now traversed by St. Louis River.

Aurora.—80 miles; Alt. 1,476 feet. Biwabik.—87 miles; Alt. 1,426 feet. McKinley.—91 miles; Alt. 1,439 feet. Sparta.—96 miles; Alt. 1,434 feet. Eveleth.—100 miles; Alt. 1,574 feet.

Allen is on till-plain, but some volcanic Keweenawan rocks protrude. Sandy moraine again crossed west, and then till-plain from Aurora to Biwabik and Eveleth. The Giant's Range, now called the Mesabi Range, lies to the north. Embarrass River, here broadened into a long lake, is crossed east of Biwabik. The large valley was formed by glacial flood waters which gathered to pass through this gap in the Range at the time when the ice edge lay at the north of the Range.

Mesaba.—77 miles; Alt. 1,519 feet. Embarrass.—84 miles; Alt. 1,425 feet. Tower.—95 miles; Ely.—116 miles; Alt. 1,416 feet. Winton.—121 milles; Alt. 1,328 feet.

Mesaba is on the till-plain which lies immediately south of the Mesabi Range. A branch line runs east parallel with the Range, crossing a swamp on upper Partridge River, to the large sandy moraine which lies east of the great Range. From Mesaba north watch for iron ore in the grade cuts! On the way to Embarrass the railroad crosses the axis of the great Mesabi Range. This high ridge, which is an old, worn down mountain range, was crossed by the ice sheets and the soil swept clean. The rocks now are bare. Ice markings on polished rock surfaces show the direction of the last ice movement to have been a little west of south. Islands of stony clayey till surrounded by swamp are crossed Embarrass to Soudan and Tower, with tracts of hilly sandy moraine. Jasper Peak, near Soudan, has an elevation of 1,710 feet, and is said to be one of the highest points in the State. Tower Junction to Robinson, past Eagle Nest Lakes, the railroad follows an old glacial channel. Waters from the edge of the melting ice sheet to the north broke across the axis of the Vermilion Range. A sandy moraine lies south of the railroad toward Ely. To the north is the hard pre-Cambrian rock, bare of soil, all swept away by the great ice sheets. An outwash plain of sand and gravel lies south of Ely and Winton. Glacial waters flooded across southwestward toward Embarrass by a broad channel which is now occupied by a long band of swamp. This channel lies across the axis of the great Giant's Range.

DULUTH, MISSABI & NORTHERN RAILWAY

Duluth.—0 miles. Proctor.—9 miles from Duluth. Adolph.—13 miles.

From Duluth the railroad makes a rapid ascent to the highland to the west. The course is first across the lake deposited clayey plain, then across the rocky highest shore-line of Lake Duluth north of West Duluth. Above the beach more pre-Cambrian Keweenawan rocks are exposed. The climb to Proctor is one to be remembered. The view of the lake and harbor from the rear platform of the train is worth the trip. Proctor and Adolph are on the highland on which lies the great moraine formed by the Labradorian glacier, and which runs around the west end of the Lake Superior Basin.

Saginaw.—23 miles; Alt. 1,364 feet. Culver.—31 miles; Alt. 1,292 feet. Alborn.—34 miles; Alt. 1,310 feet. Birch.—39 miles; Alt. 1,327 feet.

Saginaw is on the north part of the moraine, which is here divided, and interrupted by tracts of till-plain west of Pine and south of Saginaw. Cloquet flows through a till-plain east of Culver. These are red drift moraines and till-plains. Alborn and Birch are on overridden red drift moraines,—gray over red.

Kelsey.—47 miles; Alt. 1,304 feet. Zim.—58 miles. Forbes.—62 miles.

From Birch to Forbes the swampy land is muskeg, or moss peat, that holds water and blocks drainage. The plain slopes southwest. Near the river a belt of till appears because of good drainage, as at Kelsey on the Whiteface River. At Zim and Forbes also dry land appears, sandy deposits bordering St. Louis River, borne onto the plain probably by the swollen glacial stream.

Wilpen.—79 miles; Alt. 1,422 feet. Hibbing.—84 miles; Alt. 1,537 feet.

A small moraine rises west of Iron Junction, but the railroad runs on till-plain mostly to Wilpen and Hibbing.

