The STORY of

the PRAIRIES

WILLARD

McBride

THE

Story of the Prairies

OR

THE LANDSCAPE GEOLOGY OF NORTH DAKOTA

BY

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PREFACE.

A book justifies its existence if it supplies a need or assists in any way in solving the problem of life. There is a noticeable lack of books suited to the general reader in the branch of science which deals with the earth upon which we live. Splendid contributions to knowledge have been made in this line in recent years, but many of the best things that have been written are practically inaccessible to the average reader both by reason of the technical character of the language used and by the fact that the material is often contained in large volumes unhandy for general use. That these contributions are of great value to the people is indicated by the large amounts which are annually expended by the National Government and by the State surveys for their compilation and publication.

To present in untechnical language a scientific statement of a subject is not an easy task. Whether the present book accomplishes this or not an intelligent public will soon discover. The author has had in mind, as a class to whom he would make every page readable, those who have reached the degree of maturity represented by the sixth and seventh grades in the public schools. If the book is intelligible to pupils represented by these grades it should be understood by the average citizen who is interested in knowing about his own State. It has seemed impossible to avoid the somewhat technical character of certain portions, owing to the intricate and difficult nature of the subject. It may be asked if these passages might not have been omitted. To do this would have marred the book as a whole, and it seemed best to carry out the original plan, leaving to the discretion of teachers what part should be omitted in class work. Such subjects as the causes of the changes of level of Lake Agassiz, the distribution of the lakes of the State, and the chapter on "The Beginnings of North Dakota," may be omitted where these topics are beyond the mental grasp of the pupils. But to have omitted them from the book would have left unanswered questions which the more advanced pupils in the high schools, and many general readers, will be certain to ask.

It is the author's opinion that not enough attention is given in our schools to instruction relative to the character and resources of our own State. Not enough attention to our own State is given by the teachers in their private studies, and not enough careful reading is done along this line by the average citizen.

In geography instruction in our schools why do we need to go to South America and Asia and the uttermost parts of the earth for illustrations of land forms? Why do we need to study about the river systems, hills, plateaus, lakes, soils, and resources of states which are hundreds of miles away in preference to those of our own State? When the child has gained a general idea of the earth as a whole, and of North America more particularly, why should he be required to go to states and countries which are far away for concrete examples? Have we not rivers, lakes, and marshes, hills, valleys, plateaus, and plains in our own State, which are more accessible and just as real as those of other states? Have we not types of landscapes, developing river systems, desiccating lakes, mineral and forest problems? Indeed, there are no better examples in the world. And the writers of text-books for the use of schools in the Eastern states are now coming to the far West, to the Red River Valley and elsewhere, for examples to illustrate the great principles of geographic science.

The author has sought to reach three classes of readers in this book. The primary purpose has been to adapt the language and treatment to pupils in the higher grades of public schools. This purpose has been constantly kept in mind, for a large number of boys and girls to whom a knowledge of the resources of the State ought to be of the greatest value will never enter the high school. While some portions are rather difficult for pupils of the grammar grades it is thought that the book as a whole will make a profitable half year's work in the high school, satisfying the requirement of the State Course of Study in Geology or Physiography. And it is hoped to reach a large class of readers who have entered the practical school of life, but who would be benefited by a fuller and more accurate knowledge of the character and resources of the State in which they live.

It has been impracticable in a book of this character to give specific reference in the body of the text to the authors consulted, but the author wishes to give fullest credit for the use of this information.

More than all others the author is indebted to the classic work of Prof. Warren Upham, "The Glacial Lake Agassiz," a monograph of the United States Geological Survey. This work leaves little to be added regarding the landscape geology of the Red River Valley and the adjacent portions of the State. He would be a bold student who would attempt to cover the field better than has been done in this comprehensive quarto of more than six hundred pages, but its very elaborateness renders it inconvenient for those to whom its contents should be of the greatest value.

The author of this volume has drawn freely from Professor Upham's treatise, hoping to bring its vast fund of useful information within reach of the busy citizen who would not be likely to read a larger work.

Through the very kind permission of Professor Upham a number of the illustrations in his work have been either redrawn and adapted to the purpose of the present work, or copied by the Bureau of Engraving at Washington.

The author is also indebted to the valuable bulletins by Prof. J. E. Todd, of the University of South Dakota, for much that is here given regarding the Altamont and Gary Moraines and the landscape features connected with these in Logan and McIntosh and adjoining counties, and also for facts regarding Lake Dakota in Dickey County, and for several illustrations..

The valuable "Report of the State Geological Survey of North Dakota," by Prof. E. J. Babcock of the University of North Dakota, Grand Forks, has been drawn upon in the treatment of the coal deposits of the State, and the author wishes to express his appreciation for the kind permission to use several plates from this Report in the present work.

The author acknowledges his personal indebtedness to Prof. Warren Upham, Secretary of the State Historical Society of Minnesota; to Prof. Charles M. Hall, of the Agricultural College of North Dakota; Prof. E. J. Babcock, of the University of North Dakota; and to Miss Lillian V. Lambert, Instructor in English in the East Side High School, Des Moines, Iowa, who read this book in manuscript, and who by their scholarly and valuable criticisms greatly increased its value.

Acknowledgment is made to all those who have so kindly assisted in the preparation of the drawings which illustrate the book. The writer's thanks are particularly due to Miss M. Emma Davis and to Prof. Thomas H. Grosvenor, members of the faculty of the Mayville State Normal School. Many illustrations which needed to be drawn under the author's direction were made possible by their assistance. Pres. Joseph Carhart, under whose supervision the author has for several years had the pleasure of teaching, has given practical suggestions which have been of great value in the preparation of this volume.

If this book serves the purpose of making the people of North Dakota better acquainted with their State, and thereby enlarges their appreciation of the opportunities which belong to them as citizens of this growing commonwealth, the author will feel that he is amply repaid for the labor which has been expended upon it.

D. E. W.

Mayville, North Dakota, State Normal School.
May 1, 1902.

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THE LANDSCAPE.

INTRODUCTION.

How many of the readers of this book understand what is meant by the words Landscape Geology? Every one has seen a landscape, but we often hear people speak about Geology as though that meant rocks and stones and minerals and was therefore 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 are sometimes "hard and dry" also. It may not always be the fault of the subject that it is uninteresting. The trouble may be in the way it is studied.

When the author was a boy and sat upon a hard, old-fashioned wooden bench in a little country schoolhouse between the hills, in the state of New York, he used to think the reading lessons were pretty "hard and dry." Since he has become older, however, he has come to think that the fault was not in the subject, for he now finds these same speeches of Webster and Clay and Washington, and selections from Irving and Lowell and Emerson, very interesting. The trouble seems to have been in the way he studied them. He did not see the beauty in them. He saw big words hard to pronounce and harder to spell, and punctuation marks, at which he must stop, put in between the words! When he read it was to pronounce the words and mind the pauses!

The trouble was not with the lessons, for they were beautiful and grand. The trouble was not entirely with the boy, for he tried *to do* what he was *told to do*. Perhaps the fault was not altogether that of the teacher, for she did not know any better!

If after the reader has studied this book he finds Geology "hard and dry" the trouble will certainly 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 than mere rocks and stones, sand and water, then it is his fault and not that of the subject.

In geography we sometimes think of the things we are studying about as far away, in some other state, or in some other country, the features of some landscape somewhere, but we, may be, do not realize that it means our State, our neighborhood, our school grounds, our door-yard.

One who knows Botany sees a good deal more in the fields than grass and grain, weeds, trees and bushes. The psychologist says he "apperceives" more. We do not wish to talk about apperception now, at least we do not wish to call it by that name, but we wish to talk about some things which, may be, we have not seen in the fields round about us, in our own State, our own neighborhood, and so perhaps come to see the great beautiful world in a larger and fuller sense, and may be to a larger realization of what is ours to enjoy.

Just as the botanist sees more than grass and weeds and trees in the fields, so may we all see more than soil in the ploughed fields, more than a hindrance to farming in the stones in the fields, more than poor land in the hilly farm, more than a misfortune in the rugged coulee which cuts into the level prairie wheatfield, more than a hay-meadow in the level marsh, more than wheat in the waving billowy sea of grain, more than a useless waste in the boggy slough, more than a worthless waste in the sandy tract of dunes upon which barely a vestige of anything green exists. There is a grand and beautiful meaning in all the varied landscape of our State if we can but read Nature's story book. In these pages the author has tried to make readable a few of the paragraphs of this great book, paragraphs which are not too commonly read and not too fully enjoyed by the average of human kind.

Have you ever wondered why the prairies are prairie and the hills are hilly? Or have you, may be, thought about it and said to yourself that you supposed God made the prairies and hills because He saw fit to do so, and made some parts of the world hilly and some parts level because in His great wisdom it pleased Him to so arrange things? This may enable you to satisfy your wondering curiosity, but a little thinking will enable you to see that, while God in very truth made the hills and the prairies and made some parts of the world different from other parts, nevertheless this does not answer the question why things are as they are; for this great universe which an All-wise Creator made and which He rules is governed by laws in accordance with which the prairies and the hills have been formed, the water and the dry lands have assumed their places, the rivers and the lakes have established themselves, and the face of all the landscape has been fashioned.

Hills and Valleys.—Every one who reads these pages has seen a valley, and also what might 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 in those parts of our State, or some other state, 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. All 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

How the Farm is Lost.

How the Farm is Regained.

How the Farm is Retained.

FIG. 2. Showing the Erosion of Young Valleys on a Hilly Landscape.
Photographed from a Chart, by Prof. E. S. Keene.

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 aeons 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. Children have been taught sometimes (let us hope not in the schools of our own State) that rivers were established in their courses by a gathering of waters in the interior of the continent and that this water flowed across the land wherever it could go most easily, and in so doing cut a channel and became established in a definite course. Now, 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?

If we indicate a series of small areas extending from the sea-shore 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

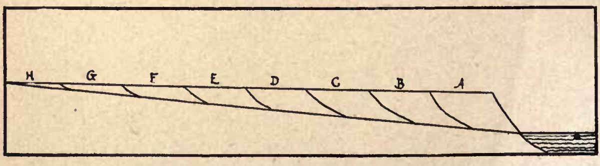


FIG. 3. Diagram showing how a Valley begins at its own Mouth.

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 of North Dakota 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

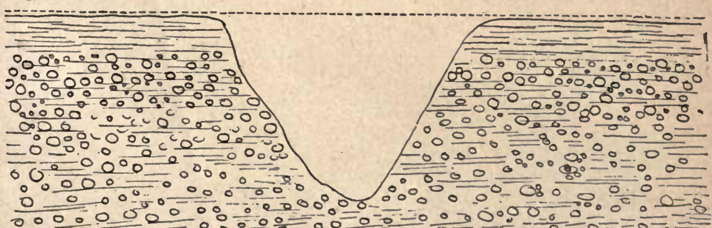


FIG. 4. Cross Section of a Young Valley.

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

FIG. 5. A Cutting Coulee, or Young Valley. *Photograph by Prof. Chas. M. Hall.*

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. In fact it grows longer in just the same way as it got started in the first place, by water falling from a higher to a lower level and carrying the soil along with it.

CHAPTER THE SECOND.

EXCURSIONS AFIELD.

A Few Comparisons.—North Dakota is one of the "prairie states." Yet those who have seen the various parts of the State often speak of the "hills" in any place as though North Dakota could be said to have real hills! Compared with Pennsylvania or New York or Vermont the "hills" of North Dakota are hardly more than knolls. When eastern people think of a North Dakota landscape they often think of broad-reaching prairies limited to the view only by the distance the eye can reach. North Dakotans will make no serious objection to such opinions being held, especially when the rugged hilly character of many eastern landscapes is considered. And even if it be contended that in the east they can almost "work the land on both sides" because the surface appears to be turned up on edge, yet we are satisfied to answer

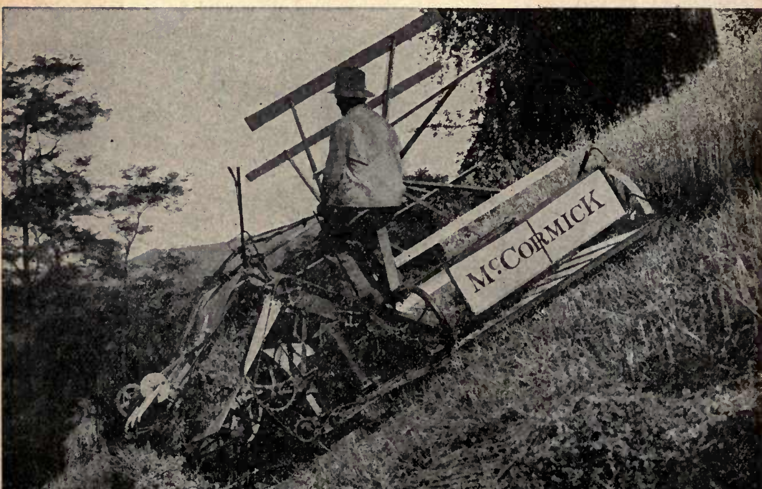


FIG. 6. In the East they work the land on both sides!
Photograph by McCormick Harvesting Machine Co.

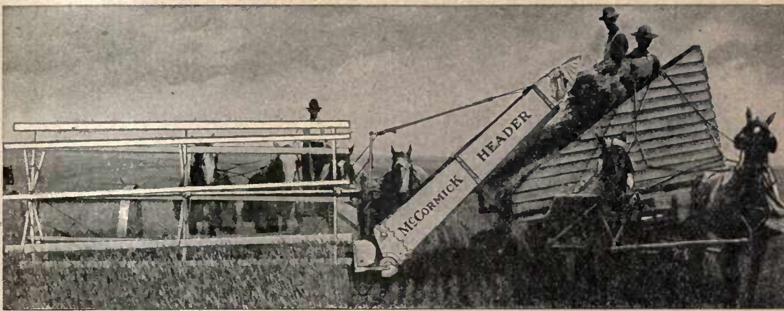


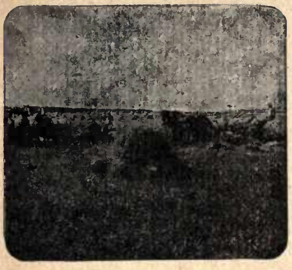
FIG. 7. In North Dakota enough can be raised on one side!
Photograph by McCormick Harvesting Machine Co.

that we can raise more on the one side of our prairies than can be raised in the states named on two sides.

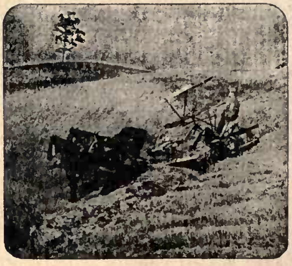
But those who know the geography of North Dakota know that the whole story has not been told when it is said that ours is a prairie state. There are prairies and prairies! Level prairies and rolling prairies. And sometimes the "rolling" is so marked that we may venture to speak of it as "hilly."

Compare the floor-like level about Fargo or Grand Forks, Casselton or Grafton, or any part of the Red River Valley; the rolling-prairie country about Langdon or Devils Lake, Oakes or Ellendale; the rugged and unploughed hills between Hope and Valley City, or the picturesque "curves" of the landscape along the Sheyenne River in Foster county; the billowy ups and downs on the Coteaus of the Missouri west of Minot; the steep and bouldery landscape south of Dog Den Butte in McLean County; the broken-prairie country about Dickinson known as the "breaks;" the ragged and rock-ribbed hills, known as "buttes," in the valley of the Little Missouri. We shall see that while North Dakota is a prairie state yet she has much diversity of surface.

Again, in some places the fields are very stony, in others hardly a stone can be found over great areas. And not only this but the stones are mostly rounded and smooth, while in some places they are nearly all angular and rough. Some of the lands are called "light," having a dry sandy soil with no stones larger than sand grains, and some are "heavy," with a clayey soil, often with large stones imbedded in the clay or on the surface. And still again, some of the fields are black, with a deep loamy soil. And these differences often occur within short distances. One who has ridden over the Great Northern Railway westward from Larimore may have observed that there is an abrupt change from the level prairie east of Larimore to the "hilly" prairie to the west. The same kind of a change, though not nearly as great, occurs four miles west of Wheatland on the Northern Pacific



LEVEL.



ROLLING.

BROKEN.

FIG. 8. Three Types of Landscape.

line, where that road rises off from the level Red River Valley onto the highland to the west.

East of the city of Devils Lake the prairie swells and rolls in graceful undulations. Go across the lake and the landscape becomes very hilly, and often the hillsides are strewn with large boulders. From Towner to Minot the country is gently uneven prairie. West of Minot there is a sudden change to a high plateau with an uneven and hilly surface. Along the Goose River east of Mayville the fields are almost as level as the floor of the school-house, and the soil is black and when wet exceedingly sticky. Travel west toward Sherbrooke and it will be observed that the soil becomes sandy, and well defined sand-ridges run north and south. About Sherbrooke the hills are sharply rolling and the soil is less black.

In many parts of the State fields free from stones and those which are very stony are intermingled. And it is noticeable that the stones are nearly all rounded and smoothed. Cross the Missouri River however in the western part of the State and the hills are seen to be different in shape. Here they are flat on top with trough-like valleys between them very different from the rounded hollows among the hills on the rolling prairies, and the "cobble-stones" or boulders, which are so common over much of the State, soon disappear entirely west of the Missouri River.

North Dakota has level and rolling prairies, hills and hollows, lakes and marshes, fields very stony and those free from stones, fertile farming lands the best and richest in the world, other lands more valuable for grazing than for farming, and the most wonderful "Bad Lands," all resulting from geologic agencies. They are not so by accident or chance. They are geologic facts. Their explanation belongs to the science of Landscape Geology.

An Excursion Among the Boulders.—Everyone has noticed boulders scattered here and there 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 rocks so finely ground or pulverized as to make the separate particles not able to be seen without 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 confusion. 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 North Dakota, and in most of the northwestern states. These can be known, however, 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.

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 rocks, these huge boulders and the great quantities of sand, were not "made" in North Dakota, that is, that they did not in the first place belong here, but have been brought here by some means from somewhere else. These rocks are not like any of the rocks in the quarries of the State, and then too these boulders, pebbles and gravel, and even the sand grains are all rounded more or less, while the rocks from our quarries or from ledges along the streams where the bed-rock comes to the surface, are all 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 North Dakota, all of that part in fact which lies east of the Missouri River. A part of this story will be told in the next few chapters.

An Excursion to Some Quarrics.—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 North Dakota is in a large measure true of other states, and other countries. Since we cannot all visit all parts of our own 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 full of stones from the fields and roadsides. Let them be collected from all parts of 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 which we have made 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 stone? 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 may be 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.

Stone quarries are very scarce in North Dakota, for reasons which we shall see a little later. Let us look again to our sister state of Minnesota. At Kasota, near Mankato, are large quarries where the splendid reddish-brown sandstone is obtained which is used for trimming the best brick buildings in many towns and cities. The bed-rock at Kasota is of this one kind of sandstone. But around about on the surface, in the fields and by the roadsides, are boulders such as these we have gathered from the fields and roadsides of our own State. So also about Sioux Falls, are boulders in the fields and along the roadsides, but in the quarries there is only the one kind of rock, quartzite.

Now if we could dig down deep enough in our own State 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. The sandstone would be different from that at Kasota, however. If we should go north into Canada, away to Hudson's 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. 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 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. These have been ground into earth and clay. Nearly all the sand patches or sandpits, like the sands of the sea-shore, are whitish, and this is because it is largely grains of hard whitish quartz.

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 of North Dakota except that part of the State which lies west of the Missouri River is covered with a great sheet or mantle of "drift." In some parts of the State this covering of drift is very deep, being more than 300 feet in some places in the eastern part of the State. It becomes thinner toward the west till along the Missouri River it is only a few feet thick and further west disappears entirely.

The black soil of our fields does not extend down very far, as you have likely noticed. But if you have watched the digging of a deep well or a place where any deep excavation was being made, you have seen that clay and boulders occur down to a much greater depth, and probably no shelf or layer of rock was struck such as you saw in the quarries.

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 "Drift Period," or Glacial Period. It was the last great geologic period before that in which man lives, the period of written history.

We shall, in the next few pages, try to see how the boulders, pebbles, sand, and clay were carried and how they come to be left as they are.

CHAPTER THE THIRD.

THE WORK OF ICE.