Sparta.—72 miles; Alt. 1,430 feet. Biwabik.—80 miles; Alt. 1,448 feet. Eveleth.—71 miles; Alt. 1,574 feet. Virginia.—74 miles; Alt. 1,449 feet. Mountain Iron.—74 miles; Alt. 1,465 feet. Chisholm.—83 miles.

Each of these places is situated about a mile distant from the outcropping hard crystalline rocks of the Mesabi or Giant's Range. The great iron deposits lie generally immediately south of the Range. The deposits are therefore generally covered by a thin mantle of drift. This overlying drift is removed from the ore beds, in the process called "stripping."

COLERAINE BRANCH

Alborn.—34 miles from Duluth; Alt. 1,310 feet. Meadowlands.—46 miles. Toivola.—56 miles. Bovey.—87 miles. Coleraine.—88 miles.

Alborn is on overridden red drift moraine. West of this the moss peat swamp lies on the flat bottom of glacial Lake Upham, to Silica. Meadowlands is on the lake clay bed which borders Whiteface River. This is free from muskeg because of good drainage. Muskeg is crossed to St. Louis River 4 miles west. This is bordered also by sandy deposits. Farther there are sandy islands in the swamp, and irregular belts of sandy deposits border the streams. The intervening wet lands are clayey in character and when drained the soil is very productive. West of Silica is rolling till-plain, and west of this a large overridden moraine—gray over red drift. A rolling till-plain east of Bovey is also veneered with gray drift. West of Bovey and about Coleraine is roughly rolling red drift moraine overridden and veneered by gray drift.

DULUTH, WINNIPEG AND PACIFIC RAILWAY

Duluth.—0 miles; Alt. 609 feet. Harney.—16 miles from Duluth; Alt. 1,207 feet. Twig.—28 miles; Alt. 1,385 feet. Bartlett.—30 miles. Taft.—36 miles; Alt. 1,340 feet. Ellsmere.—55 miles; Alt. 1,347 feet. Peary.—66 miles; Alt. 1,339 feet. Virginia.—77 miles; Alt. 1,433 feet.

The railroad ascends from the lake-washed till-plain at Duluth at an elevation of 602 feet (lake level) to the highest beach of Lake Duluth, at an elevation of 1,200 feet, and crosses the large moraine of the Labradorian glacier, which lies parallel with the lake shore, 1,200 to 1,400 feet above sea level. This hilly moraine continues to Grand Lake and

Cloquet River. Cloquet River is in a large glacial valley. Taft to Shaw is a stony till-plain. After passing Shaw there is rolling till-plain with intervening marshes and swamps. The till-plain has a surface veneer of gray drift over red drift. East at Ellsbury is red drift moraine made less stony by veneering of gray drift from the northwest. Muskeg swamp becomes wide up to the sandy plain that borders the St. Louis River at Peary. The sand is glacial flood deposit, and is free from moss-peat because of good drainage. Stony till-plain north of Peary to Virginia. East of Virginia is an elbow of the great Mesabi Range extending south to Eveleth.

Britt.—86 miles; Alt. 1,480 feet. Angora.—97 miles; Alt. 1,351 feet. Cook.—104 miles; Alt. 1,311 feet.

The axis of the Mesabi Range is crossed north of Virginia. This is a main fold of the ancient mountain range, and the "oldest rocks in the world" are exposed. The ice sheets passed over the hard ridges and promontories, and many boulders of granite, porphyry, and quartzite, and other very hard rocks, plucked by the ice from this hard range, now strew the fair land far to the south,—to and beyond St. Paul. From Putnam to Angora alternating stony moraines, tracts of till-plain, and swamps. At Angora the high shore-line of the extreme eastern point of Lake Agassiz. The sandy beach ridge of this bay of the ancient lake lies parallel with the shore of Vermilion Lake in a northwest-southeast direction. Cook is on a plain of wave-washed clayey till of the ancient lake bottom. Gheen is on the sandy beach at the north shore of the bay.

Alvina.—114 miles; Alt. 1,364 feet. Glendale.—118 miles; Alt. 1,299 feet. Cusson.—123 miles; Alt. 1,332 feet. Kinmount.—137 miles; Alt. 1,320 feet. Ray.—152 miles; Alt. 1,160 feet. Ericsburg.—160 miles; Alt. 1,117 feet. Ranier.—169 miles; Alt. 1,130 feet.

From Glendale to Kinmount and beyond is barren rock the surface soil from which was swept southward by the great ice sheets. A belt of red drift moraine overridden by the ice of the Keewatin ice sheet borders the shore of Lake Agassiz at Gheen. Pelican Lake, west of Orr, is a large lake of ponded waters held back by the moraine to the south. Ray and Ericsburg are on the plain of the ancient lake bottom, though the exact location of the shore-line west of Gheen has not been exactly traced. Another overridded moraine is crossed south of Ranier. Ranier is on Rainy Lake, amidst the hard outcropping pre-Cambrian rocks. Rainy River is crossed here and connection made with the Canadian Northern Railway.

CANADIAN NORTHERN RAILWAY

Beaudette-Spooner.—227 miles from Duluth; Alt. 1,075 feet. Pitt.—234 miles. Graceton.—239 miles; Alt. 1,134 feet. Williams.—245 miles;

Alt. 1,147 feet. Roosevelt.—251 miles; Alt. 1,154 feet. Swift.— 258 miles; Alt. 1,134 feet. Warroad.—264 miles; Alt. 1,060 feet. Winnipeg.—379 miles.

The Canadian Northern enters the State at Beaudette and Spooner from across the Rainy River. A tract of heavy clay borders the river, at Beaudette and Spooner. This soon gives way to lake-washed clayey till. At Pitt a large sandy beach of Lake Agassiz is crossed. This beach extends interruptedly for many miles northwest and southeast across the flat plain. Williams is on sandy wave-washed till, and between Williams and Roosevelt another sandy beach is twice crossed. Between Roosevelt and Swift another large beach is crossed, and still another smaller one south of Warroad. Warroad is near the shore of Muskeg Bay, an arm of Lake of the Woods. The sandy plain continues from Warroad to the international boundary. To the west is swamp, with occasional sandy islands.

MINNEAPOLIS & RAINY RIVER RAILWAY

Deer River to Little Fork.—88 miles (with branches).

This line runs along the west side of a large moraine of red drift which was overridden by the Keewatin glacier, to Marcell, and then crosses the moraine to Big Fork. The hills are roughly rolling, and there are frequent boulders from the hard-rock region to the north. The gray drift, however, has supplied a less stony covering and somewhat softened the roughness of the red drift moraines. Till-plain lies north of Deer River, then extensive wet land. Swamps also intervene frequently between the rolling hills. Jessie Lake, Stanley, and Round Lake are on branch lines, located on the overridden moraine. Marcell is on the moraine and surrounded by a fine group of morainic lakes. Big Fork is on till-plain, with gray drift forming the surface. Kenney is also on the gray drift till-plain. This great territory will be valuable farming land when it is improved. Some miles north of Kenney the highest shore-line of Lake Agassiz is crossed. Several more sandy beach ridges are crossed north to Little Fork. Islands of clayey till beaten by the waves, also overridden moraines some of which stood above the waters of the lake as islands, are crossed in the great muskeg swamp which covers most of this part of the bottom of Lake Agassiz.

This muskeg is a moss-peat growth on a gently undulating surface. Beaver dams, willows, and moss have blocked the natural drainage. The muskeg is from 1 to 25 feet deep. When this land is reclaimed the surface will not be as flat as that of the present muskeg surface.

HILL CITY RAILWAY

Mississippi.—8 miles from Swan River.

From Swan River the railroad traverses a plain covered with fine sand or silt borne by the glacial floodwaters of the Mississippi and tributary streams to the head of glacial Lake Aitkin. The east shoreline of Lake Aitkin is a conspicuous sandy beach ridge east of the river at the crossing, and lying nearly parallel with the Mississippi for 25 miles to the south. West of the river the railroad crosses the flat and swampy plain. Under the peat is sand along the track, but a few miles south is clay, on which the waters of Lake Aitkin were ponded. Sandy islands and one of clayey drift are crossed.

Hill City.—24 miles.