The Great Ice Sheet.—All of North Dakota east of the Missouri River is embraced in that part of North America which was covered by the ice during the Glacial Period. We have wondered how the boulders and rounded pebbles came to be here, scattered all about as they are, when they are so different from the bed-rocks and also so different from each other. Geologists agree that ice was the agent which transported these rocks here; that it was by the action of the ice that the rock fragments were first broken from their parent ledges and carried, smoothed, broken, and ground to powder; that the way the boulders, gravel and sand are distributed is due to the ice melting and leaving the rocks which it carried; and the peculiar hills and rolling prairies which mark the landscape have been formed by the dumping of these transported materials from the great ice-plow.

All the northern portion of North America was covered by this great flood of ice. In all the northern states from North Dakota to Maine and the Atlantic Coast about New York City occur boulders, sand and clay, and peculiar rounded hills such as are seen between Larimore and Devils Lake, along the line of the Great Northern Railway, about Cooperstown in Griggs County, west of Hope in Steele County, at intervals along the line of the Northern Pacific Railway from east of Valley City to Bismarck, east of Lisbon in Ransom County, about Oakes in Dickey County, and, in fact, here and there throughout the whole State west of the eastern tier of counties and east of the Missouri River, occur irregular generally rounded hills, and valleys without outlets. These are hills which mark positions where the edge of the great ice-sheet stood for a time, and, melting, left the materials of which these hills are composed. Wherever such hills are seen the country has been "glaciated."

The ice-sheet was a good deal deeper or thicker in some places than in others. We shall get the right idea if we think of the great flood of ice slowly flowing or shoving its way across the country, covering the

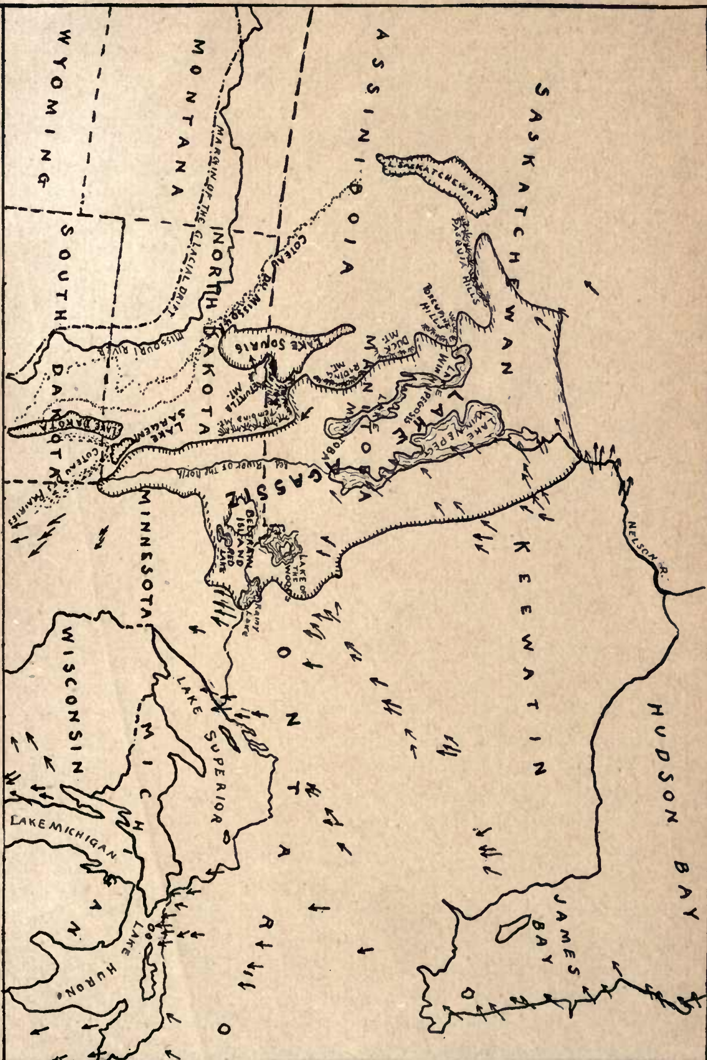


FIG. 9. Map showing Position of Extinct Glacial Lakes and Direction of Ice Movement. *After Upham.*

hills and filling the valleys, planing off the hill-tops and filling the valleys with the materials of the hills. It may seem a little strange to think of ice flowing over the land, but there are a great many strange things in the world and we should not refuse to study them because they are strange. In another chapter we shall try to see some of the reasons which have led geologists to think that it was a great ice-flood, a vast sheet of snow-ice slowly creeping or flowing from the northeast toward the southwest which has caused all these strange things. We must try to be fair and honest in a study of this kind and not refuse to think about things because we cannot at first understand them, or cannot see how such things can be.

No one claims that we know these to be the facts absolutely. No man was on the earth at this time to write a history of what occurred; or if there were any men then at least they did not write any history which we know about. All that we can tell about what occurred is by studying the records left in the rocks and clays and gravels, and the peculiar hills and valleys. The collection of boulders, pebbles and sand, the clay dug up from below the fertile soil, the hills and hollows themselves which we walked over and through, and the rocks we studied in the field, all enter into the great subject of the history of this period of the earth's changes.

Without trying at this time to explain the causes of the extreme cold which made such a gathering of snow and ice possible, let us see what the physicist says, the man who has studied the action of ice and snow and water, and other substances under various conditions, about the behavior of ice in very large masses. Then we may afterwards seek what reasons or evidences there are for thinking that ice was the agent which did all this work; or that what has been called an "ice-invasion" has really at some time occurred.

Behavior of Ice Under Pressure.—We are accustomed to think of ice as a brittle substance; and we know that when struck a sharp blow with a hard instrument it will break into pieces. But it can be shown in a laboratory where all things needed are at hand, or in great glaciers where the mass of ice is very great, that when ice is placed under great pressure and 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 it is given time, bulging out on all sides from the pressure of its own weight.

To get some idea of the way the ice will act let us use some figures.

A cubic foot of ice weighs about 62.25 pounds. If we imagine two blocks of this size placed one upon the other, the bottom one will hold up a weight of 62.25 pounds. If ten blocks are piled up on top of the first one then the bottom one will be holding up 622.5 pounds. If we imagine the blocks to be piled up as high as the highest grain elevator, say 100 feet high, then the pressure upon the bottom due to the weight of the ice blocks would be 6,225 pounds, or more than three tons. Imagine the whole weight of a load of a hundred bushels of wheat to rest upon one such block of ice. It would be crushed, would it not? Now, suppose that the whole landscape round about were covered with ice to a thickness of 100 feet. Each square foot of land might be thought of as having a pile of one hundred foot-cubes of ice resting upon it. Each bottom cube would be prevented from crushing the way the load of wheat was imagined to crush a single block because there would be more blocks all around it and each one trying just as hard to crush. The lower layer of ice would therefore be under a great stress.

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 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 those mountains which were so covered 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 their very summits. The ice must therefore have been more than a mile deep in those regions. Many careful observations have led to the conclusion that the ice was in some places two or more miles deep. What, then, must have been the pressure upon the bottom layers due to the weight of the ice? One mile is 5,280 feet. The pressure upon the bottom of each square foot, therefore, must be 5,280 times 62.25 pounds, or 328,680 pounds, or nearly 165 tons. Since the ice cannot crush, being hemmed in on all sides by more ice under just the same pressure, the stress upon the bottom layers will be very great. Under these conditions of great pressure ice behaves like a thick, viscous substance, such as 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 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

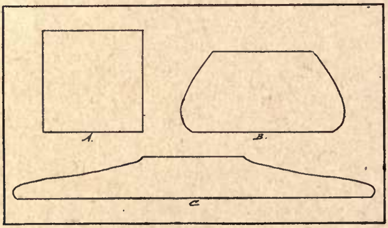


FIG. 10.

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 has 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 forming clay, and the small fragments in the form of gravel and sand, together with the large boulders, were left where the melting ice dropped them.

Alpine Glaciers.—Ice can be seen flowing down mountain sides at the present time in many countries, in Switzerland, Norway, Greenland, Alaska and the Rocky Mountains in our own country. Ice-streams flowing down the slopes of mountains are called Alpine Glaciers, from the Alps Mountains in Switzerland, where there are splendid examples of glaciers in action, and because it was there that the flow of ice in glaciers was first studied.

If you have been on the top of Pike's Peak, or through the Yellowstone National Park, in the hottest months of summer you have seen great patches of snow here and there among the crags and pinnacles, above what is known as the "snow-line." Where there are high mountains with their crests reaching far 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 high among the clouds and craggy peaks.

When, on the mountain tops, enough snow gathers so that its weight becomes very great the lower layers become more like ice than snow because of the pressure from the mass overlying. And if the amount of snow becomes very great it will by and by begin to move slowly down the mountain.

The snow does not need to gather upon a mountain slope in order to flow. We saw that stiff, hard pitch flowed across a level surface by reason of its own weight. The place of starting of glaciers is often high on mountain tops where it is too cold even in mid-summer for all the snow to melt. But a glacier may be formed upon a level surface, the conditions which cause a glacier being that more snow shall fall during the winter than melts during the summer.

When either high upon mountain tops or on a plain, therefore, more snow falls than melts, so that it gathers deeper and deeper and piles up higher and higher; after a while the snow which is near the bottom becomes pressed so hard by the weight of that which lies above it that it changes its form from flaky snow into a sort of snow-ice known as *neve,* and when the pressure has become great enough it will begin to flow out at the sides or edges of the snow-field and push down the mountain side, or out over the plain.

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, 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."

Those rounded hills and long, irregular ridges which we have no-

FIG. 11. View Along the Top of a Terminal Moraine. Western Walsh County.
Photograph by Ray Abel.

ticed west of Larimore and Hope, about Cooperstown, Valley City and Oakes, are morainic hills, and the whole group of hills to which they belong, in each locality, is a Moraine. They were left where they are by the melting of the ice of the great continental ice-sheet, just as the smaller heaps and irregular piles of broken stone and earth, left by the melting of the glaciers on the mountain sides of Switzerland, or on the west coast of Greenland, are Moraines.

There are several kinds of Moraines, or, rather, several forms in which "heaps of stones" or earth are deposited by the melting ice. At the lower edge of the ice, where the melting back is just about equal to the pushing down, so that the glacier end seems to stand still, will be a great gathering place of broken stones, earth and soil which were carried down by the ice. These will be dumped in heaps and irregular ridges. Small fragments of rock, sand, clay and soil from the land-surface will all be piled together in great confusion. Hollows will be between these knolls and ridges, small and large, round and irregular, deep and shallow, and some of them will be filled with water from the melting ice.

This whole affair—the heaps and piles of earth and broken rock, 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 rock 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. These are sometimes upon the ice and being carried along with it, and sometimes they occur as ridges skirting the edge of the ice 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. If the glacier melts away entirely these long side-ridges are left upon the sides of the valley down which the glacier moved. They are side moraines, therefore, in just the same way that terminal moraines are end moraines.

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 will meet, like the two parts of a letter V, and below the point of meeting the two ridges will become one, and this will continue 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.

Sometimes a glacier moves farther down a mountain valley than at other times. We have seen how a terminal moraine is formed at the end of a glacier. If now the ice should melt back for some time faster than it moved down the slope then the belt of terminal moraine ridges, heaps and hollows, and maybe lakes, would be left below the glacier. If then the glacier should advance, or move down more rapidly than it melted at its lower end, the ridges, heaps and hollows would be ridden over and shoved farther down the slope. Along the bottom of the glacier, on the ground which the ice-stream 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, would be shoved along and ground under or near the bottom of the ice. This material, together with that of the terminal moraine which is pushed along and over by the advancing ice will be 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 will be left as a Ground Moraine.

There are thus seen to be four kinds or forms of moraines, Terminal, Lateral, Medial and Ground. These are not always sharply separated from each other. It is not easy sometimes to see just where one begins and another ends. All these forms of deposits from glaciers are of interest to us because they all occur on a very large and grand scale, making conspicuous landscape features in North Dakota, and all the Northern States and Canada. Various forms and modifications of these make up many, indeed, most of the hills and swells of the prairies of our State.

CHAPTER THE FOURTH.

AN EXCURSION TO SOME GLACIERS.

Illustrations from Norway.—Norway furnishes many good examples of alpine glaciers, and much may be learned about the hills and prairies of our own State by studying the behavior of glaciers as they exist to-day. We cannot all go to Norway, or to Switzerland, or even to the snow-capped mountains in our own country where glaciers flow down their sides. Since it is not possible for us to see the actual glaciers, let us see how much we can learn from pictures.

In Figure 12 the barren and lofty peaks of the Jötenheimen Mountains in Norway are shown. Here is the gathering-ground of the snow which descends the mountain sides as glaciers. This is said to be the wildest and most bleak and dreary tract in all Norway. Here the mountain tops are rock, naked of any vegetation, and covered in some places the whole year with ice and snow. Standing on the high, cold, bleak landscape, nothing but crags, snow, ice and lakes formed from melting snow can be seen for long distances. The water from the

FIG. 12. The Snow-field on the Mountain Top.
Photograph by A. Thorson.

melting of the snows of this region in part goes to the Atlantic Ocean on the west coast of Norway, and in part south by the River Glommen past Christiania to the Skager Rack. The distance shown in the picture, from the foreground to the high crags in the background, is about ten miles. The highest of the crags in this group are the loftiest peaks in Norway. A glacier flows down the mountain side to the right from the snow-field shown in the foreground. Another large glacier de-

FIG. 13. A Glacier and Terminal Moraines. *Photograph by A. Thorson.*

scends to the left from the snow-field among the crags in the background. The waters from the melting of this glacier are the headwaters of the largest river in Norway, the River Glommen.

Figure 13 shows an ice-stream or glacier as it moves slowly down the side of the mountain. 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 or 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.

Then comes a broad, low moraine with gravel and coarse pieces of rock, the large fragments of rock showing dark in the picture. Two or three huge masses stand above the general surface—immense blocks broken from the mountain side, shoved down with the ice and dropped here where the ice melted. The light belt behind these is the crooked stream of ice-water which flows from under the glacier.

Next are two large, ragged, dark-appearing ridges which are covered with scattering, scrubby trees. The stream from under the ice comes from the right in the picture from between these two ridges and turns sharply back toward the right.

Farthest over and near the ice-front is another ridge. Still another which cannot be seen lies back of this, between it and the ice-wall. All these ridges, all the sand, gravel and boulders, make up the terminal moraine. Sometimes a single ridge is spoken of as a moraine, but the term is correctly applied to all the ridges and piles which together make up the dumping-ground of a glacier at any period of its existence.

FIG. 14. An Ice Cave. *Photograph by A. Thorson.*

If the glacier has at some time extended considerably farther down the mountain side and left a moraine there, and this older moraine is separated from the later or the one forming now by a tract which is comparatively free from boulders and piles of gravel and earth, then these are often spoken of as the older and the younger moraines. They represent stages of advance and retreat of the glacier.

FIG. 15. An Ice Cascade. *Photograph by A. Thorson.*

Back of the dark-appearing terminal moraine ridge in the left of the picture is a lateral moraine, marked v v. 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 thirty 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.

Figure 14 shows a near view of a small part of the same ice-front which was seen from a distance in Figure 13. A great cave is hollowed out in the ice-wall, out of which flows the sub-glacial or under-the-ice stream shown in Figure 13. The ice is clean, blue and hard. Huge blocks have fallen from the melting and undermining at the bottom. The man is standing on the ridge of stones and broken ice which was spoken of before as lying close to the ice, and not able to be seen in Figure 13.

In Figure 15 more than half of the picture, embracing the foreground from the upper left corner to the upper side of the black belt near the lower right corner, is a part of the lateral moraine of the glacier. The crest of the moraine is the dark part running diagonally across the middle of the picture. The rugged surface of the glacier is back of the dark crest of the moraine, behind the two men. It moves from near the upper left corner toward the centre of the right side of the picture. The snow in which the men are standing has fallen upon the moraine and is not part of the glacier. The big, dark boulders or blocks of rock in the snow are part of the lateral moraine.

In Figure 16 a nearer view of the front of the glacier is shown than in Figure 13. The morainic ridge which lies close against the ice is cut

FIG. 16. Terminal Moraine, Front of Glacier, and Glacier in Distance.
Photograph by A Thorson.

through by the sub-glacial stream which comes from under the ice where the black place is seen at the bottom of the ice, near the centre of the picture in the foreground. At the time this picture was taken the ridge was being pressed upon by the ice and apparently shoved down by it.

Near the centre of the picture is 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 centre of the picture. This is what is called an ice cascade or cataract, corresponding to what in rivers of water instead of ice is a water-fall. 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. There is a roaring and booming as of a mighty cannonading as the great, slowly-creeping mass of ice comes to this jumping-off place, breaks up into huge masses by its own weight, and goes crashing down this great "toboggan." 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 centre of the picture.

The sub-glacial stream which has been noticed before coming out from under the ice, descends into the ice at the foot of the cataract where some of the ice is melted by the friction from the fall, and flows under the glacier till it emerges at the end or foot of the glacier.

Below, toward the foreground of the picture, the ice-powder has become solid ice again, and at the ice-front or end of the glacier it is seen to be hard, blue, stratified ice.

The ice in the background of Figure 16 is the same as that in Figure 15, and the lateral moraine in Figure 15 is behind the dark mountain in the background at the left in Figure 16.

Figure 17 is taken a little to the right of Figure 16. The man is standing in the edge of the river which flows away from the glacier. The morainic ridge is about eight feet high, and is being pushed by the ice from behind. It is composed of small broken stones and coarse gravel. The pieces of rock are mostly angular, not having been carried in the ice far enough to become much rounded.

Figure 18 shows a part of the ice-front taken a little to the left of Figure 17. The stratified structure of the ice is here well shown. The morainic ridge near the ice is about twenty feet high. The two black places at the bottom of the ice show where water emerges from under the glacier to form the river of ice-water noticed in Figure 13. The morainic

FIG. 17. Terminal Moraine and Ice Front Crowding Upon It.
Photograph by A. Thorson.

FIG. 18. Terminal Moraine Being Washed Away by Glacial Stream.
Photograph by A. Thorson.

ridge has been mostly washed away by the stream, in this picture. A hill, or pile of boulders and broken bits of rock, lies between the two places where the water emerges. Morainic boulders, angular fragments and gravel are strewn about in the foreground.

In Figure 19 is shown a large boulder-strewn moraine formed by a glacier which once occupied a valley at the left of the picture, that is, the glacier had its end or terminus at the moraine shown in the picture, the ice moving down the valley from the left toward the right. The moraine extends from the foot of the mountain at the extreme left across the valley toward the right. The glacier has melted back or retreated so that the moraine is left as a mark of its former greatness. The snow-field from which the glacier comes is among the crags shown in the background of Figure 12.

The houses which stand on the moraine are what are called "Sethers"—summer dwellings used while grazing herds in these mountain regions during the warmer months of the year. The house at the left is used as a tourists' hotel.

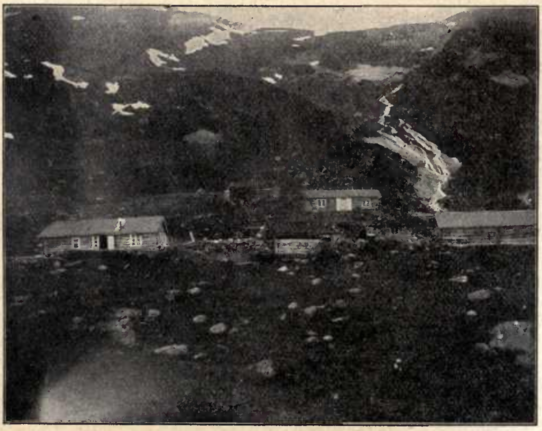


FIG. 19. An Old Moraine. *Photograph by A. Thorson.*

CHAPTER THE FIFTH.

THE GREAT ICE-SHEET IN NORTH DAKOTA.

The Dakota Glacier and Its Moraines.—The landscape of North Dakota is marked by many hills similar to those made by the alpine glaciers of Norway, only our hills are grown over with grass like the old moraine in Figure 19. Just as the hills we saw bordering the ice were made of materials brought down by the ice and left where it melted, so our hills are morainic hills deposited by the ice of a greater glacier.

This great glacier was a lobe of the Great North American Ice-Sheet. There were several large lobes along the southern edge of the Continental Ice-Sheet, but the lobe which covered our State, which is known as the Dakota Glacier, interests us most. A similar lobe pushed its way across Minnesota and as far south as central Iowa. This is known as the Minnesota Glacier.

The position of these two lobes or glaciers and their relation to each other and to the Great Ice-Sheet from which they pushed out, and of which they were a part, is shown in Figure 20. The moraine forming at the edge is that of the Ninth or Leaf Hills stage. The position of this moraine and the others in the State are shown on the Map, Figure 1.