On rolling till-plain. North are overridden moraines. The rough knolls of the stony (Patrician) red drift are smoothed over by the gray (Keewatin) drift, which forms a veneer of less stony material over the more stony red. The topography is quite rolling, and a fine growth of hardwood forest on these hills since the original pine was cut. A large woodenware manufacturing plant is located here.

MINNEAPOLIS, RED LAKE & MANITOBA RAILWAY

Bemidji.—0 miles; Alt. 1,347 feet. (Beltrami County.) Puposky.—16 miles from Bemidji; Alt. 1,363 feet. Nebish.—24 miles; Alt. 1,366 feet. Redby.—33 miles; Alt. 1,210 feet.

The great gravelly outwash plain continues north from Bemidji 10 miles. North of the outwash plain is a large gray drift moraine, decidedly rolling, with many fine lakes. Puposky is in the midst of a fine group of lakes on rolling till-plain. Both the moraine to the south and the till-plain are clayey. Nebish is on another moraine to the north, which is somewhat more sandy in character. The clayey till-plain extends west about Island Lake. Another lies east of the moraine at Nebish. This is clayey in character. It extends beyond Funkley, Kelliher, and Mizpah. Two sandy and gravelly beaches of Lake Agassiz are crossed near Redby, these lying south of and parallel with the shore of Red Lake. Redby is located on the sandy lake-washed plain between these two beaches. Lake-washed sand covers the plain east past Quiring, and north to Foy and Shotley. The soil is without stones, easily worked, and is moist because the clayey till lies immediately under it.

ELECTRIC SHORT LINE RAILWAY

Minneapolis.—0 miles. Watertown.—30 miles; Alt. 943 feet. Winsted.—40 miles; Alt. 1,011 feet. Silver Lake.—50 miles; Alt. 1,052 feet. Hutchinson.—60 miles; Alt. 1,042 feet.

The road runs most of the way through rolling moraine to Watertown. Small lakes and ponds amongst morainic hills. South Fork of Crow River is crossed east of Watertown. This stream cuts through the moraine which lies about Watertown. Two miles west of Watertown the hilly moraine flattens to a rolling till-plain.

About Winsted is a group of small lakes on the rolling till-plain. Three miles west of Winsted a narrow moraine is crossed, followed by rolling clayey till-plain to Hutchinson, many lakes occupying depressions in the rolling plain. Hutchinson is on the rolling till-plain, with a hilly moraine and many fine lakes west and north.

GLOSSARY

Alluvium, or Alluvial.—Loose earth materials deposited by modern streams upon their valley bottoms, forming floodplains.

Archæan.—A term that means **old.** Applied to the most ancient geologic times and also to the rocks formed during that time. These ancient rocks are mostly granitic.

Bed-Rock.—The rock formations that underlie the drift; in many places in layers or strata. Bed-rock may be granite, slate, sandstone, shale, limestone, or clay.

Conglomerate.—A "pudding stone," or mixture of rounded stones and sand cemented into a hard solid mass. The rounded stones may be of all sizes from sand grains to cobbles and boulders. A formation of wave-worn fragments of a sea shore that have been cemented into solid rock would be a conglomerate formation.

Cretaceous.—Applied to a period of geologic time preceding Tertiary, also applied to the rock formations that were deposited on the sea bottoms of that time.

Crust of the Earth.—The outer portion of the earth. It includes all the rock formations of the earth to a depth of several miles. The exact thickness or depth of the earth's crust is not known. We know it only to a depth of a few miles.

Diabase.—A hard, dark, lava rock making up a large part of the lava flows from the Lake Superior Region.

Dolomite.—A form of limestone. It differs from ordinary limestone in that it contains the element magnesium in addition to calcium. Many forms of white marble are magnesian limestones.

Drift.—Any form of earth materials carried by glaciers and deposited when the ice melted.

Drift Sheet.—Applied to the drift deposit of any ice invasion. It includes ground moraine or till-plain, terminal moraines, and outwash plains.

Formation.—Any rock mass that occurs naturally in the earth. It may be solid rock as limestone or granite, or it may be loose as sand, gravel, clay, or soil.

Glacial Invasion.—See Ice Invasion.

Glacial Period.—The entire time from the first ice invasion till the close or melting away of the last continental glaciers.

Glacial River.—A river formed by waters from the melting ice of a glacier.

Glacial Stage.—The time during which the continent was covered with ice, as distinguished from an interglacial stage. (See Ice Invasion.)

Glacial Valley.—A valley cut by the waters of a "glacial" river. Such valleys are generally out of all proportion to the streams that now occupy them and their sides are commonly steep and their bottoms broad and flat, and a small stream may or may not meander over the bottom.

Ground Moraine.—See Till-plain.

Ice Age.—Sometimes used in referring to the glacial period.

Ice Cap or Center.—The place from which the ice of a glacier seems to come. The place where the snows gathered from which the glaciers were formed. The Keewatin Ice Cap was over the old province of Keewatin; the Patrician Ice Cap was over the old province of Patricia; the Labradorian over Labrador. A Greenland Ice Cap covers most of Greenland today.

Ice Invasion.—The on-coming or advance of a continental glacier. Applied also to the period of time during which the ice held sway.

Ice Sheet.—A term applied to continental glaciers. The ice spread by its own weight and flowed over the land, and it is therefore referred to as an ice sheet.

Igneous Rocks.—From Latin **Ignis,** meaning **fire.** Igneous rocks are those that have been melted by the heat of the earth's interior. They may have been forced out upon the surface in the form of lava, or forced into spaces between other formations below the surface.

Illinoisan Glacier or Ice Invasion.—A Labradorian glacier that extended into Minnesota depositing the "Old Red Drift."

Interglacial Stage, or Time.—The interval between two ice invasions. The climate may have been, and probably was, much like that of the present. There is evidence that a sub-tropical climate has existed much farther north than at present.

Joints.—Cracks in the strata or layers of rocks whereby the rocks are broken into blocks. The jointing is crosswise of the strata.

Kansan Glacier.—A Keewatin glacier that deposited the "Older Gray Drift."

Keewatin.—The name of a Province in Canada. Applied to the glaciers which originated from that region. Also applied to the gray drift deposits from those glaciers.

Keeweenawan.—Applied to a period of geologic time and to the rocks formed during that time. The name is from Keeweenaw Point, Michigan, where rocks of that formation are exposed. Keeweenawan rocks are in part volcanic lava-flows and in part, sea-sediments.

Labradorian.—Applied to the glaciers that came from Labrador, and also to the drift deposits of those glaciers.

Lacustrine.—Pertaining to a lake—deposits made on the bottoms of lakes. Applied to the sediments deposited on the bottoms of extinct glacial lakes.

Lava.—Molten rock from the depths of the earth, poured out from volcanoes or from fissures in the earth's crust.

Loam.—Used in describing soils. Loam is made up of a mixture of sand and clay. If clay predominates it is clay loam. If sand predominates it is sandy loam. If there is much stone it is stony loam or stony clay loam, or stony sandy loam.

Loess.—A soil formation consisting of dust carried by the wind during the glacial period and deposited upon vegetation-covered land surfaces. It is fine-grained, without stones, and very uniform in texture.

Moraine.—Earth materials deposited by a glacier. If at the end or terminus of a glacier it is called a terminal moraine. If deposited under the glacier it is called ground moraine, or till-plain. Ground moraine and till-plain are terms applied to the drift materials which make up much of the prairie landscape. It is the material that was carried in the bottom of, or ridden over by, the great continental glaciers.

Nebraskan Glacier.—A Keewatin glacier that deposited the "Older Gray Drift."

Old Gray Drift.—Drift deposited by the Keewatin glacier of the second or Kansan ice invasion.

Older Gray Drift.—Drift deposited by a glacier from the Keewatin center, but which was earlier than the Kansan. It is sometimes referred to as the Nebraskan.

Old Red Drift.—The drift deposited by a Labradorian glacier during the third or Illinoisan glacial invasion.

Outwash.—Earth materials carried away from the edge of a glacier by escaping ice waters, usually sandy and gravelly.

Outwash Plain.—Materials from a melting glacier, generally sandy, washed away from the ice by the glacial floodwaters and spread out often over wide areas; sometimes spread along the bottom of a glacial valley as a sandy or gravelly valley filling.