The moraines in North Dakota which are most important are the terminal moraines. They extend across the State in a generally north-northwest and south-southeast direction. Sometimes a moraine is a ridge or single range of hills and sometimes it is a belt of hills, hollows and ridges from one to several miles wide. The hills of a moraine may be high, sometimes becoming 150 to 200 feet above the hollows at their bases, and they are sometimes merely low swells on the prairie.

Lakes are a feature of a morainic landscape. A dozen, a score, half a hundred, may occur in a single township. Plymouth Township in Massachusetts is said to have 360 lakes. Such lakes fill the hollows which are deep enough to receive more water than can evaporate.

The region which lies between two moraines is most commonly ground-moraine, that is, boulders, gravel, sand and clay, which were shoved and pushed along the bottom of the glacier and run over and ground up. But often a terminal moraine blends with the ground-moraine so that it is difficult to say where one begins and the other ends.

Generally the land between moraines, or between the belts and ridges of the same moraine, is good farming land, and is what is com-

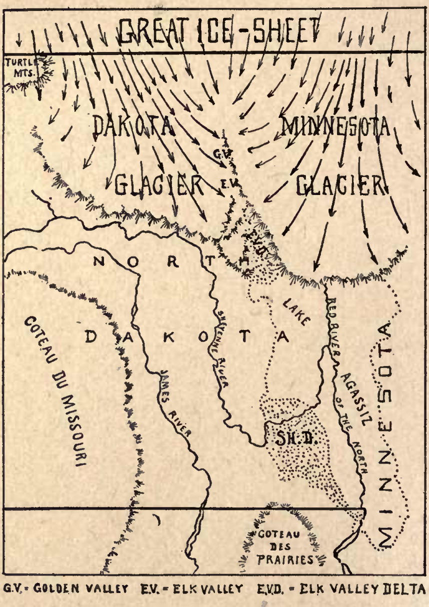


FIG. 20. Dakota and Minnesota Glaciers. *From a Drawing by Prof. Thomas H. Grosvenor.*

monly called the "rolling prairie." Shallow lakes often occur on these rolling lands, caused, like the lakes among the hills and ridges of a moraine, by more water collecting in the low clay-bottomed places than can evaporate. Many "alkali lakes" are such "pans" from which during dry seasons the water evaporates leaving the white alkaline minerals which were dissolved from the soil, forming a white crust over the bottom.

Lateral and medial moraines do not so much concern us in North Dakota, because they cannot generally be distinguished from terminal moraines. The series of long hills known as "The Ridge" and "The Mountains," which lies between Larimore and Edinburg, shown in Figure 20, is a medial moraine formed between two great lobes or glaciers of the ice-sheet.

Do not forget that each moraine or belt of hills means that here was the edge of the glacier at one time; that these hills, all the gravel and boulders, all the clay and sand, of which they are composed, were deposited from the melting of the ice at or near the glacier's edge. It should also be borne in mind that the melting of a great mass of ice means that a large amount of water must find escape somewhere. These ice-waters formed large rivers which flowed away, making great channels with their mighty currents, and carrying down their courses gravel, sand and fine silt. Many lakes also were formed along the edge of the glacier from waters pouring off from the ice and from underneath it.

The marks of these glacial rivers and lakes are now plainly seen upon our prairie landscapes. Broad valleys with steep and high banks are seen in many parts of our State, and these often have only a tiny, meandering brooklet threading its way over the broad, level bottom. And sometimes there is no stream at all in such a valley.

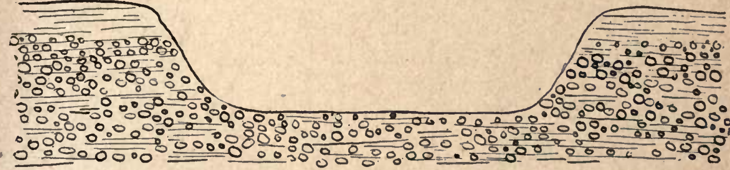


FIG. 21. Cross Section of the Valley of a Glacial Stream.

The great Sheyenne Valley is one of the most notable examples of this kind, and one of the grandest in all the Northern States. It requires no great effort of the imagination to see that the present small and slow-flowing Sheyenne River did not make the great valley in the bottom of which the river now flows.

Many broad, fertile prairies, a little lower than the surrounding rolling prairie, and having hills alongside and not very far distant, may be the place where has been a sheet of ice-water from the melting glacier

—a temporary glacial lake. The richness of the soil on such prairies is often due to the fact that waters flowing into the lake carried fine silt or rock-flour and deposited it over the bottom of the lake. This temporary lake disappeared after its supply of water from the melting ice ceased. Sometimes, however, a pond or marsh remains as a vestige of the larger lake.

The Dakota Glacier flowed south and a little east from the direction of Lake Manitoba and the region west of Lake Winnipeg, and at the time of its greatest extent reached across North and South Dakota. The Dakota Lobe and a part of the Minnesota Lobe at a later stage, when the ice had melted back a long way, is shown in Figure 20. When it stood at the position shown in Figure 22 the outermost moraine, called the First or Altamont Moraine, was formed, along the edge of the ice. On the west side of the lobe was formed the irregular system of hills shown in Figure 1 crossing the State through McIntosh, Logan, Emmons, Kidder, Burleigh, McLean, Ward and Williams Counties.

Across the State from Ashley in McIntosh County (see Map, Figure 1), northeast to Park River in Walsh County, a line would cross the ten great Terminal Moraines formed by the Dakota Lobe or Glacier of the Great Ice-Sheet in North Dakota. These moraines have been named in their order from the one first formed at the outer edge of the glacier to the one far to the north in Canada. They are numbered as well as given geographic names.

The outer or First is the Altamont Moraine, the name meaning high hills; the Second or Gary Moraine, the Third or Antelope, the Fourth or Kiester, the Fifth or Elysian, the Sixth or Waconia, the Seventh or Dovre, the Eighth or Fergus Falls, the Ninth or Leaf Hills and the Tenth or Itasca. The Itasca Moraine was formed after the ice had retreated to the next stage after that represented in Figure 20. The reader need not try to remember these names. They are given here for reference, for convenience later. The names are geographic names from places where the moraines are well developed, as for example the Fergus Falls Moraine is named from the fact that the city of Fergus Falls, Minnesota, stands upon this moraine, where the hills are very conspicuous. The names have no more meaning than the names of persons.

Lakes and streams of ice-water skirt the edge of the glacier. Great streams also poured off from the surface of the ice and spread out upon the ground adjoining. Much gravel, sand and finer rock-powder were

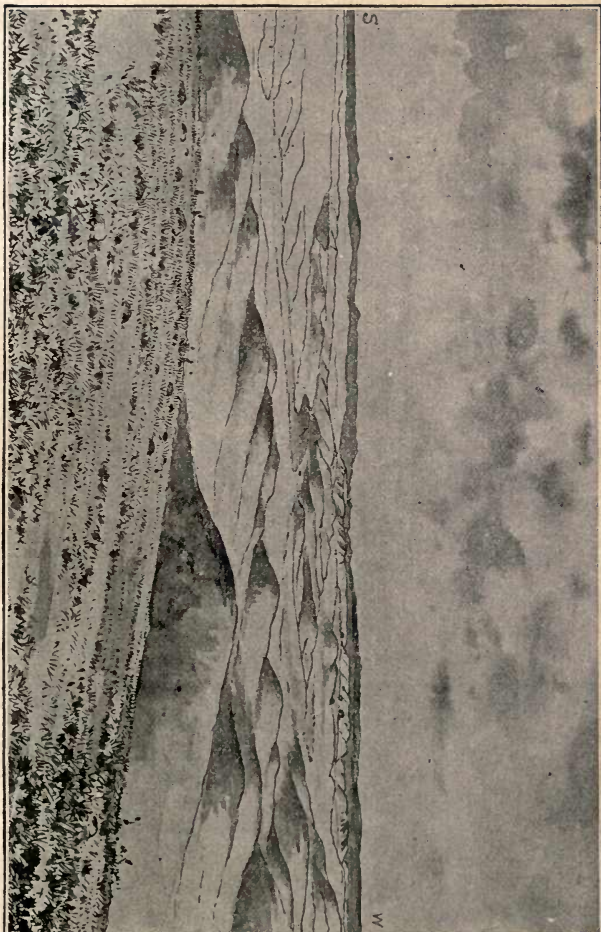


FIG. 22. Beaver Lake and Glacial Channels. Southwest Logan County. The Drainage Channels from North and South, just outside the Outer Moraine, meet here and break through the Highlands west, forming Beaver Creek.
U. S. Geological Survey.

washed by such streams from the ice-front and spread as "over-wash plains" upon the land. The streams cut wide and deep channels, for the waters were kept at flood by the continued melting of the ice. When the ice had melted of course the streams ceased to be, but their channels were left and they mark the landscape to-day in many parts of the State.

South of Devils Lake are some of the largest hills in the State. There was probably a large range of hills there before the ice-sheet

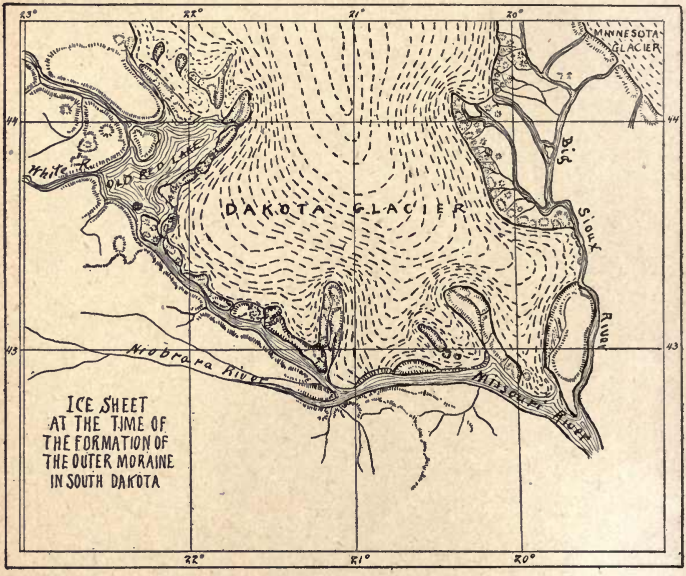


FIG. 23. *After Todd.*

covered the country. When the Dakota Glacier extended across North and South Dakota these hills were buried in the ice.

At the time of the formation of the Leaf Hills Moraine, or when the Dakota Glacier reached as far south as is shown in Figure 20, the ice edge stood upon the hills south of Devils Lake, not being deep enough to flow over them. East of these hills it pushed farther south. The ice of the Dakota Glacier moved from the north in the direction of Lake Manitoba toward the south and a little east, and that of the

Minnesota Glacier from the region beyond Lake Superior and south of Hudson's Bay toward the south and west. The two lobes of the Great Ice-Sheet thus met along the Pembina Mountain highland. It was in the hollow or ice valley between the lobes that the Glacial Elk River flowed, at first probably on the top of the ice, and later formed what is now known as the Elk Valley. It was this great glacial river which carried down the sand and finer rock-flour which made the Elk Valley Delta, from about McCanna and Larimore south to Portland.

The Work Done by Moving Ice.—Let us now inquire as to the effect of a great moving mass of ice upon the land-surface it passes over. If there are rough places on the rock surface these will be ground off and smoothed, and the fragments which are torn away will be shoved or carried along with the moving mass. The rubbing of the moving ice

FIG. 24. A Small Hill Being Planed Down by the Ice.

serves to give a peculiar polish to the stones carried in it. Such smoothed and polished rocks are very 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 smoothed but having straight lines cut in their surfaces. These lines have been caused by the stone being shoved against another hard rock. Boulders or pebbles having marks made in this manner are said to be "striated," and the fine lines or furrows are called "striae."

Boulders or fragments which are carried or shoved along the bottom of the ice upon a hard rock floor will indeed receive severe treatment. Not only will their rough corners be ground off, but any except those which are very hard will be likely to be ground to powder. Much

FIG. 25. Showing Formation of Moraine, and Stratification of the Ice.
Photograph by Prof. T. C. Chamberlin.

FIG. 26. Showing Moraine, which is being Crowded upon by the Moving Ice.
Photograph by Prof. T. C. Chamberlin.

FIG. 27. A Striated and Polished Boulder. *Photograph by M. B. Erickson.*

of the clay of our fields is rock-flour thus ground by the great glacier-mill.

While these rock fragments which are carried along by the moving ice are being thus ground to powder, what is the effect upon the underlying bed-rock? It must be getting a pretty hard scouring! Figure 29 is a photograph of striae on a surface of hard quartzite rock in South Dakota. If a hummock or little hill lies in the path of the glacier, and if its width and height are so great that it cannot be broken off, then the ice will surround it and flow over it. The hummock will be combed and rasped by the ice and by the pieces of rock which are being carried in it. If the hummock should withstand the harsh treatment, when the glacier disappears by melting and leaves the once ice-covered landscape, the little hill or hummock may look something like A—Figure 30—or like B—Figure 30—the ice having moved in the direction of the arrows.

The Turtle Mountains furnish a good example in our own State of a large and broad "hill" which was covered by the ice and "veneered."

FIG. 28. Granite Pebble, Showing Ice Planing and Striæ. *Drawn by Miss Jessie Dawson.*

FIG. 29. Photograph of Striæ on Quartzite, South Dakota. *U. S. Geological Survey.*

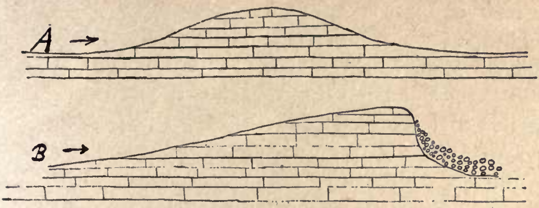


FIG. 30. Hills Worn Down by Action of the Ice.

The "Mountains," so-called, really are not mountains at all, but a plateau. Before the ice-invasion this plateau looked something like A —Figure 31—standing upon the prairie like a great, broad biscuit on a table or floor. After the ice had passed over it, it looked more like B —Figure 31—which is about as it appears to-day. The steep side at the left is near Bottineau and the section extends northeast across the International Boundary.

Devils Heart Hill and Sully's Hill south of Devils Lake are "veneered" hills. East of the Missouri River many long hills with

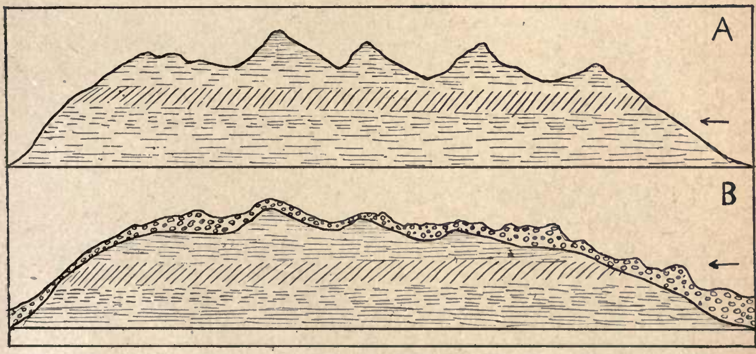


FIG. 31. Ideal Sections of the Turtle Mountain Plateau, A before, and B after, being Crossed by the Ice-sheet.

smooth outlines have a core of stratified rock, but have been combed across by the ice and strewn with boulders and finer glacial gravel and sand, and so are "veneered" with drift.

The great fertility of the Red River Valley and the eastern part of our State comes not alone from the fact that the land in the Valley was once covered by a lake, but we have inherited a large amount of limestone, in the form of soil, from the limestone beds in western Manitoba. This limestone has been ground to powder by the ice as it shoved it along. We have noticed that the Dakota Glacier moved south and a little east from the region about Lake Manitoba west of Winnipeg. This gave the Red River Valley and the eastern portion of the State a valuable "shipment" of the best wheat-producing limestone soil from our neighboring Province to the north. This pulverized and ground limestone is the best and most fertile known for wheat growing.

Advance and Retreat of the Ice Front.—In the chapter on the Glaciers of Norway something was said about the advancing or pushing ahead of the front of a glacier due to the movement of the ice being greater than the melting, and again the ice melting away more rapidly than it flowed down, causing a retreating or moving backward of the edge of

FIG. 32. A Veneered Hill, Ideal Section of Mauvais or Big Butte.

the glacier. We may now apply what we saw then to the great Continental Glacier.

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 and leave its supply of earth, sand, gravel, boulders and clay to show where it had been. If the edge had stood for some time at one place there would be a long heap or ridge of materials forming what has been called a moraine. If the ice melted back somewhat rapidly there would be scattered boulders, gravel, sand and clay over the area between the moraine and the ice front. If the forward movement of the ice and the melting should now balance for a time so that the ice front became 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, leveling them down and pushing their materials along. This melting back and pushing ahead have occurred a great many times, as a study of the terminal moraines of our State and of other Northern States show. Such advance and retreat of the ice front would tend to cause the terminal moraine to become not a simple line or long heap of earth and stones, but a belt of such materials. And as not all the earth and rock of the hills and ridges would be shoved along in front of the advancing ice but would be run over by the ice, the depth of the material in a moraine-belt becomes often very great, and so much material piled up in front of the ice would act as a dam to the on-flowing ice and hinder its advance.

The terminal moraines which mark the places where the edge of the Great Ice-Sheet stood are not merely ridges of earth and rocks, 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 have been lakes have given place to marshes or "hay-meadows" by the blowing in of dust and the continued growth of rushes and water plants till the lake has been filled. 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.

Figure 33 is a photograph taken in "The Hills" southwest of Minot in Ward County. Boulders are seen scattered in abundance over the hills. In the foreground is a patch of boulders which have been brought together from far away. Limestones, granites and quartzites are here side by side. The limestones came from over in Manitoba, perhaps a hundred miles away. The granites and hard quartzites may have come from much farther away, possibly 200 miles or more. Such boulders have sometimes been traced back to their parent ledges over a distance of more than 300 miles.

The hill at the right where the carriage stands is one of the highest, if not the highest, in this section of the State. It can be seen from more than twenty miles distant on the prairie. Many lakes of small size and hay-sloughs can be seen from its crest. The smoke rising from the chimneys of the shops at Minot can be seen also twenty miles away. To the left of the centre of the picture is a small circular lake now nearly filled so that it is a marsh. Two others can be seen, one at the right and one at the left on the margin of the picture. These are the "meadows" from which the ranchmen get their supplies of hay during summers when there is not too much rain. They are lakes during wet seasons.

If we imagine that the ice pushed ahead, leaving its burden of earth and stones and then in turn melted more rapidly so that the edge of the

FIG. 33. In the Hills Southwest of Minot.

ice was farther back; and if we imagine that it, so to speak, stood still here for some time so as to leave another mass of earth and stones; and if again the ice should advance and plough through and over the nearer masses of morainic material, and this process should be repeated again and again, when the ice should have finally all disappeared and left the landscape to become covered with plants and trees, we should expect that a very rough and hilly landscape would be the result. And if, as has been suggested, the materials piled up at the ice edge stood in the way of the forward movement of the ice, the tongues of ice would push out where there was less material in the way, and this would help to form the irregularities such as we now see in terminal moraines.

CHAPTER THE SIXTH.

MORE EXCURSIONS.

Shore Boulder Chains.—We may now understand better perhaps why the soil changes in character so much in going short distances. A farm may be located in a morainic region and its soil be stony, gravelly or sandy, or all of these, and it may be very hilly and rough, with small lakes or sloughs and marshes. Another farm only half a mile away, or even only a few rods distant, may be nearly level, of fine black loamy soil, and almost entirely free from stones. Still another may have a gentle slope or undulating surface, with almost no stones, but the soil may be very sandy, so that when the wind blows it may drift into dunes or heaps of sand. The first farm may be on what was the land barrier or moraine which hemmed in a temporary lake on one side; the second, where was once the deep water of the lake and hence received the fine sediments; and the third may be on what was a delta in the lake.

Sometimes again a chain of boulders may lie in great collections along some parts of a farm or section of land, and other parts near by be entirely free from such boulders. Such chains of rocks are often seen along the shores of lakes, especially of lakes whose waters are shallow. During cold winters such lakes freeze to their bottoms. And lakes which are deeper in some parts and so do not freeze to their bottoms will freeze to their bottoms in the more shallow parts nearer shore. If rocks and boulders are lying on the bottom, these become frozen into the ice. The sheet of ice cracks and breaks during the winter and the cracks become filled with water and this freezes and in freezing expands, and so the ice sheet covering the whole lake becomes larger and it therefore shoves outward upon the shore. In so doing the blocks of stone and boulders which were frozen into the bottom of the ice are shoved toward shore with the ice. This not only moves them a little way shoreward, but it serves also to loosen them from the bottom. When the ice "breaks up," in the spring, these rocks will be carried with the floating ice cakes until by melting of the ice they are again dropped. Whichever way the prevailing winds blow the ice cakes will tend to be moved and the rocks with them. The result is that the boulders are moved toward the shore in the direction of the prevailing wind. Winter after winter they are caught by the ice and shoved and carried a little way toward shore. Finally they are stranded along the bottom near the shore. Then they are frozen in and shoved up on the shore by the expansion process spoken of until finally there is a great chain of rocks and boulders piled along the shore, shoved up above the water's edge and left there by the melting of the ice. Hence if often happens that there is a great shore chain of rocks piled along the windward shore of a lake, as though they had been hauled there and dumped by some titanic force. Such chains of boulders were sometimes piled along the shores of glacial lakes, and when these lakes disappeared and the lake bottom became a dry field here were left the boulders to mark where once had been the lake.

Boulder-Strewn Prairies.—There are many places where boulders of all sizes are scattered over the land in great numbers. Great blocks weighing many tons often lie upon the prairie as though they had been dropped there by some gigantic force. Sometimes the land is strewn with boulders so that one can walk for a considerable distance without stepping upon soil at all. Large and small sizes, and different kinds, granites, quartzites, limestones and others, appear as though they had been carried there and thrown down.

Just how these boulders, these huge masses and the smaller blocks,

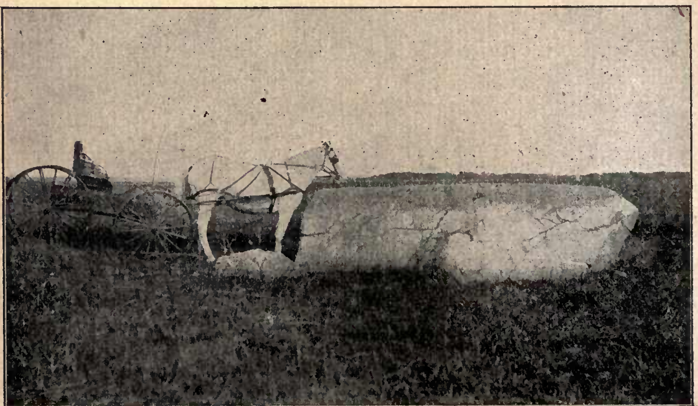


FIG. 34. A Huge "Foreigner." *Photograph by Prof. Chas. M. Hall.*

came to be distributed just as we now find them we need not now trouble ourselves about, only to observe that they are all "drift" boulders or "foreigners," and that they have been transported from some other place by the great ice-sheet, and when the ice melted they were left just where the ice happened to drop them. Their corners are nearly always rounded and their surfaces smoothed by the rubbing and grinding of the great ice-mill in which they were carried.

Buffalo Boulders.—It quite frequently happens that a large boulder lies in the center of a small basin or hollow, as though the basin had been dug around the rock. Such hollows are usually not large, extending only a few feet each way from the stone. This has suggested the idea that buffalo, wandering in herds over the once unbroken prairie, rubbed their bodies against the sides of the rock, and in treading about it ploughed up the soil. Loose soil is easily carried by the wind, and so the hollow might easily have been formed by the joint action of the hoofs of the buffalo and the wind.

The rocks are sometimes polished on their sides with a sort of greasy polish, but no such thing is seen on the tops of the boulders beyond the reach of the animals' heads.

Sometimes when these hollows become quite deep, or are on low ground, water collects in them during wet seasons and they become "buffalo wallows." When this is the case the soil would be carried away on the bodies of the animals.

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 arranged in beautiful layers, one above another like the boards in a lumber pile. 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 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 it becomes coarser as we proceed, or it may become finer; and many times we see that a layer becomes thinner and thinner in one direction and finally ceases entirely.

When we attempt to picture to our minds the way in which this gravel mass came to be here, remembering that each of these grains of sand and gravel, however small, and every boulder and cobble, was once a part of a larger rock, that 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 by some process, we shall no longer simply wonder how these things came to be, but will try to definitely explain them.

We have seen before how lakes of longer or shorter duration might be formed at the front of the ice-sheet, hemmed in by masses of earth

FIG. 35. Section in a Gravel Pit, Showing Stratified Sand Below, and Coarse Gravel and Boulders Above. *Photograph by Prof. Chas. M. Hall.*

and stone outside the line of the ice front. We have seen how streams flowing into such lakes would carry great quantities of earth, fine silt or rock-flour, and sand, and even coarser materials, the product of the great ice-plow on the rocks over which it has passed. We have seen how such lakes might have deltas formed at their shores and reaching out over their bottoms, and how finer sediments would be scattered all over their bottoms, and how they might finally become entirely filled. We have seen that these lakes might be of all sizes, from mere ponds to deep and broad bodies of water many miles in extent. The streams which flow into them may be few and small, or they may be many, and large as well as small. They may flow with swift or slow currents, and may carry coarse or fine materials, according to what materials were in the ice and the speed with which the current flowed, for a swiftly-flowing stream can carry a great deal more material and a great deal larger fragments.

Now, let us suppose that the ice has crowded its way close upon the already formed terminal moraine. The ice front stands as a great wall, maybe 100 feet or 150 feet or 1,000 feet high. The melting causes great streams of water to flow down off from the ice and out from its base. These waters flow away from the ice as fast as they can find a way to escape over the earth and stones. Torrents carrying earth, sand and gravel pour their dirty waters into a basin filled already with water, and even roll cobbles and boulders into the lake. As soon as these rapid currents enter the still waters of the lake they become slower and throw down their burden of earthy materials. The heavier particles will be thrown down first, then the lighter, and finally farther from shore the finest of all.

Suppose this keeps on till a layer of gravel or sand or finer silt has been formed, an inch or two inches or even more in thickness. Meanwhile the ice front may have changed its position or form by movement of some part of its mass, or by melting, or both, so that the course of the stream has become changed and hence the gathering of sediments carried into the lake will be changed. Conditions may be such that sediments will not be carried into the lake at the same places as before, and so the layer which was forming on the bottom may not be added to, but other parts of the bottom will receive the sand and finer sediments, and only fine silt may be deposited on the top of the layer of coarser sand.

Then other changes may cause still other manner of distributing the gravels, sands and silts. We may imagine some coarser material being left as a third layer. The incoming currents of water may become more swift by more rapid melting of the ice or by the ice of the glacier moving in such way as to cause a steeper bed to the water course, and hence while some of the materials already thrown down may be again taken up and carried farther along into the lake by the swifter currents other coarser materials now being carried by the swifter streams may be left on the top of the finer layers already laid down, so that now there are four layers lying one above another, the first of sand, then one of very fine rock-flour or silt, then a coarser layer again, and finally another layer which may be coarser still than the last or it may be finer, according as the waters which carried it were moving more swiftly or more slowly than the waters which carried in the last layer before.

Now, still other changes may occur and other streams may flow into the lake in greater abundance in some other parts of the lake, and these streams may carry still different materials. But coarser materials will be dropped nearer the shore and the finer carried farther out, and some of these may be scattered over the layer just described, the fourth in the series, and so a fifth layer be added. And a sixth and a seventh may follow, according to the time the lake remained and streams continued to pour in their muddy and sand-laden waters. The thickness of the layers depends upon the changing conditions which have just been noticed, a layer of coarse sand or gravel accumulating more rapidly than a layer of fine silt.

If occasionally a boulder occurs imbedded in the fine layers we shall understand that even large rocks may be rolled and even carried by streams if their currents are very swift. Larger and smaller boulders may therefore be expected to be found imbedded in the layers of gravel, sand and silt.

The coulees or young valleys and the larger streams which are now furnishing sediment to fill the lakes, and many other changes in the appearance of the landscape surrounding glacial lakes, including the growing of grass and trees, and the crumbling of rocks by action of frost, air and wind, and the dissolving of soils by the rains, are things which have occurred since the ice of the great Ice-Sheet disappeared to return no more, in other words, these are what are called post-glacial changes, or changes which have occurred since the Glacial Period.

A Hard Problem for a Boy to Understand.—It is not an easy thing to think that all the materials of the fields, the sand, gravel and larger rocks of the hills, all the materials in fact of which the landscape for many feet below the surface is composed, have been brought from somewhere else, are transported materials, that the whole top of the earth, as it were, has been shoved in from outside, has been brought here in or on or under the ice. This seems a great piece of fiction perhaps at first. We have seen earth and rocks carried by ice, but not on such a scale as would amount to anything like the great covering of drift which overlies the bed-rock over the greater part of our State, and over many of the Northern States. Considerable exercise of the imagination is needed to realize the force of this great fact.

A young man once brought to the writer a stone which he had found in the earth thrown up in the digging of a well, and he thought it very strange that there was what he called a "petrified butterfly" in the stone! His face wore a surprised and puzzled look while a few simple things were explained to him that this stone was a "glacial" pebble, that the "petrified butterfly" was not a butterfly at all, but a fossil form of a sea animal which had long ages ago lived upon the sea bottom, and the shell of the little animal had been buried there in the mud. This stone had once been part of that mud. In the lapse of the ages the ocean had disappeared from that part of the earth, the mud had become solid rock, and when the great Ice-Flood spread itself over the land the rock in which this little animal had had its tomb for so long was broken away by the moving ice and had been carried here along with other stones, clay and soil, and the fragment of rock had been dug up from the drift, the boulder had broken to pieces, and so here was the "fossil" remains of the little sea animal!

"A sea animal!" he exclaimed. "Why, it was nearly a thousand miles from the ocean where I found this piece of stone!"

"Yes, but all the land, all the solid rocks have been formed from mud in the bottom of the ocean, and afterwards the ocean bottoms have become dry land, and the muds of the ocean the solid rocks. The ice carried the stone to where you found it long after the ocean had gone."

"The ice carried it!" he exclaimed again, still puzzled. "That seems to me a pretty big story to believe, for it was down more than twelve feet in the ground and there were other large stones above it."

Now, to the reader who has followed these pages, it is hoped that the story does not seem "too big" to be understood. It is hoped that the reader is able to understand, after reading the pages of this book thus far, that ice spreading and flowing over the land in a vast sheet could have carried the soil of the fields, the rocks and clays of the hills and prairies, and that in this way is explained the occurrence of large and small stones, stones of many kinds, and clay and sand, all in a great mixture, making up our landscape.

When we try to picture to our minds the distance to the Moon, to the Sun or to the planet Neptune, we cannot without some effort realize these great distances. The mind cannot at first readily think them. But we think of the Sun as being much farther away than the Moon, and Neptune as much farther away than the Sun, and of the stars as vastly farther distant in space than Neptune. We dwell upon the figures representing those great distances, and finally come to a realization of the immensity of space and of the extent of the great universe. So when the untutored youth tried to follow the thought of the explanation of the stone which contained the "petrified butterfly," the sea animal which was found a thousand miles from the ocean, his mind was quite unable to grasp the problem, and so he exclaimed, "It is a pretty big story to believe!"

To the minds of many persons who have not trained their imaginations to an enlarged view of things about them; who have, it may be, never asked themselves the reason why rivers run in valleys or why valleys are bounded by hills or whether prairie plains must some time become hilly slopes; who have never wondered why the boulders and gravel, the clay and soil are distributed as they are, such an explanation as that related above would be as hard to understand and believe as it was to the boy. We must not therefore expect to grasp the full force and meaning of the geological story of our own neighborhood or State at the first effort. If we could all visit the great ice fields of Greenland and look upon the vast ice sheet, see the great promontories of ice standing like huge walls of rock as high above the ground

FIG. 36. A Joint Moraine Formed by the Meeting of two Glaciers.
Photograph by Prof. T. C. Chamberlin.

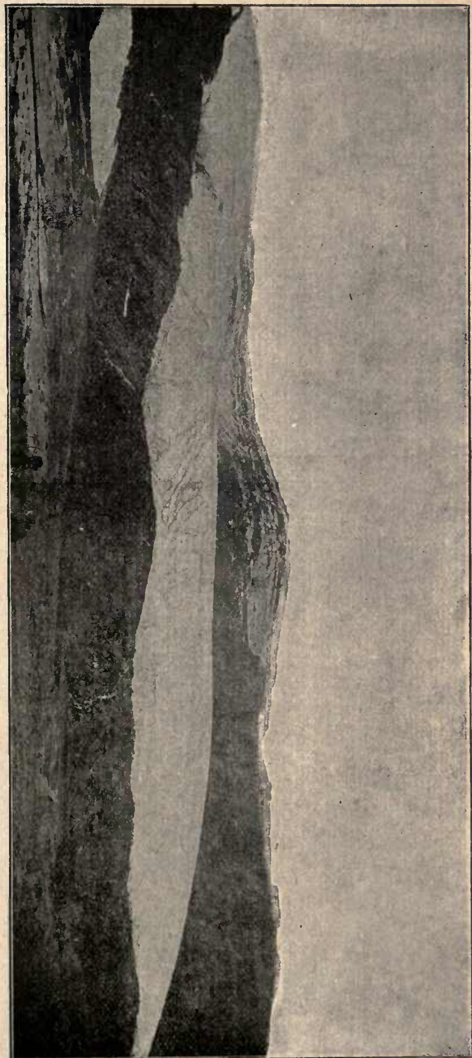


FIG. 37. A Glacier and its Moraine. *Photograph by Prof. T. C. Chamberlin.*

in front of them as would be measured by standing three of the highest church spires in our State one above the other; if we could look upon the great masses of rock which are being carried, shoved and broken, and left in great terminal moraines; if we could walk or climb upon the top of the great slowly moving mass of ice; if we could behold the great expanse of snow stretching away in the distance and from which reach out towards the lower regions the great ice tongues or glaciers, it would help us to understand the meaning of a great Continental Glacier or Ice-Sheet. We should be better able to see how the stone which the boy found in the well digging could be a part of a great mass of materials which had been carried by the great moving ice-sheet from the regions of the North. The hills known as moraines, of which our State has a great number, would then be more easily understood as the dumped material left from the melting of the ice.

If we can imagine a great ice-sheet many times larger than the great ice-sheet now covering Greenland to be spread over two-thirds of North America, and instead of the ice having a depth three times as great as the height of the highest church spire you have seen, we imagine the whole country to be covered by ice to a depth of half a mile to a mile or more, we shall be still better able to understand the meaning of the landscape with its hills and prairies, lakes and marshes, boulders and sandy plains.

CHAPTER THE SEVENTH.

NORTH DAKOTA, THE OLD AND THE NEW.

Three Types of Landscape.—North Dakota may be said in a general way to have three kinds of topography or landscape features: first, the level-prairie portion, which is almost perfectly flat, and is almost undrained by streams; second, the rolling-prairie portion, which is marked by ranges of rounded hills, some of them high, and many small lakes without outlets; and, third, the region which is drained by streams having well-established courses, many high hills with flat tops and steep sides, and no lakes.

The first kind of landscape includes those parts of the State which were for a considerable time covered by large bodies of water during the time of the melting of the ice of the Great Ice-Sheet. There are four regions in the State which belong to this class. These are the great Red River Valley, embracing the eastern tier of counties of the State; the Mouse River Valley, including parts of Bottineau, Ward, McHenry, Pierce and Rolette Counties; a small area in the southern part of the State extending south from Oakes and embracing the eastern part of Dickey County; and a region covering most of Sargent County, and a part of Ransom.

The second kind of landscape includes all the great central portion of the State west of the Red River Valley, to the Missouri River, except the Old Lake bottom areas just mentioned.

The third kind of landscape includes all that part of the State west of the Missouri river, and includes the famous region known as the "Bad Lands."

There are, therefore, the Old Lake bottom regions, the glaciated regions which have not been covered by large bodies of water, and the region which was not at any time covered by the ice of the Great Ice-Sheet.

The Manitoba Escarpment.—A line of highland extends across the State from Pembina Mountain on the International Boundary southward to the hills known as the Coteau des Prairies near the southern boundary of the State in southeastern Sargent County, near Rutland and Havana. This highland continues far north into Canada, and south across South Dakota and into southwestern Minnesota. The highest part of the highland within our State is the Pembina Mountain, five or six miles south of the International Boundary and about five miles west of Walhalla. It forms the highland which rises west of Larimore and which is plainly seen from the passing railway train south to Northwood and Hatton, on the Breckenridge Division of the Great Northern Railway. Farther south it is not so high. Where it is

FIG. 38. Map of North Dakota, showing the Highlands
Drawing by Miss M. Emma Davis.

crossed by the Northern Pacific Railway west of Wheatland it is only a prairie swell fifteen or twenty feet high. South from here to Havana it continues low, but rises suddenly at Havana into the high-hilly region of the Coteau des Prairies.

The Coteau du Missouri.—More than one-third of the State of North Dakota is embraced in what is known as the Plateau du Coteau du Missouri, a rather large name, but which simply means the hilly upland plain of the Missouri. The eastern edge of this great plateau rises quite suddenly 300 to 400 feet from the prairie lands eastward. The line of the eastern edge crosses the International Boundary near the northwest corner of the State in Williams County, and extends in a southeasterly and southerly direction across the State, passing fifteen or eighteen miles west of Minot in Ward county, Dog Den Butte in northern McLean County and Hawk's Nest in southeastern Wells County being outlying hills belonging to this plateau; thence it runs in a more southerly course about ten miles west of Jamestown, five to eight miles west of Edgeley in western Lamoure County, and about fifteen miles west of Ellendale in Dickey county. The whole of the Missouri "slope," within our State, lies upon this great plateau. The eastern part of the plateau is the watershed between the Missouri River and the rivers draining into Hudson's Bay,—the Mouse, the Sheyenne,—and the James Rivers. This highland extends westward with gradually increasing altitude till it flanks the Rocky Mountains.

The Turtle Mountains, lying upon the International Boundary about 100 miles east of the edge of the Coteau du Missouri, belong with this great plateau geologically. That is, the Turtle Mountains were once a part of the great Missouri plateau, but they have been cut off by the great valley which now lies between—the valley of the Mouse River. The layers of rock in the Turtle Mountains are the same as those in the larger plateau, and the strata or rock layers once extended across the valley.

We see therefore that there is a general rise in elevation westward from the Red River of the North on the eastern boundary, which is 951 feet at Wahpeton, 900 feet at Fargo, 835 feet at Grand Forks, and 753 feet at Pembina, to an altitude above sea-level at Buford, near where the Yellowstone River enters the Missouri, of 1,950 feet, more than 2,400 feet on the general level away from the river, and west of Sentinel Butte where the Northern Pacific Railway crosses the State line, 2,810 feet.

All these highlands, except the region west of the Missouri River, were covered by the ice of the Great Ice-Sheet, the western limit of the ice being nearly along the present course of the Missouri River. The vast ice-sheet by its melting supplied a great amount of water, but at the same time those streams which flowed toward the north were dammed up by the ice so that lakes accumulated in the valleys south of the ice-front where the highlands furnished a wall to hem in the waters. The waters finally were compelled to find escape by overflowing southward.

The Manitoba Escarpment formed a highland on the west which prevented the escape of the waters of Lake Agassiz into the James River Valley. Lake Dakota, of which the northern end only reached into North Dakota, was hemmed in by those same highlands on the east and by the Coteau du Missouri on the west, lying in the trough of the James Valley between these two highlands. This trough was the valley of the James River before the invasion of the ice, as it is now. Lake Souris occupied the lowland lying between the Turtle Mountains and the Coteau du Missouri, extending as far south as Velva, at the Ox-Bow of the Mouse River, and west to Minot and east to Rugby.

The Missouri River.—It is natural to wonder how it happened that the great Missouri River should flow almost exactly along where the edge of the Great Ice-Sheet was. We naturally wonder if the ice-sheet had anything to do with causing it; and when we notice the course of the upper portion of the river from far west in Montana, and notice also how the great Yellowstone River enters the Missouri at Buford from the southwest bringing waters north from the Big Horn Mountains in Wyoming, and still again observing that the Little Missouri River flows north for 200 miles from the Black Hills in South Dakota and Wyoming, finally emptying into the Big Missouri; and when we notice what a great elbow or bend the Missouri makes, turning almost south and following the edge of the drift-covered region all the way till it empties into the Mississippi at St. Louis, we are almost ready to think that the great river was changed from its old course and compelled to seek a new one.

The direction of the three streams, the Upper Missouri, the Yellowstone, and the Little Missouri, is toward a point in North Dakota, and suggests that they may have once flowed toward the east and finally discharged their waters into Hudson's Bay or Lake Superior. Then add to this that when the ice-sheet was all over the land half a mile or a mile deep the waters would be prevented from flowing east or north by the great ice wall, and so their waters would keep flowing down *to the ice*. There must, therefore, be a great lake formed along the ice wall where these streams met or else the waters must escape *along the edge of the ice*.