Patrician.—From the old Province of Patricia in Canada. Applied to the glacier which came from that center, and also to the drift deposited by that glacier.

Prairie.—A grassy plain as distinguished from a forest covered plain. Prairies may be roughly rolling (moraines) or more nearly level (till-plains).

Preglacial.—Before the glacial period. Generally refers to time immediately preceding the glacial period.

Quartz.—A hard mineral from which glass is made. It occurs in the form of crystals, or it may be massive, and either fine-grained or coarse-grained.

Quartzite.—A hard rock consisting largely of quartz. Many quartzite boulders occur in the drift. Being very hard the rock resists the wearing action of ice while being carried or shoved in glaciers. It dissolves very slightly in water, and weathers very slowly. It is one of the boulders often spoken of as "hardheads."

Recent or Postglacial Time.—The time since the ice of the glacial period finally disappeared.

Retreat (of the Ice Front).—When a glacier melts more rapidly at its edge or end than it moves ahead or advances then the front is said to "retreat."

Rock.—Any natural formation or deposit of earth materials, whether in the form of solid rock strata, or sand, or clay, or soil.

Sandstone.—A formation made up of finely broken rock fragments, or sand, and laid down generally as a sea-bottom deposit. Sandstone formations are often shallow sea deposits; sometimes they represent shore formations. There are several sandstone formations in Minnesota, as the St. Peter, St. Croix, Dresbach, Jordan. These were deposited when shallow seas covered this part of the continent.

Sedimentary Rock Formations.—Mud, sand, any form of broken rock worn by erosion from a land surface and borne to the sea and deposited becomes a sedimentary formation. Such formations may be limestone, sandstone, shale, conglomerate, etc., according to the character of the sediments deposited.

Silt.—Rock ground to fine powder by ice in glaciers. It is properly called "rock flour."

Stone.—A piece of rock which has been separated from its parent ledge. It is rock as long as it is in its original position in a formation. When it has been broken and forms a loose fragment then it becomes a "stone." Boulders, pebbles, and sand grains are stones which have been broken from their parent rock ledges.

Strata.—The layers or beds of a formation or deposit.

Stratified.—A term applied to layers of rock or to ice in glaciers. Any formation that is in definite layers or beds. Limestones and other rocks occur in layers. Sands and gravels are often in definite layers Ice in glaciers has been observed in definitely stratified form.

Superior Lobe or Glacier.—The tongue of ice or lobe of the Labradorian glacier that pushed westward through the Lake Superior Basin. It deposited a red drift.

Terrace.—The floodplain of an earlier river. When a river erodes its valley so that at flood it no longer covers its former floodplain then the remnants of the former floodplain remain as benches or terraces.

Tertiary Time.—The period of geologic time that preceded the Glacial Period or Quaternary.

Till.—Sometimes called boulder clay. In the present volume it is applied to drift materials generally which have not been assorted by water. It is generally made up of clay with more or less of boulders and small stone fragments.

Till-plains.—Same as ground moraine. Drift overridden by the ice of the continental ice sheets. Materials carried in the lower portions of the moving ice, or that was deposited from the ice and later overridden by the advancing ice. A terminal moraine overridden and leveled by a re-advance of the ice becomes till-plain or ground moraine. Most of the undulating or gently rolling prairies of Minnesota are till-plain or ground moraine.

Tilth.—A condition or quality of soil favorable to cultivation and the growth of crops.

Weathered Zone.—An old land surface (soil) which had been weathered or oxidized by long exposure and later covered by another deposit or formation.

Wisconsin Stage or Ice Invasion.—The fourth or latest invasion of the continental glaciers. Three glaciers entered Minnesota during the Wisconsin stage, viz.: a Keewatin glacier depositing a gray drift, the Patrician, depositing a pinkish-red drift, and the Labradorian glacier (Superior Lobe), depositing a red drift.

Young Red Drift.—Drift deposited by the Patrician glacier which is pinkish red in color, or the red drift deposited by the Superior Lobe of the Labradorian glacier, both of the Wisconsin ice invasion.

Young Gray Drift.—Drift deposited by the Keewatin glacier during the latest or Wisconsin ice invasion. All the gray drifts contain limestone boulders and fewer granitic boulders. The glaciers came from a limestone country.

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