The melting of the ice along the edge of the Glacier caused vast floods of water which would add to that of the rivers. This too must escape. So it seems likely that a stream channel came to be formed along the edge of the ice. So when the ice finally melted away the river could not get out of this new channel. And so here the great Missouri River has staid ever since.

The Ox-Bows in the River Courses.—It is a striking fact that so many of the streams in North Dakota make a bend or ox-bow in their courses, curving to the east and south and then to the east and north. A notable example of this is the great bend or ox-bow of the Mouse River. Another is the big bend of the Sheyenne. And when we look at a map of the State it is noticed that nearly all the tributaries of the Red River of the North flow first south and east, then bend around to the north and east.

In order to see this more forcibly draw a heavy line on a sheet of paper to represent the Red River of the North, and then draw the course of the Sheyenne from east of Devils Lake to its entrance into the Red River of the North north of Fargo. Then draw the Maple River, the Wild Rice, the Goose with its principal headwaters, the Turtle, the Forest or Big Salt, the Park, the Tongue, and the Pembina. Notice the direction of the headwaters of the Goose, Turtle, Forest, Park, and Tongue, particularly. Draw a line on your map to show the western shore of Lake Agassiz. Why do these streams at first flow in a southeasterly direction? Because the highland of the Manitoba Escarpment is higher toward the north and becomes gradually lower southward. But they must flow east also because the front, or edge, of the highland slopes rapidly that way. But why do they so soon turn toward the north after getting upon the Red River Valley bottom? Let us answer this by asking whether the Red River Valley is higher toward the north or toward the south? The Red River flows *down* north. It is easy

FIG. 39. The Streams of the Red River Valley all make a Southward Curve.

then to see why they turn toward the north and east after flowing for some distance to the south and east.

But when these streams first started they emptied into Glacial Lake Agassiz. As this lake grew smaller and its shores became farther and farther east from the foot of the highland, these streams followed the retiring waters of the lake, pushing their channels along over the shore-sand of the lake. They thus came to have a direction more nearly east. Finally as the lake gradually grew smaller, and sediments, deposited along the central axis of the lake where now runs the Red River, blocked the way of the streams, they turned more and more northward. Some of the small streams between Turtle and Forest Rivers are unable to get to the Red River and spread out into marshes. Forest River nearly suffers this fate, but escapes toward the north after spreading out into a lake in southern Walsh county.

Many Small Lakes.—Lakes are always found in a region of country which has been covered by the ice. They are commonly small and without outlets. Such lakes show that the drainage of the region in which they are has not yet become established. Since the great ice-flood filled the former channels and left the landscape without definite stream courses, the development of land drainage, as described in Chapter One, has not yet had time to become worked out. One has but to glance at any map of the State which shows the rivers and lakes to see the marked contrast between that part of our State which lies west of the Missouri River, where the land was not covered by the ice-flood, and that part of the State which was covered by the ice. The network of rivers and small streams and the absence of lakes west of the Missouri River, and the absence of rivers or even small streams and the great number of small lakes, over a vast region east of the river, strike the eye at once and hold the attention of the thoughtful reader. The rounded hills which are so marked a feature east of the Missouri River to the Valley of the Red River of the North, between and among which hills are the round, oval, and irregular hollows often filled with water forming the lakes just mentioned, are morainic hills, which have been described before, and the lakes are morainic lakes.

The Old (Pre-Glacial) Landscape of North Dakota.—What was the land surface of North Dakota before the Glacial Period? What was then the land surface is not now, except that part of the State which lies west of the Missouri River. The old landscape, or what we may call Old North Dakota, is buried beneath the drift, covered by a mantle of clay, boulders, sand, and gravel from four or five feet to 300 feet in thickness. It will be of interest to inquire what was the appearance of the landscape before this great change took place,—before the hills were planed down and the valleys filled, by the great ice-plow.

The Cretaceous Inland Sea.—In order to understand what the old landscape of North Dakota was, it is necessary to go far back in the story of the past to the time when nearly or quite all of what is now North Dakota was under the sea, and the rocks which now form the bed-rock under the drift were being deposited as mud on the sea bottom.

At this time the Gulf of Mexico extended up the Mississippi Valley to the mouth of the Ohio River, and a great arm from the western part of the Gulf of Mexico formed an inland sea extending north over what is now western Texas, and Indian Territory, and covering Kansas, Nebraska, South and North Dakota, thence extending far into British America. (See Fig. 75, p. 174.) The sediments washed into this sea from the land were spread over its bottom as mud. These became the layers of shale and sandstone now the bed-rock of the North Dakota landscape. This period of Geologic Time is known as the Cretaceous Era. All the strata or layers of shale and sandstone which come to the surface in our State, or which are pierced by borings for wells, belong to the Cretaceous series of rocks. All the sediments of which they are composed were deposited upon the bottom of the great Inland Sea during the Cretaceous Era. This great Cretaceous sea bottom therefore became the original landscape of what is now North Dakota.

Underneath the mantle of drift are the layers of rock which were once the mud of this sea bottom. Where the streams have cut down through the overlying drift these rocks are exposed to view, and in the Bad Lands where there is no drift, the upper layers of these rocks are well exposed in the steep sides of the buttes, for the layers of rock, cut into by the streams, form the buttes for which this part of the State is noted.

Pre-Glacial Erosion.—The flat tops of the buttes and table-lands were once part of the great plain which was lifted above the sea to form the land of North Dakota. Erosion, or the cutting of valleys by streams, has been going on in this western region since the time before the Glacial Period. The rocks which are at the surface in the western part of the State may therefore be imagined to extend eastward underneath the drift materials. The edges of these layers outcrop or come to the surface along the eastern front of the Coteau du Missouri. The edges of the layers outcrop because the layers which once extended farther east have been carried away by erosion.

The Coteau du Missouri and the Turtle Mountains are regions which were higher before the Glacial Period than the country east of them. The region embraced in the great central portion of the State was a broad lowland plain. Streams had formed valleys; the old ocean bottom, which had been elevated and become dry land, had become cut up by valleys. The hills were slowly being carried away by rains and rivers. This process had gone on till nearly the whole land surface of the central part of the State had been worn down to a new level.

The Missouri River and its tributaries from the west, the Little Missouri, the Heart, and the Cannon Ball, in North Dakota, and the Grand, Moreau, and Cheyenne, in South Dakota, probably once discharged their waters to the east and north by the course of the present Red River of the North. This great northward-flowing river had made a wide valley in eastern North Dakota and western Minnesota. The present Red River of the North now occupies this valley, but of course the Red River Valley is now on top of the great mantle of drift which fills the old valley. Pembina Mountain and the highland south to the Coteau des Prairies form the western boundary of this valley. Pembina Mountain rises 350 to 450 feet from the lower land to the east. Sixty miles farther south, the Great Northern Railway rises more than 300 feet in passing on to this highland from Larimore to Petersburg.

CHAPTER THE EIGHTH.

GLACIAL LAKE AGASSIZ.

The Conditions.—It has already been observed that there was a wide and deep valley occupying the present Red River Valley before the Glacial Period. The western side of this valley was the Manitoba Escarpment, the continuation of Pembina Mountain southward to the Coteau des Prairies. The eastern side of the valley was the higher land of northwestern Minnesota, the "Great Divide" or continental watershed, called in our geographies the "Height of Land," from which streams flow south by the way of the Mississippi River to the Gulf of Mexico, east by Lake Superior to the Gulf of St. Lawrence, and north by the Red River of the North to Hudson's Bay.

The head of this great valley was south of Wahpeton in the region between the Coteau des Prairies west of Lake Traverse and the Height of Land on the east.

The map, Figure 9, shows the portion of North America which was covered by the Great Ice-Sheet, and the position of the State of North Dakota. You see that all of the State except the southwest corner was covered by the ice. The great valley of the Red River of the North was filled with ice; the Coteau des Prairies and Pembina Mountain, and the Turtle Mountain Plateau, were covered, and the great interior region occupied by the valleys of the Sheyenne, James, and Mouse Rivers was filled; and the eastern edge of the great western plateau, the Coteau du Missouri, was also buried beneath the vast sheet of ice.

Imagine yourself standing upon the surface of this great sheet of ice and looking away over its broad expanse. Everywhere is snow and ice, the surface of a great snow sea, no land anywhere in sight, nothing but snow and ice. Deep, very deep, all over the land lay the great sheet. How deep was the ice? Let us see. How high are the highest grain elevators you have seen? Less than 100 feet perhaps. Suppose that ten elevators were placed one above another, even then the height of all these would not reach up one-half as high as the surface of the ice was here in North Dakota, probably. And if this height were multiplied by ten even this great amount would be much less than the depth of the ice in some parts of North America. Remembering what has been said about the effect upon the lower parts of the ice of the pressure from the weight of the mass, think of the force which this tremendous mass of hard ice, moving slowly from its own weight, exerted upon the rocks and hills which it came against. Think what it means for ice to flow, pushing its way into the valleys and filling them, and riding over the hills and grinding off their sides. You can picture to your mind something about how so much "drift material," fragments of rock and earth, were broken loose and scraped from the surface of the ground underneath, and shoved and carried along by the moving ice.

You can now understand how it comes that there is the great depth of clay, gravel, sand, and boulders all over the bottom of the Red River Valley, for these are the broken and ground up rocks which were carried by the ice, and when the ice melted these materials were left. In some parts of the Red River Valley these drift materials are as much as 300 feet in thickness.

Of course there was no river where is now the Red River of the North when the ice-sheet covered this region, because the whole valley was filled with ice. But there were rivers flowing away from the ice-sheet toward the south, for the melting of the ice caused great quantities of water, and these flood waters had to escape somewhere, and the only escape was toward the south into the Mississippi River. Many streams which flowed away from the great ice mass as large rivers have ceased to be, and their names are not in our geographies. There is no melting ice-sheet to furnish the water to keep them running. Their old valleys are still left, often wide and deep channels. In some of these old channels much smaller streams still run, supplied with water by the rains which fall upon the land.

One of these large river channels is that in which Lakes Traverse and Big Stone, on the boundary between South Dakota and Minnesota, now lie, and along the old bottom of which the Minnesota River now flows to its big bend at Mankato. This old river channel is of much interest to us because it was for a long time, as we shall see presently, the outlet of Lake Agassiz. The great river which cut this wide and deep channel has been given a name, although that name does not appear in our geographies. It has been called the River Warren, in honor of General G. K. Warren of the United States Army, who in 1868 discovered the old channel and explained its origin.

The Beginnings of the Lake.—If now it is recalled that the land about Lakes Traverse and Big Stone is higher than the land to the north (and this must be so since the Red River flows toward the north), and that the Coteau des Prairies near the southeast corner of the State and the line of highland from these north to Pembina Mountain are higher than the lands to the east, and the Height of Land in Minnesota is higher than the Valley lands to the west, it will be easy to understand how the glacial Lake Agassiz came into existence. For, when the ice had melted back so that the regions about Wahpeton and Fargo were no longer covered by the ice-sheet, but the ice front was still as far south as Hillsboro and Blanchard, the water from the melting ice filled this basin. From the melting of the ice the basin began to overflow, and the outlet naturally was formed at the lowest point of the rim. This outlet was by the old channel in which, as has been stated, Lakes Traverse and Big Stone now lie, and which was the former channel of the Sheyenne River before Lake Agassiz began to be.

If we think of the great ice-sheet retreating toward the north, that is, that it melted at its southern edge more rapidly than the mass moved southward, it will not be difficult to understand how it was that this lake became larger, until finally it spread over a great area, the extent of which in North Dakota, Minnesota, and Canada has been determined by Mr. Warren Upham to have been as much as 110,000 square miles. On the map, Figure 9, you will see that Lakes Winnipeg, Manitoba, and Winnipegosis still occupy a part of the old lake bottom. These are remnants of Lake Agassiz which still remain to tell of the glory which has been.

After the ice had melted back from the position it occupied when the Dovre Moraine was formed, the Sheyenne River discharged its waters by way of the River Warren and the present large channel of the Minnesota River into the Mississippi and so to the Gulf of Mexico. But when the ice had melted farther back and a lake began to be formed, then the Sheyenne discharged its waters into the lake. The Sheyenne was a much larger stream than it is now because the waters from the melting ice kept it at flood, and it carried a large amount of sand cut from its channel and silt from the melting ice. These at first helped to build up the flood-plain of the River Warren, but when the ice had melted farther back so that the river spread out into a long narrow lake, a delta began to be built up at the mouth of the Sheyenne. The great Sheyenne Delta thus began to be formed as soon as Lake Agassiz began to exist.

When the ice had melted back farther and Lake Agassiz had become larger, the delta first formed served to block the course of the river and turned its waters to the east, so that the Sheyenne then discharged its waters toward the east into Lake Agassiz, and continued to build up the delta into a broad sand-plain. The waters of Lake Agassiz overflowed south by the River Warren.

We see therefore that at first Lake Agassiz was a long narrow sheet of water about thirty miles in length and only one, two, or three miles in width, extending in a northwest and southeast direction from the Big Bend of the Sheyenne east of Lisbon away toward Hankinson. The higher land west formed the shore on that side, and the wall of the glacier formed its eastern shore. Lake Agassiz was therefore at first little more than a broadening of the Sheyenne River.

On the western shore of this first beginning of Lake Agassiz was formed the Milnor Beach or shore-line for a distance of about ten miles. This beach is about twenty-five feet higher than the highest beach formed after the lake became a larger sheet of water. The waters of the long narrow lake, finding outlet by the channel of the River Warren, cut down this channel about twenty-five feet. It was at this lower level that Lake Agassiz stood during the time when the highest Herman Beach was formed, called the Herman Stage of the lake.

Increase in Size and Depth.—The lake soon became much larger with the retreat of the ice toward the north. A large and conspicuous moraine, the Fergus Falls Moraine, marks the next halting place of the edge of the glacier. Lake Agassiz at this time was a sheet of water covering an area of about 5,000 square miles. It extended from the outlet at Lake Traverse to the wall of the ice front as far north as Ada, Minnesota, and Caledonia, Hillsboro, and Blanchard, North Dakota. Its eastern shore in Minnesota was about eight miles west of the City of Fergus Falls and three miles east of Barnesville. Its western shore in North Dakota was near Wyndmere, at Sheldon, and about five miles east of Buffalo. Its depth at Breckenridge and Wahpeton was about 100 feet, at Fargo and Moorhead about 200 feet, and about 275 feet at Caledonia. It was while the lake occupied this area that the highest shore-line, known as the Herman Beach, was formed about this part of the lake.

The Fergus Falls Moraine is easily recognized on the east side of the lake bottom in Minnesota by its high, rounded and irregular hills and hollows. It appears again on the west side of Lake Agassiz in North Dakota as rolling hills or very uneven prairies near Galesburg, and becomes more rugged and like the usual type of morainic hills east of Erie. 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 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 uneven prairie extends across the Red River Valley from Ada and Rolette in Minnesota in a west-northwesterly direction to Caledonia, Reynolds, Buxton, and Cummings, North Dakota, and thence southwesterly to Blanchard, varying in width from three to six or seven miles.

The undulations in the prairie surface upon the belt of this leveled moraine vary from three to five feet, though sometimes eight or ten feet, above the adjacent hollows. Over this belt many boulders are scattered and gravel is more common than elsewhere upon the lake bottom. They sometimes occur in chains or long patches upon the beach ridges, having been carried or shoved up onto the shore by the lake ice during the winters, as suggested in the chapter on Shore Boulder Chains. (Chapter Six.) Such a boulder chain extends for several miles along the crest of the Blanchard Beach between Hillsboro and Mayville.

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

The next increase in the size of Lake Agassiz was caused by the recession or melting back of the ice-sheet to the position of the Leaf Hills Moraine.

The Leaf Hills Moraine of the Minnesota Glacier is marked upon the area of Lake Agassiz by slight undulations in the prairie surface, as in the case of the Fergus Falls Moraine. The two moraines run together where they cross the Red River so they cannot be separated from each other. From near the Red River the Leaf Hills Moraine extends northeast nearly to Red Lake in Minnesota, and northwest along the east side of the Elk Valley Delta east of Larimore, and continues as "The Ridge" and farther north as "The Mountains" on the east side of Elk and Golden Valleys to Edinburg. The area of Lake Agassiz will therefore be seen to have been increased by two triangular areas, the larger of which embraces the region about Mayville and Portland and north to Arvilla and McCanna, the other being north and east of Caledonia, in Minnesota.

The positions of the Dakota and Minnesota Glaciers or Lobes of the Great Ice-Sheet at the time of the formation of the Leaf Hills Moraine are shown in Figure 20. It will be seen that it was the Minnesota Glacier which covered the northern part of the Red River Valley and formed the moraine just described.

The next increase in the size of Lake Agassiz is very marked. It would seem as though 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 all that part of North Dakota 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 Glacier had not yet melted entirely from off North Dakota. The moraines which are crossed by the Great Northern Railway between Lakota and Devils Lake and those extending across the northeast corner of the State between Pembina Mountain and Devils Lake and west to the Turtle Mountains were formed at later stages than the Leaf Hills Moraine, and after Lake Agassiz had spread over the whole Red River Valley in North Dakota and Minnesota from Lake Traverse to near the City of Winnipeg. These moraines, formed during the successive stages of the Dakota Glacier while it covered this part of the State, belong to the Itasca Stage of the Dakota Glacier. The Minnesota Glacier extended as far south as Lake Itasca in Minnesota, and formed the hills which hem in the waters of that and other small lakes in Minnesota.

Still another period occurred when the forward movement of the ice-sheet was not so rapid as the melting, and Lake Agassiz extended still farther northward to the southern ends of Lakes Winnipeg and Manitoba, and eastward nearly to the Lake of the Woods, and westward to a line running nearly south from Lake Manitoba to Pembina Mountain. The hills forming the moraine which marked the position of the ice at this stage of the development of Lake Agassiz are known as the Mesabi Moraine.

Finally another recession of the ice, due probably to increased warmth of the climate, 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. This 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.

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, 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 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.

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's Bay because of the Great Ice-Sheet which barred the way. This still lay upon the land between the present Lake Winnipeg and Hudson's Bay and probably still filled the basin of Hudson's Bay. The waters therefore discharged by some northeastern outlet into Lake Superior. 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.

The melting along the edge of the ice-sheet, which was the north shore of the lake, as we have seen 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 ones 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 it built, as we shall see later.

The lands of the Valley of the Red River of the North are the most fertile and the most nearly level probably in the world. They are the most fertile because the fine sediments of ground up limestone and

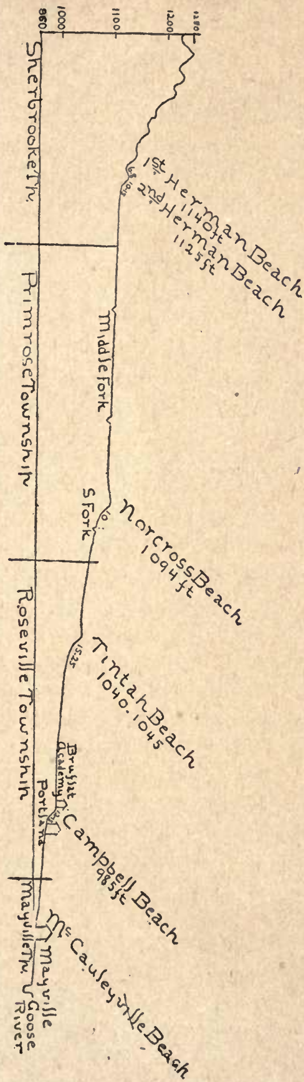


FIG. 40. Contour Line from Mayville west to Highest Shore of Lake Agassiz.

other rocks which were deposited upon the bottom of Lake Agassiz make a most productive soil, and this is rendered still more fertile by the black organic matter which gathered while the waters were drying off from the old bottom. It is the most nearly level large tract of land in the world probably, because of the leveling action of the waters of the vast lake which covered it.

The Red River Valley.—While the old lake bottom is nearly level, there are some uneven parts which are of much interest. Ridges of sand and gravel extend for great distances along the level prairie on the east and west sides of the Valley. These are beach ridges or off-shore sand-bars piled up by the waves of the lake. But the shore did not remain always at the same place, and a margin or belt of land was left along the edge which was not covered by the water. What had been lake bottom became land. Where the waves had once beaten upon the shore and left long ridges of sand and gravel the waters ceased to reach. The level of the lake had become lower, and the shore line had 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 bottom of the lake as we now 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.

Lakes often build up off-shore sand-bars because, when the waves roll in toward shore carrying and rolling over 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

FIG. 41. Typical Section Across a Beach Ridge of Lake Agassiz. Scale, 100 feet to an inch.
U. S. Geological Survey.

the water loses a good deal of its force, the sand and gravel which were 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 fifteen to twenty 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 places are often seen on the prairies of the Red River Valley, and the soil in such low places is generally more "heavy" or clayey, and not infrequently marshy, while the crest of the ridge is sandy or gravelly only a few rods 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.

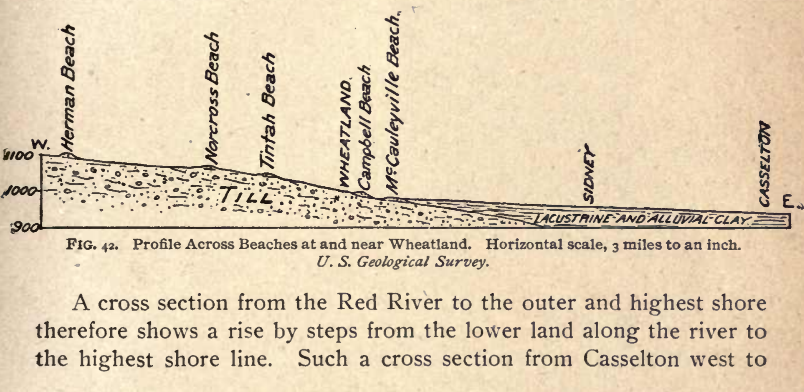


FIG. 42. **Profile Across Beaches at and near Wheatland. Horizontal scale, 3 miles to an inch.** *U. S. Geological Survey.*

A cross section from the Red River to the outer and highest shore therefore shows a rise by steps from the lower land along the river to the highest shore line. Such a cross section from Casselton west to

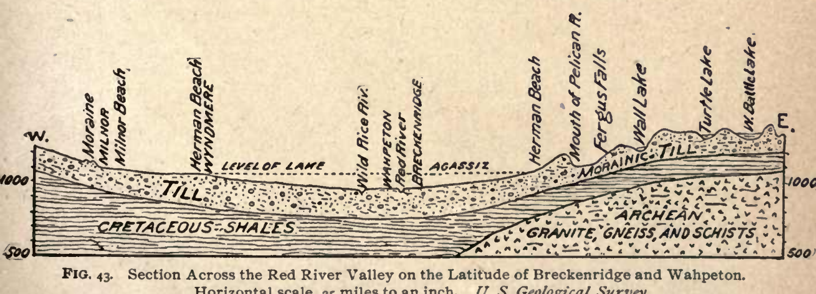


FIG. 43. **Section Across the Red River Valley on the Latitude of Breckenridge and Wahpeton. Horizontal scale, 25 miles to an inch.** *U. S. Geological Survey.*

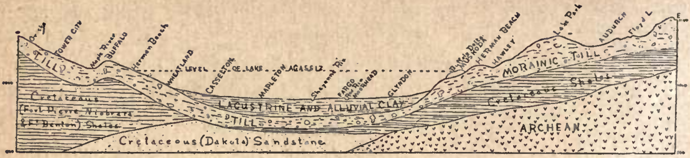


FIG. 44. Section Across the Red River Valley at Fargo. *After Upham.*

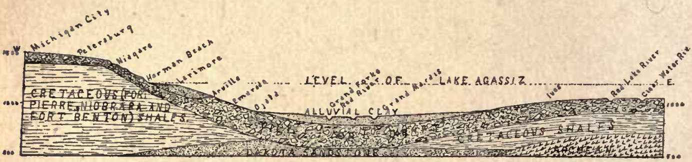


FIG. 45. Section Across the Red River Valley at Grand Forks. *After Upham.*

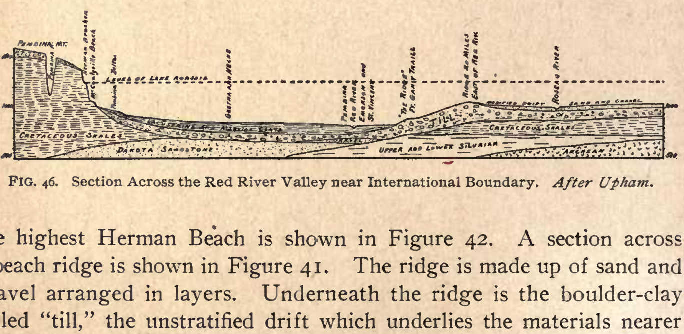


FIG. 46. Section Across the Red River Valley near International Boundary. *After Upham.*

the highest Herman Beach is shown in Figure 42. A section across a beach ridge is shown in Figure 41. The ridge is made up of sand and gravel arranged in layers. Underneath the ridge is the boulder-clay called "till," the unstratified drift which underlies the materials nearer the surface which were arranged in layers by the waters of the lake.

Sections across the Red River Valley at Wahpeton, Fargo, Grand Forks, and along the International Boundary, are shown in Figures 43, 44, 45, 46. These sections show the till or boulder-clay underlying the wave-washed materials, and underneath the till the layers of the stratified rocks, the top of which was the land surface, the preglacial landscape, before the great ice-sheet spread over the land.

The upper portion of the clay which makes up the deeper sub-soil of the Red River Valley is arranged in layers, as is shown in Figure 47. This is due to the fact that the upper part of the drift clay of the Red

River Valley was deposited in the water and spread over the bottom of Lake Agassiz. This material was dropped from the melting ice while the ice-sheet was receding and the lake was increasing in size, and was washed by the waves and deposited in layers upon the bottom.

FIG. 47. Stratified Clay, Sediments of Bottom of Lake Agassiz. Excavation in City of Mayville.
Photograph by the Author.

CHAPTER THE NINTH.

THE DELTAS AND BEACHES OF LAKE AGASSIZ.

Three deltas were formed on the western side of Lake Agassiz on that part of the bottom now embraced in North Dakota. These are known as the Sheyenne, the Elk Valley, and the Pembina Deltas. They were formed by the Sheyenne River, the Glacial Elk River, and the Pembina River. These rivers were flooded by the waters from the melting ice-sheet, and when their swift currents entered the still waters of Lake Agassiz their speed was checked and they threw down the burden of materials they were carrying, the coarse gravel and sand first, and later the fine sand and silt. The finer sand was carried for many miles into the lake and spread out as a great fan, and the finest silt was spread over all the bottom of the lake, being distributed by the waves and currents.

Not all the streams which flowed into Lake Agassiz formed deltas. It is interesting to inquire, therefore, why the Sheyenne and Pembina Rivers, and also the glacial Elk River, which ceased to be a river at all after the ice-sheet had melted away, should have formed deltas, while other streams flowing into Lake Agassiz formed no deltas.

We have seen that much earth material was carried by the ice, and that much water flowed away from the edge of the ice-sheet from the melting. If a river had its head near the edge of the ice-sheet, or flowed along its edge so as to receive these waters, then whatever gravel, sand, and earth the ice contained might be in considerable part carried to the river. Some parts of the ice-sheet probably carried more gravel and sand than other parts, depending upon the kind of land surface it had passed over. Then, too, the edge of the ice-sheet was very irregular and indented by jagged places made by the melting, and so there would be many small hollows and lakes in which the earth materials from the ice would be deposited, so that not all the streams which flowed at flood height from along the ice-sheet's edge received such great burdens of gravel and sand. When, therefore, a river had its head near a portion of the edge of the ice-sheet where a good deal of sand was left so that it was washed into the river's channel this stream, having a swift current because its channel was kept flooded, would carry much sand and gravel down its course.

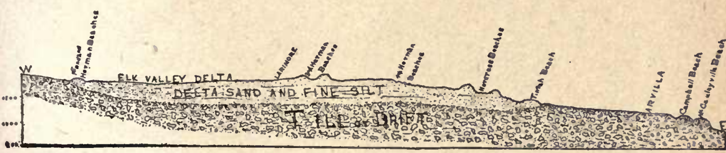


FIG. 48. Profile of Elk Valley Delta and Beaches at Larimore and Arvilla. *After Upham.*

Again the Elk River was a stream which at first probably flowed on the surface of the ice-sheet in the hollow between the Dakota and Minnesota Glaciers (see Figure 20), though it later formed a channel in the drift between these Lobes, and this river formed a delta thirty to thirty-five miles long and from five to twelve miles wide.

In Minnesota, of the rivers entering Lake Agassiz, only the Buffalo and Sand Hill Rivers formed deltas, although the Red River, the Wild Rice River, and the Red Lake River, on that side of the lake were as large or even larger than these.

The Sheyenne Delta.—When the ice-sheet had receded so that its edge rested upon the high hills south of Devils Lake, the Sheyenne River received a great influx of water from the melting ice, and with it the finer materials which were in the ice. These were carried by the stream down its course. The water was muddy, something as the waters of our streams now are muddy after a hard rain, or when they are swollen from melting snows. Not only this, but sand and gravel which were too coarse to be carried any distance by the current would be rolled along the bottom, or taken up and carried for a short distance and thrown down again, perhaps forming a sand-bar, to be in turn taken up and carried on again by the varying current. So at the mouth of the stream where the current met the still waters of the lake these were thrown down, first the coarser gravel and then the finer sand. These became the delta.

Little by little the river kept adding more materials to the delta, the coarser being dropped nearer the shore or head of the delta, the finer being carried farther out, and the finest, which would remain in suspension in the water for a long time, being carried far out and distributed over the lake bottom as the so-called lacustrine silt.

The delta is made up mostly of sand and gravel arranged in layers. Whoever has traveled along the lower Sheyenne River south and east of the Big Bend has noticed how sandy is the soil, also the hills along the river and over great areas farther from the river. The sand has been blown and piled into heaps by the wind, forming the "dunes" which are a conspicuous landscape feature.

The Sheyenne Delta covers an area of about 800 square miles, being mostly in Ransom and Richland Counties, but extending also into Cass and Sargent Counties. From the Big Bend eight or nine miles below Lisbon the Sheyenne River flows north for ten miles along the western edge of the delta, then flows east and north across its surface, leaving the delta front about three miles south of Kindred. The town of Sheldon is located on the western edge of the delta plain, and its western edge extends from here north about three miles into Cass County. Thence the northern edge extends eastward a little to the north of Leonard, and eastward and southward near Walcott, Colfax, and Barrett, on the Great Northern Railway; thence south to Mooreton, on the Milnor branch of the Northern Pacific Railway, and a little east of Hankinson to the Lightning's Nest, a very large wind-blown sand-hill or dune. The southern and western edge of the delta extends from the Lightning's Nest west and north by Taylor, Willard, and Swan Lakes, to a point about four miles northeast of Ransom in Sargent County, and from here northwest to Milnor and the bend of the Sheyenne River. Much of the surface of the delta is now marked by wind-blown sand piled into dunes of all sizes from little choppy knolls two to four feet high to large hills fifty to one hundred feet high.

FIG. 49. Section Across the Sheyenne Delta. *After Upham.*

Along the northeastern front the waves of Lake Agassiz cut a cliff or bank, so that in approaching the delta from the northeast the landscape rises suddenly in passing from the adjoining prairie onto the delta plain in some places as much as seventy-five feet. Figure 49 shows a cross section of the delta in which the valley of the Sheyenne River is shown at the left, and near this the Herman Beach, which marks the highest level of Lake Agassiz. A tract of dunes more than ten miles across is near the center of the cut, and the steep delta front sixty to seventy feet high is shown at the right.

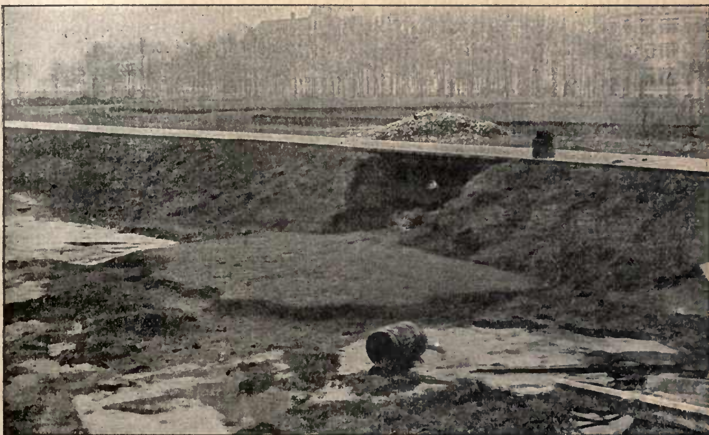


FIG. 50. Delta on University Campus, Chicago. *Photograph, 1894, by the Author.*

Figure 50 is a photograph of a small delta which was formed during a single night. The current of water from under the sidewalk was slackened as it poured out upon the low flat area in the foreground, and the materials carried by the little stream were thrown down layer upon layer in the same manner as the sand and gravel of which the great Sheyenne Delta is composed.

The Pembina Delta.—The Pembina Delta was formed by the Pembina River after the ice-sheet had melted back so as to leave the Pembina Mountain uncovered, the delta lying along the foot of that Mountain. The delta plain rises quite abruptly from the level prairie of the valley bottom to the east, and is locally known as "First Pembina Mountain." It covers an area of about eighty square miles, or only about one-tenth of that of the Sheyenne Delta. Its average depth is estimated to be about 150 feet. The average depth of the Sheyenne Delta is estimated to be about forty feet, so that the volume of the Pembina Delta is more than one-third that of the great Sheyenne Delta. The materials of which the Pembina Delta is composed are not only sand and gravel brought from the melting ice-sheet, but shale from the underlying rock-formations of Pembina Mountain, into which the river has cut a very deep valley, and also pebbles of granite and other hard rocks up to six inches in diameter. Large boulders of granite lie upon its surface, dropped perhaps from blocks of floating ice from the lake.

The delta extends from the foot of Pembina Mountain about four miles south of the International Boundary east and a little south to near Walhalla, thence curving south and east to its widest point, and south and west to the foot of Pembina Mountain again a mile south of Tongue River, being about eight miles wide at its widest part. Its western boundary thus lies along the foot of Pembina Mountain. Its highest point is about six miles southwest of Walhalla and a little more than a mile south of the Pembina River. It is here 1,270 feet above sea-level. The highest, or Herman, shore-line of Lake Agassiz is about two miles east of this point, and about fifty feet lower. This shows that the river piled its burden of sand, gravel, shale, and pebbles up to a height at the head of the delta greater than that of the level of the lake. The surface of the delta slopes gradually to the north, east, and south from this highest point or head.

Along the foot of the delta front run the Norcross, Tintah, Campbell, and McCauleyville Beaches, marking the height of the waters of Lake Agassiz during those stages of the lowering of the lake immediately following that during which the delta was formed,—the highest or Herman Stage. The waves of the lake washed against the front or edge of the delta plateau and eroded the loose materials, forming a steep bank or wave cliff which on the northeast side of the delta is more than 150 feet high. In crossing the delta from the level prairie east of Walhalla to Olga, about twelve miles southwest, after crossing well marked McCauleyville Beaches, the road rises suddenly up the steep face of the wave-washed and tree covered cliff 150 feet, from the top of which the surface of the delta plain spreads out as a great undulating plain with scattered clumps of trees here and there. From Beaulieu on the delta plain the road leads up the steep face of Pembina Mountain (called Second Mountain, to distinguish it from the delta plateau which is called First Mountain) a height of about 300 feet. The outcropping Cretaceous shales are exposed by the roadsides and in the coulees, and drift boulders of granite are scattered upon its sides.

Where the Pembina River cuts across the crest of Pembina Mountain the valley has been cut 350 to 450 feet into the soft shales and clays which underlie the drift, and tributary streams which have also eroded deep valleys, give to the landscape, which is covered with trees, a wild and picturesque appearance. The delta plain or plateau is also much cut up by streams. The Pembina and Little Pembina Rivers have cut deep gorges in the delta, even cutting down into the till which underlies the delta and on which it was built upon the lake bottom, so that a section through the 150 feet of delta sand and gravel is shown. The Cretaceous shales and clays (these belong to the Fort Pierre group of the Cretaceous series) are well exposed in the sides of the valley of the Pembina River where it cuts through the (Second) Mountain, and

FIG. 51. Section Showing Stratified Sand of the Elk Valley Delta. Erosion by Tributary of the Goose River. *Photograph, 1900, by M. B. Erickson.*

farther down its course the layers of the delta sands and gravels are similarly exposed.

It is worthy of notice here that what seems to be a small "butte" stands about a mile north of the northern end of the delta and three miles south of the International Boundary, a half mile east of the face of Pembina Mountain. It has much the appearance of the small rounded buttes of the Bad Lands. It looks from a distance much like a large haystack, being thinly covered with grass. Badger holes near its top and on its sides showed clean shale such as that of the Mountain. If this is its true character it is an outlying fragment of Pembina Mountain, and so was a tiny island in Lake Agassiz when its waters washed the eastern face of the Mountain. It is interesting also as being the most eastern "butte" in the State, and perhaps in the United States.

The Elk Valley Delta.—The Elk Valley Delta covers an area of about 300 square miles, extending from McCanna east of Larimore and south to Mayville and Portland, and covering the area west to the shore of Lake Agassiz. No river which could have formed this delta now exists. The stream which formed it, the glacial Elk River, is no more. The reasons for thinking that such a stream did once exist are found in the structure of the delta itself, the materials of which it is composed, and the form of the landscape near to the delta. The delta is higher north of Larimore and its surface slopes gently toward the south, west, and east, as though the "head" or place where the materials of which it is composed were poured into the lake was at this point. The materials making up this delta are of a finer character than those of the Sheyenne and the Pembina Deltas, being mostly fine sand and silt brought from the ice of the great ice-sheet, and are not mixed with shale gravels from the Cretaceous rocks underneath the drift, as are those of the other deltas. And then, extending north from Larimore and McCanna, just where a river ought to have been to have formed this delta as it is, the broad flat bottomed valley extending for more than forty miles to Edinburg and Gardar is what is known in its southern portion as Elk Valley and farther north as Golden Valley. It is, however, all one valley, varying in width from about four miles along the greater part of what is called Elk Valley to two miles at Ramsey's Grove, where begins the part called Golden Valley, and this portion varies in width from one to two miles.

Figure 20 shows the positions of the Dakota and Minnesota Glaciers, or lobes of the Great Ice-Sheet, at the time of the formation of

FIG. 52. Angular Outlines, not Passed over by the Ice-sheet.
Photograph by Prof. T. C. Chamberlin.

FIG. 53. Smooth Outlines, Showing Effects of Moving Ice.
Photograph by Prof. T C. Chamberlin.

the Elk Valley Delta. At this time the Leaf Hills Moraine was formed at the edge of the ice. Remember what has been said about the thickness of the ice-sheet, and that the surfaces of these lobes were higher along their axes or centers and the ice thinner near the edges. The arrows indicate how the ice spread out or flowed toward the south, east, and west, near the southern ends of the lobes.

There was melting of the ice on the surface of the ice-sheet as well as at the edge. Water would therefore collect in the hollow along the line where the two lobes met. When the ice-sheet reached farther south, as at the time of the formation of the Fergus Falls Moraine, the ice extended across from one lobe to the other, in the region shown in Figure 20. As the ice melted and the edge came to be farther back a hollow came to be upon the surface of the ice-sheet. At the time the Leaf Hills Moraine was being formed a large stream flowed in the hollow where the two glaciers met, having its bottom and sides of ice. This was the glacial Elk River.

Soon the ice valley became deeper from the melting due to the stream and from the melting at the edges of the lobes. The sand and silt which were elsewhere left at the edge of the ice as moraines were washed away by the swiftly flowing river. This was added to the material of the delta.

In time, however, this glacial river came to flow upon the ground between the two glaciers, being kept at high flood by the waters from the melting ice, which poured in from both sides. As the ice of the two glacier edges on each side of the hollow kept moving toward each other, and each delivered its burden of sand and silt, a large amount of earth material was left along the course of the stream only to be quickly carried away by the rapid current of the stream which was constantly renewed by the inpouring of waters from the ice. So it would seem that the conditions must have been such as to form a large river burdened with a great load of earth, and when the still waters of the lake were entered a delta must result.

FIG. 54. Profile of "the Ridge" and Beaches at Inkster. *After Upham.*

There was, however, more drift piled into this valley from the melting ice than could be carried away by the river. The west side of the valley is the highland of Cretaceous rocks which formed the western boundary of Lake Agassiz. Along the top of this highland was left the Leaf Hills Moraine of the Dakota Glacier. On the east side of the valley the Minnesota Glacier piled its moraine, a chain of hills which is now locally known in its southern portion as "The Ridge" and the northern part as "The Mountains." This chain of hills extends from McCanna north to Edinburg, a distance of about thirty-five miles. "The Ridge" is a series of three morainic hills from one to three miles in length and from a half mile to three-fourths of a mile in width. "The Mountains" are two long, large hills, one about six miles long, lying west of Conway, the other about fourteen miles long and two to three miles wide, lying west of Park River and extending north to Edinburg.

After the Leaf Hills stage of Lake Agassiz, when the ice-sheet had receded to the position of the Itasca Moraine, this chain of hills formed islands in Lake Agassiz, and the valley of the Elk River was a great sound or strait between these islands and the western shore of the lake. This is shown by the beach ridges which mark the height of the water on the sides of the islands and the west shore of Elk Valley. Figures 54 and 55 show profiles across the Elk and Golden Valleys, the Ridge and the Mountains, and the upper beaches of the Lake.

FIG. 55. Profile across Beaches at Park River and Westward.
Horizontal scale, 3 miles to an inch. *After Upham.*

The northern mountain is crossed by the south branch of Park River, west of the city of Park River, in a well-marked valley. Farther south to the west of Conway and Inkster is a gap two or three miles wide between the southern mountain and the northern hill of the ridge. The three branches of Forest River send their waters through this gap after they have united into one stream, cutting across the beach ridges which extend along the east side of the chain of hills. West of Orr the ridge is broken in two, but Lost Creek, which is formed by several small tributaries from the higher land west of the shore of Lake Agassiz, fails to flow across but becomes "lost" on the flat, marshy prairie—the old sand and silt bottom of the Elk Valley.

Between these islands were straits or necks of water connecting the main lake with the large sound west of the islands. The bottom of Elk and Golden Valleys is a level tract forty miles in length and from one to four miles in width with no stream on its bottom representing the great Elk River which once surged down its course and built the broad delta at its mouth. It has so little slope that no stream flows upon the level bottom for more than a few miles. In fact, Lost Creek, after it enters the flat bottom of this valley, struggles toward the north instead of south in the direction of the Elk River, and after two or three miles gives up and becomes a marsh. West of the northern mountain several small streams flow into the valley from the highland to the west and become "lost," spreading out into a marsh.

The Pembina Delta was formed after the ice of the Great Ice-Sheet had melted back so that Lake Agassiz extended north beyond the International Boundary to the city of Winnipeg, but the lake remained at about the same level, for the same beaches which run across the eastern side and along the front of the Elk Valley Delta also cross the eastern side and run along the steep front of the Pembina Delta. And the Herman Beach, which marks the highest level of the lake, runs along the western or shore side of both deltas. And similarly the Norcross, Tintah and Campbell Beaches run across the eastern side of the Sheyenne Delta, and the McCauleyville Beach along its front, while the Herman Beach runs near its western or shore side. The highest or Herman stage of Lake Agassiz therefore continued during the several stages of "retreat" or melting of the ice-sheet, which are marked by the Dovre, Fergus Falls, Leaf Hills and Itasca Moraines. The stages of Lake Agassiz should, therefore, not be confused with the stages of retreat or melting of the ice-sheet.

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 pre-glacial 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 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, known as 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. The outlet of the lake was across the soft drift materials of the Dovre Moraine. 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 five or ten 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 twenty 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 about fifteen 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 fifteen feet and the forming of the lower Tintah Beach. Again the level of the water was lowered about fifteen or twenty 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 twenty 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 to the northeast, the waters escaping 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 five or ten feet, although the water stood for a considerable time at this level. Then while the outlet was being cut down fifteen or twenty 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.

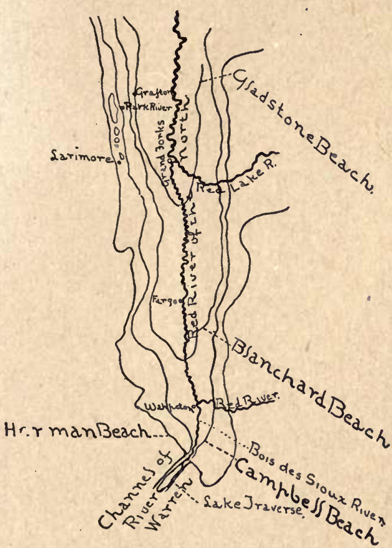


FIG. 56. During the Higher Stages the Lake Outflowed Southward. The Lower Beaches Cross the Red River of the North.

Figure 56 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

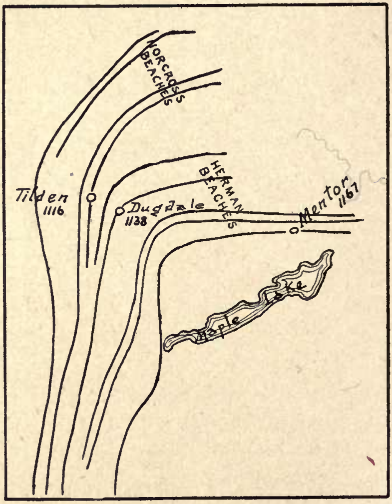


FIG. 57. Map of Portion of the Herman and Norcross Beaches, near Maple Lake, Minn., showing the Multiple Character Northward. The five Herman Beaches become one Beach, and the four Norcross Beaches one.

of eight, fifteen, thirty and forty-five feet; that is, the highest Herman Beach is there eight feet higher than the next lower, that is, fifteen feet higher than the next lower than this, making the highest twenty-three feet above the third one, and this third one in turn is thirty feet higher than the fourth, making fifty-three feet from the highest to the fourth lower, and the fourth is forty-five feet higher than the fifth, so that the first or highest is ninety-eight 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

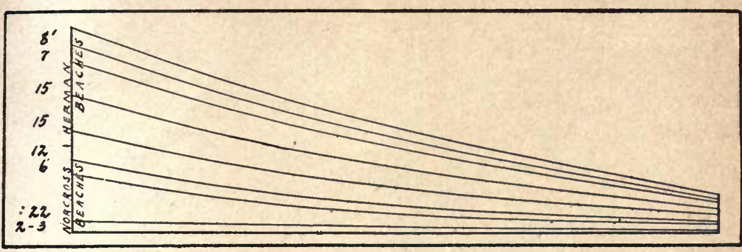


FIG. 58. Diagram Showing the Progressive Elevation of Beaches Northward in Vicinity of Maple Lake, Minn. Continue the lines to the right and the upper five meet in one, and the lower four in one.

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 it, 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 ninety 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.

* 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.

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's 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's Bay has been estimated to be from five to ten 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 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

* Dr. Robert Bell.

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 fifteen feet lower than the McCauleyville Beach, the second twenty feet lower than the first, the third fifteen feet lower than the second, the Hillsboro twelve or fifteen feet lower still, the Emerado thirty feet, the Ojata twenty-five feet, the Gladstone twenty feet, the Burnside twenty feet, the Ossawa fifteen feet, the Stonewall twenty feet, the Niverville forty-five feet, and from the Niverville Beach still another fall of forty-five feet reaches the earliest level of Lake Winnipeg, and the cutting down of the Nelson River outlet has lowered Lake Winnipeg still further twenty feet.

Let us now briefly review the history of Lake Agassiz. The lake first began as a body of water from one to three miles wide and about thirty 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 northeast, 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, twenty-five 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 one and a half times the whole State of North Dakota, 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 sixty-five 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 THE TENTH.

OTHER EXTINCT GLACIAL LAKES.

Glacial Lake Souris.—Glacial Lake Souris occupied the Valley of the Souris, or Mouse River, from which river it gets its name. It was formed by the waters from the melting ice-sheet, as was Lake Agassiz, and, like that lake, had the wall of ice for its northern shore, the ice acting as a dam preventing the escape of the waters northward.

After the ice had melted back from the position of the First or Altamont Moraine, the waters began to fill the basin between the higher land along the eastern front of the great Missouri Plateau, the Coteau du Missouri, and the edge of the ice. The First or Altamont Moraine lies on the top of the eastern portion of the great plateau, extending in a northwest and southeast direction across Ward and McHenry Counties, being crossed by the Great Northern Railway between Tagus (Wallace) and Palermo, the distance between these stations representing the width of the Moraine. West of Balfour and Anamoose the high hills of the Second or Gary Moraine appear, marking the second halting place of the edge of the Dakota Glacier or lobe of the ice-sheet as it slowly melted off from the landscape. It was probably in the interval between the times of formation of these two moraines that Lake Souris began, being at first a long, narrow lake fed by the waters flowing directly from the melting ice-sheet and the then great glacial river, the Des Lacs. The upper course of the Souris or Mouse River was probably at this time covered by the ice.

The earliest outlet of Lake Souris was to the south by the broad valley which extends from near Velva at the southern point of the Ox-Bow or Big Bend of the Mouse River south and west of Balfour and Anamoose, and then conducted the waters across to the Missouri River probably by Pony Gulch, or the channel to the west of Dog Den Butte, in which lie Strawberry, Long and Crooked Lakes, forming a channel across the great Altamont Moraine. This valley south from Velva is a broad, level tract of prairie, low in many places and covered with lakes and hay-sloughs. It varies in width from a quarter to a half mile or more. That this was the outlet for a considerable time

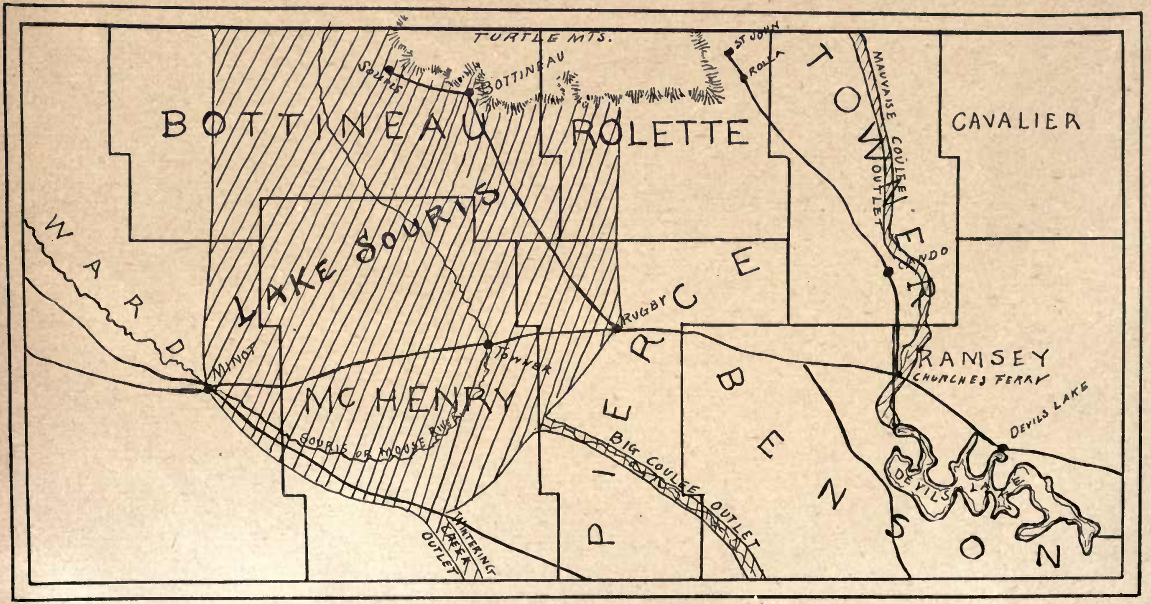


FIG. 58a. A Map of Lake Souris.

is shown by the fact that the old channel is well marked, having clearly defined banks and a broad, flat bottom.

After the ice had melted back farther, probably to the position of the Fourth or Kiester Moraine, and at the time when the edge of the great ice-sheet rested upon the high hills south of Devils Lake, the outlet was changed so that the waters escaped by the channel of the present Big Coulee and Girard and Buffalo Lakes to the upper course of the James River.

This old outlet channel is about 125 feet deep and a third of a mile wide. The Big Coulee, which now occupies this valley, is one of the head streams of the Sheyenne River. A well marked channel a half mile in width leads across from the valley of the Sheyenne to the valley of the James in northern Wells County, by which the waters of Lake Souris were carried to the James Valley from the upper course of the Sheyenne, the lower valley of the latter being at this time still buried beneath the ice. This old channel connecting the Sheyenne and James Valleys is now a "dry" waterway. In time of high water there is a stream on its bottom flowing toward the Sheyenne, the valley of the Sheyenne being now a deeper and larger valley than that of the James. The Big Coulee now extends as a well marked valley to within about twelve miles of the Mouse River. Here, then, is an old waterway, from the basin of Lake Souris to the Valley of the James, fifty miles in extent, in which now lie the Big Coulee, and Girard and Buffalo Lakes, the upper valley of the Sheyenne and the abandoned channel which connects the valleys of the Sheyenne and James Rivers.

Afterward, when the ice-sheet had melted back so that its edge extended from west of the Turtle Mountains to the high hills south of Devils Lake, and south and east through Nelson, Steele and Barnes Counties, the Sheyenne River, now receiving flood waters from the melting ice, was cutting its broad and deep channel and building its delta in Lake Agassiz. With the deepening of its channel the waters from Lake Souris were diverted from their course to the James, and Lake Souris became connected with Lake Agassiz by the Sheyenne River. The old channel which formerly carried the waters of Lake Souris to the James now became a reversed waterway. The Valley of the James is lower than the former mouth of this old channel, so that the headwaters of the James are not cut off and drawn away by the Sheyenne, although in time of high water a sluggish current moves in this channel toward the Sheyenne.

When at a later time the ice had melted back so that the Turtle Mountain plateau was uncovered and the lower land north of these mountains was freed from its burden of ice and was covered by the waters of the now larger Lake Souris—for the lake grew larger as the ice melted back—still another outlet lower than that by the Big Coulee was formed north and east of the Turtle Mountains, about twenty miles north of the International Boundary, and the waters of Lake Souris flowed south by the course of Badger Creek in Manitoba, through Lac des Roches in Towner County, and thence south by the Mauvaise Coulee into Devils Lake. At this time Devils Lake drained into Stump Lake, and Stump Lake drained into the Sheyenne River. So Lake Souris still furnished water to keep the Sheyenne at flood while it was cutting its deep channel and building up the great Sheyenne Delta in Lake Agassiz. On the northwest side of the lake the Assiniboine River was pouring in its waters and building a delta upon the bottom of Lake Souris, and its waters also were added to the volume of the Sheyenne.

During the time that Lake Souris was discharging its waters by the Big Coulee outlet into the James River, and later into the Sheyenne, and probably also at the time of the later outlet north of the Turtle Mountains to Devils Lake, another large glacial lake far north in Canada, Lake Saskatchewan, was sending its waters into Lake Souris also, so that there was a vast waterway from 200 miles north of the International Boundary in Canada by the way of Lake Souris and the Sheyenne to the southern part of Lake Agassiz, and from Lake Agassiz south by the River Warren and the present course of the Minnesota River into the Mississippi and so to the Gulf of Mexico.

At a still later stage in the melting of the ice Lake Souris was drained by the Pembina River into Lake Agassiz, and its waters helped to build up the Delta of the Pembina in Lake Agassiz, and deepened the channel of the Pembina River where it crosses the crest of Pembina Mountain to a depth of 350 to 450 feet.

The Dakota Glacier or ice-lobe still lay upon the northeast corner of North Dakota at the time Lake Souris was drained by Lac des Roches and the Mauvaise Coulee into Devils Lake, the southern end of the ice-lobe forming a point which rested on the highland west of Park River, Conway, and Inkster, and formed the moraine which extends from west of Inkster northwest to the northeast corner of Towner County. But the ice had entirely melted off from North Dakota at the time of the Pembina River outlet. The water of Lake Souris had by this time lowered so that the southern end of the lake did not reach south of the International Boundary, and the lake was finally entirely drained while the waters outflowed by this outlet.

Thus, while Lake Souris began a long time before Lake Agassiz, Lake Agassiz was still at nearly its highest stage when Lake Souris was entirely drained. Lake Souris began after the ice had melted back from the position of the First Moraine so that there began to be a basin between the highland of the Missouri Plateau and the edge of the ice-sheet. The region of the Red River Valley was buried beneath the ice of the Minnesota Lobe till after the time of forming of the Seventh or Dovre Moraine. About the time when the Sheyenne River began to broaden out to form the first long, narrow lake, which was the beginning of Lake Agassiz (page 80), Lake Souris was changing to its third outlet and the waters of the Lake covered the whole region of the Ox-Bow of the Mouse River. During all the time that Lake Souris was being drained into the Missouri River and then by the Big Coulee into the James River, Lake Agassiz had not yet begun to exist. But the long time that Lake Agassiz continued while all the beaches below the Herman and Norcross stages were being formed makes it much older in length of time of existence.

By reference to the Map (Figure 1), it will be seen that the shoreline of Lake Souris crosses the International Boundary near the northwest corner of Bottineau County, extending south to the city of Minot. thence follows nearly parallel with the Ox-Bow of the Mouse River to Rugby, thence north to the Turtle Mountains, and skirts the base of these mountains around their south, west and north sides, and then extends north for forty miles, making the area in Manitoba about the same as that in North Dakota, and this is just about the same as the area covered by Lake Agassiz in North Dakota.

It will thus be seen that all the great expanse of prairie from Rugby, Willow City and Bottineau west and south to Towner, Velva and Minot, and north to the International Boundary, is lake bottom. This vast region embraces a natural basin of nearly 4,000,000 acres within the State of North Dakota and an area of about equal extent in Canada. When the Great Ice-Sheet covered the continent this great basin and the surrounding highlands were filled and covered by the ice. It was the melting of this enormous mass of ice which furnished the water which, hemmed in by the higher lands on three sides and by the ice on the fourth or north side, caused the lake. When, therefore, the ice of the great glacier had melted back farther north than where Velva now stands a lake began to be formed, growing larger as the ice continued to melt away toward the north. There was at this time, of course, no Mouse River, because the land which it now drains was buried under ice probably half a mile deep.

Just how long it took for the ice to melt away, and therefore how long the lake lasted we do not know, but it was a long time measured in years, perhaps several centuries, for the outlet channels were cut down a good way into the land surface, and the shore marks made by the washing of the waves indicate that the water stood here for a long time.

It will be noticed upon the Map (Figure 1) that the moraines stop at the edge of the lake. The ice left these earth materials upon the lake bottom as well as upon the land outside the lake. But the waves and currents of the lake leveled down the hills to a large extent and spread the materials upon the bottom. The lands are not perfectly level on the old lake bottom just west of these hills, but are quite rolling, or undulating. They have been leveled a good deal so that the rough and high places have been softened and toned down, giving a gracefully curved contour to the surface. One can trace the line of hills of a moraine across the lake bottom in many places by the rolling and undulating character of the land surface. The lake bottom hills have low-rounded, smooth surfaces quite different from the rugged and irregular heaps and ridges of clay, sand and boulders which make up the moraines east of the lake shore.

Since the waters of the lake have gone the old bottom has become a grassy prairie. Boulders are scattered upon its surface as they were left by the melting ice of the glacier, or were dropped from floating cakes of ice formed on the surface of the lake during winters and so scattered over the prairie.

The hills on the lake bottom are often quite sandy, and dune tracts are common. The sand comes from the Turtle Mountains and the region south, for the ice-sheet in crossing the Turtle Mountain plateau combed off great quantities of the soft sandstone rock which makes up a large part of the rock layers of these mountains. The underlying rock south of the mountains is sandstone also, so that as the ice ploughed over the landscape, sandstone rock was broken loose and ground up, and so when the ice melted it left the sand in morainic heaps. The waves and currents of the lake washed away much of whatever clay and earth was carried by the ice. The clean, almost white, sand was therefore left. The "heavier" soils became covered with grass and other vegetation, and the sod so formed prevents the wind from carrying the particles. The sand does not readily become sodded over and so it is taken up by the wind and blown and piled into dunes.

Some large dune tracts are crossed by the Great Northern Railway

FIG. 59. **Sand Dunes, North of Towner, McHenry County. The Sand is Carried by the Wind over the Crest of the Hills, and is Burying the Forest.** ***Photograph by F. N. Molyneux.***

where it passes over the old lake bottom from Rugby to Minot. A scant growth of scrubby timber holds a footing on many of the dunes. Some of these hills are made up of almost perfectly clean whitish sand, and they are moved across the country in drifts in the same manner as drifting snow travels with the winds.

During the time that the Antelope Hills were being formed at the edge of the ice Lake Souris still discharged by the Spring Creek outlet to the south, and to the Missouri River. If the lines of the moraines shown on the Map are extended across the lake bottom to show where the edge of the ice was across the lake it will be seen that the lake was as yet only a small sheet, for these lines mark the position of the ice-shore on the north side of the lake. It was, however, supplied with water by the Des Lacs and Mouse River drainage from along the edge of the ice-sheet far to the northwest. The outlet and shores were high at this time, and it seems likely that the well marked ridge which extends about fourteen miles from south of Balfour north and west to Pendroy at the Mouse River is a beach ridge formed on the east side of a bay which formed the southern end of the lake, and which extended south until the waters broke over the summit near Balfour. This ridge, the famous "Balfour Ridge," is as smooth and well-defined as a railroad grading, becoming higher and broader toward the north. It rises six to eight feet above the prairie at the south end about Balfour and rises gradually and evenly till at the north end, where it is abruptly cut off by the Mouse River, it is thirty feet high. Such a beach would be built higher where the lake was wider and the waves rolled higher, and this accords with the form of this southern bay, which had its narrow point ten to fifteen miles south of Velva, near Balfour.

That this shore, and the southern Balfour or Spring Creek outlet, were higher than the Big Coulee outlet, which was opened after the Antelope Hills had been formed, or which likely began to be cut while the last ridges of these hills were being formed, is shown by the fact that Wintering Creek flows from along the east side of the Balfour Ridge toward the Big Coulee outlet, several small coulees which enter it flowing in deep cuts across the ridge.

Glacial Lake Dakota.—North Dakota has a "majority" in the number of old lake bottoms within the limits of the State. Besides Lake Agassiz and Lake Souris, a third lake, which lay mostly in South Dakota, extended over a small area in Dickey County in North Dakota. This old lake has been called Lake Dakota. Like the other two large glacial lakes which have been described, it was caused by the flood waters from the melting ice-sheet, but not in just the same way as were these.

Lake Dakota was formed when the edge of the ice on the western side of the Dakota Glacier stood at the position of the Third or Antelope Moraine, when the Valley of the James River had but just been uncovered from the ice. The lake lay in the Valley of the James River. It was an enlargement on a very large scale of the James River. The waters could not escape at the south fast enough, being dammed by a ridge of hard rock, the Sioux Quartzite, the rock which is spoken of in Chapter Two as being at the surface in central eastern South Dakota. This rock is very hard, and the ice-sheet in passing over it did not plane it off as it did the softer rocks to the north. The result was that a ridge or low hill of this rock lay across the course of the James River and acted as a dam, causing the waters to accumulate and spread out north of it, thus forming the lake. The edge of the ice-sheet lay along the east side of the James Valley and so there was much water flowing down its course from the melting of the ice.

The ridge of hard quartzite was at Alexandria, South Dakota, and the lake extended north from here along the present Valley of the James River to Oakes in North Dakota. Its length was about 175 miles, and it varied in width from eight or ten to thirty miles, and its depth in the deepest part was probably 175 feet.

Only the northern end of this lake extended into North Dakota. Where the southern boundary line of the State crosses the old lake bottom it is about eight miles in width. It extends a few miles north of Oakes in North Dakota, and covers a territory in this State of a little more than 100 square miles.

Glacial "Lake Sargent."—In the interval after the draining away of Lake Dakota and before the beginning of Lake Agassiz, a glacial lake covered the greater part of Sargent County, a small part of Ransom County, and extended about ten miles into Marshall County, South Dakota. No name having been given to this extinct lake, it is here called "Lake Sargent."

The broad morainic belt on the western line of Sargent and Ransom Counties served as the western shore of this lake, this moraine and the Coteau des Prairies the southern shore, and the wall of the melting ice-sheet the northern and eastern shore. As the ice melted on the eastern side of this moraine adding its waters to those of the lake the area of the lake extended eastward following the melting ice, till the Dovre Moraine was formed. This moraine became the eastern shore and was washed on its western side by the waves of the lake. The shore-line thus extended from Nicholson and Straubville south across the State Line to Burch, South Dakota, then north and east around the head of the Coteau des Prairies to Lake Tewaukon or Skunk Lake, and north by Cayuga and Ransom, covering the Stormy Lakes, and extending north into Ransom County, its area covering probably between 600 and 700 square miles.

Lake Dakota had been drained away before the beginning of Lake Sargent, and the James River was flowing across its old bed. Lake Sargent at first discharged to the southwest across the now dry bottom of Lake Dakota into the James River. Later when Lake Agassiz had begun to be formed a lower channel of discharge probably was found to the east from Lake Tewaukon close north of the Coteau des Prairies highland and south of the high range of hills (Dovre Moraine) which extends south of Lidgerwood, passing through a low place in the moraine, and entering Lake Agassiz about four miles south of Hankinson, and twenty miles east of Lake Tewaukon.

The depth of the lake at the time of its highest stage was probably about 50 feet at Forman, 100 feet at Perry and 150 feet along the northeast side in the vicinity of the Stormy Lakes, though the eastern outlet may have lowered the water before it became as deep as these figures indicate.

The eastern two-thirds of Sargent County is now drained into the Red River of the North by the Wild Rice, which enters the area of Lake Agassiz near Wyndmere. A cut of twenty-five feet in the moraine east of the James River twelve miles south of the State Line at Amherst, South Dakota, would permit the waters of the James River to be carried by the course of the Wild Rice to the Red River of the North. The elevation at Amherst is 1,312 feet above sea-level. Wild Rice station, near the mouth of the Wild Rice River, where it enters the Red is 911 feet above sea-level, so that there would be a fall of about 400 feet from the James River to the Red River of the North in a distance of about 100 miles, a fall about four and one-half times as great as that of the Red River from Lake Traverse to Lake Winnipeg. Had it not been that the James River cut a channel deep enough to prevent it breaking over to the east while the ice-sheet still covered the land to the east and was forming the large moraine which lies east of the Valley of the James, that river might have taken an easterly course to the Red River of the North instead of its present southerly course. This is an interesting example of the way the ice-sheet changed and directed the course of rivers.

At Nicholson a broad channel widens out onto this old lake bottom, a channel by which a large glacial river entered this old lake. This old channel was occupied by the Sheyenne River before the ice-sheet had melted back far enough to allow this river to cut its present channel south of Valley City to Lisbon. It is about two and a half miles wide where it is crossed by the Fargo Southwestern Branch of the Northern Pacific Railway at Englevale. It extends north into the Fort Ransom Military Reservation, and south at Nicholson broadens out onto the bottom of Lake Sargent. Ridges of drift formed islands in the broad river, and deep channels cut in its flat bottom perhaps by currents of the old river during winters when the melting of the ice-sheet was less rapid, are now filled with water and give to the old valley the name of Big Slough.

The Sheyenne River received water from all along the edge of the ice-sheet north to Devils Lake, and probably during this time received the waters from Lake Souris by the way of the Big Coulee outlet. It did not, however, cut a channel so deep but that, when the ice had melted back farther than to the position of the Dovre Moraine and the course of its present valley was uncovered and Lake Agassiz began to be formed, it cut its deep channel south and east to Lisbon and began to build up its delta at Milnor.

When, therefore, Lake Sargent had been lowered by the opening of its eastern outlet from Lake Tewaukon to the east into Lake Agassiz and the Sheyenne River had ceased to pour its waters into Lake Sargent this lake rapidly ceased to be, and later still the drainage from the Lake Sargent area was established by the course of the present Wild Rice River. So Lake Sargent came into existence after the formation of the large moraine which consists of the combined Fourth, Fifth and Sixth Moraines along the western boundaries of Ransom and Sargent Counties, and continued to grow larger during the time that the ice was melting back to the position of the Seventh or Dovre Moraine, after which it quickly disappeared by the drawing off of its waters to the east and by the changing of the course of the Sheyenne River so that its waters did not enter this lake. Lake Dakota began at or before the time of depositing of the Fourth Moraine and had disappeared before the beginning of Lake Sargent at the time of the Sixth Moraine. Lake Agassiz began with the same events which caused the closing of the existence of Lake Sargent, that is, the withdrawing by melting of the edge of the ice-sheet farther east than the Dovre Moraine so that the basin of the Red River of the North began to be uncovered, and the withdrawing of the waters of the Sheyenne River from Lake Sargent to that basin and at the same time causing the drawing away of the waters of Lake Sargent.

CHAPTER THE ELEVENTH.

THE HISTORY OF DEVILS LAKE.

The history of Devils Lake is interesting not only because it is "The Great Salt Lake" of North Dakota and the largest lake in the State, but its history forms an interesting chapter in the geology of the State.

The Cause of the Lake.—A line connecting Stump Lake and Devils Lake and extending northwest through Ibsen, Hurricane, Grass, Island and Long Lakes probably marks the place of an old river valley which once extended from near the Turtle Mountains to the Red River. This old valley was filled or nearly filled with drift. The Blue Hills southwest of Stump and southeast of Devils Lake, the high and massive hills south of Devils Lake, Mauvais Butte, or Big Butte, south of Lake Ibsen, the eastern end of which is about eight miles west of the western end of Devils Lake, a hill about ten miles long, and the high land northwest from Mauvais Butte which forms the watershed or divide between the Mouse Valley and Mauvaise Coulee, which is the highest point crossed by the Great Northern Railway between Grand Forks and the Missouri Plateau west of Minot, form a series of highlands which were probably the southern and western side of this valley. This it will be understood was a valley upon the landscape of "Old North Dakota," or the pre-glacial landscape.

When the ice-sheet melted off from the land the valley was nearly filled with drift. It was not entirely filled for its course is still able to be traced for 100 miles from the east end of Stump Lake to Long Lake south of the Turtle Mountains. All these lakes lie lengthwise of this valley as we should expect them to do if this were the partially filled valley of an old river.

The Blue Hills are veneered hills, that is, hills which were there before the ice-sheet came, and which have been covered with a mantle of drift. So also the high hills south of Devils Lake were hills before the ice melted in trying to cross over them and dumped the drift hills on top of them. Mauvais or Big Butte is also covered with a mantle or coating of drift, but is not itself made up of drift.

The Blue Hills, which rise from 100 to 200 feet above Stump Lake, the massive hills south of Devils Lake, the highest of which, Devils Heart and Sully's Hill, rise 275 to 290 feet above the water of Devils Lake, and Mauvais Butte, which rises at its higher western end nearly 300 feet above the prairie at its base, are all elevated masses of Cretaceous (Fort Pierre) shale, their rough surfaces having been combed off and smoothed by the ice-sheet passing over them, and leaving a covering of drift as it melted.

Devils Lake and Stump Lake occupy deep hollows in this old valley where it was less filled with drift. Stump Lake is said to be nearly 100 feet deep in its deepest place, and Devils Lake in the centre of the widest portion of the eastern end is 75 to 80 feet deep. The drift on the surrounding prairies is from 10 to 50 feet deep on the general landscape and as much as 100 feet deep in the morainic hills. These lakes thus lie in a trough in the rocks which underlie the drift materials. They are, in fact, lakes formed by the damming of a river valley. At least it seems probable that they lie in such a valley. Some of the arms or bays of Devils Lake are very likely the partially filled valleys which were tributary to the main valley. Some of the bays are caused by moraines which were dumped into the valley and now form the bluffs on the north side of the lake, but it does not seem that these gave the general form to the outline of the lake. The sides or shores on the south side seem to be the underlying rock only thinly covered with drift.

Devils and Stump Lakes were much larger bodies of water during the time when the ice-sheet was melting north of these lakes and a flood of ice-waters was being poured into them. There are marks made by the waves twenty-one to twenty-five feet higher than the present surface of low-water in these lakes. If the water in Devils Lake should rise sixteen feet above low-water a connection would be made across from its eastern end near Jerusalem to Stump Lake, and if it should rise five to eight feet higher still, Stump Lake would also drain into the Sheyenne River. An old channel connects Stump Lake with the valley of the Sheyenne, as also a lower channel which connects Devils and Stump Lakes, showing that there has in time past been an outflow to the Sheyenne as well as connection between the two lakes.

If we follow the Chain-of-Lakes and the Mauvaise Coulee to Lac des Rochés near the international boundary, and thence by Badger Creek to Pelican Lake in Manitoba, and to the Souris River, a natural waterway is seen to almost connect the Souris with Devils Lake. This was the course of the outlet of Lake Souris to Devils Lake and the Sheyenne River before the ice-sheet had melted off from the northeast corner of North Dakota.

At the time the waters of Lake Souris flowed by this course, Sweetwater, Dry, and De Groat Lakes, which are fenced in by the terminal moraine which lies south of them, were higher than now because of the flood of ice-water they received from the melting ice-sheet, the edge of which was but a little north of them at this time, and flowed across to the south into Devils Lake.

Fluctuations of Level.—The waters of all lakes vary in the height of their water-level during periods of years. Devils Lake has been much higher than it is now, as is shown by beach-lines marked by the waves at levels considerably higher than the present high-water level. It has also been much lower than the present low-water, as is shown by forests which are now submerged along the shores below low-water. Such trees now stand with their roots imbedded in the mud in Stump Lake, and also in the Washington Lakes a few miles south of Devils Lake in Eddy county. It is said that the name Stump Lake came from this fact.

The year 1889 marks a low stage in the waters of Devils and Stump Lakes, while about sixty years before, in 1830, the waters of these lakes were sixteen feet higher than in 1889. This was about the time of the highest known flood of the Red River of the North, when its waters rose so high that they covered the land on which the City of Winnipeg stands to a depth of five feet. The waters of Devils Lake rise and fall through a height of four feet in a dozen years. Since Fort Totten was built, about thirty-five years ago, the lake has fallen ten feet. At the time of the high water in 1830 the height of the water in Devils Lake was limited by an overflow into Stump Lake, a channel about sixteen feet above low-water, as has been stated, connecting the two lakes. It is likely it has risen high enough to discharge into Stump Lake many times in the period since the Ice Age.

At the time the melting ice-sheet was pouring its waters into these lakes their level was twenty-one to twenty-five feet higher than the low stage in 1889, and Stump Lake then discharged into the Sheyenne River. The channel from Stump Lake to the Sheyenne has a nearly flat bottom 150 feet wide, and hills rise on either side fifty to seventy-five feet high. The bottom of this old channel is higher than the

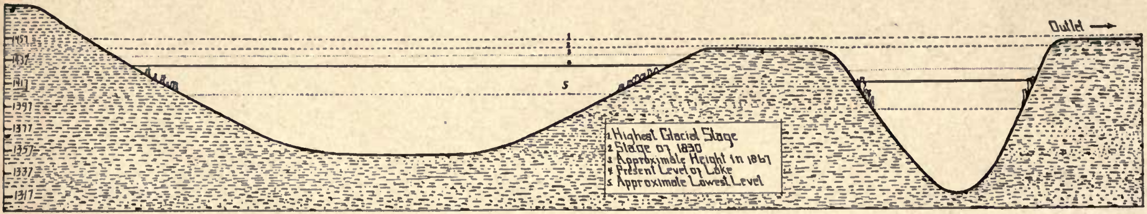


FIG. 59a. A Generalized Section of Devils and Stump Lakes, showing fluctuations in level.

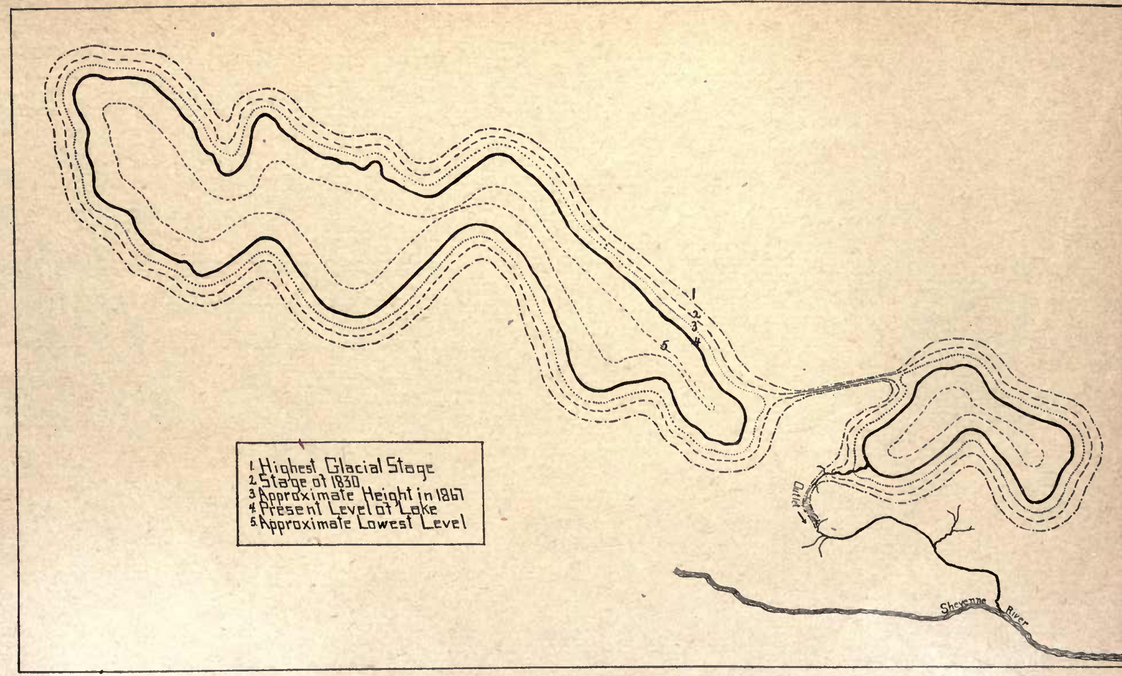


FIG. 59b. A Generalized Map of Devils and Stump Lakes, showing stages.

beaches which were formed by the waves during the probably quite long time when the waters were at the high stage of 1830, which are sixteen feet higher than the low stage of 1889, but these beaches are higher than the bottom of the channel connecting the east end of Devils Lake at Jerusalem with the west end of Stump Lake, and these beaches are marked on the sides of this channel showing that the two lakes were then united or joined by a strait.

The heavy and older forests which border these lakes extend across the highest shore-line which marks the height of the waters at the time of the melting away of the ice-sheet, and down to the beach which marks the high stage of 1830. Below this shore-line are only smaller and scattering trees, one of the largest of which is reported to have been cut by Captain Heerman and to have had fifty-seven annual rings of growth. During the 19th century, therefore, these lakes probably have not stood above the high shore-line of 1830. The old submerged forests may date back 200 years earlier to the time of the great period of drought when Pyramid and Winnemucca Lakes in the Great Basin of Nevada were dried up.

CHAPTER THE TWELFTH.

THE LAKES OF NORTH DAKOTA.

The Kinds of Lakes.—If we glance at a map of North Dakota it will be seen that all that portion of the State west of the Red River Valley and east of the Missouri River, except the Mouse River Valley, is dotted with lakes, and there are hundreds, yes, thousands, of small lakes not shown on even the largest maps. These are "glacial lakes"—that is, lakes which occupy basins or hollows amongst drift hills. They are more common among the hills of terminal moraines, and hence are often called "morainic lakes."

Lake Agassiz, which covered the Red River Valley, Lake Souris, which covered the lower Mouse River Valley, and Lake Dakota, which occupied the Valley of the Lower James River, a small part of which lake extended into North Dakota, and Lake Sargent, covering most of Sargent County, were glacial lakes; but these owed their existence to the presence of the melting ice-sheet, and they lasted only so long as the ice-sheet remained to fill their basins with water, and at the same time to dam the northern drainage courses, except in the case of Lake Dakota, which, as we have seen, was dammed at its southern end by a ridge of hard rock. These lakes disappeared with the final melting of the ice-sheet; they are therefore called extinct lakes.

The Cause of Existing Lakes.—All existing lakes in North Dakota owe their being to the fact that the rainfall is greater than the evaporation, and the hemming in of their waters by morainic hills or other land barriers which form the sides of their basins. They are "glacial lakes," therefore, not because their waters come from the melting of the ice of a glacier, but because the glacier which was once here caused their basins to be formed among the heaps and ridges of earth left where it melted.

A good deal of the drift is clay, and this holds water about as well as a porcelain dish. Wherever there is a hollow in which more water falls or collects than disappears by evaporation or soaking into the ground there will be a lake, and it is called a "glacial lake" if its basin was formed by the action of the ice of the great ice-sheet. All the lakes in North Dakota are glacial lakes.

It is not necessary that the land forming the basin of a glacial lake should be entirely in drift deposited from the melting ice in order for it to be a glacial lake. The materials from the glacier may cause a lake to be formed without the entire rim of the lake being of drift. A river valley may be partly filled with drift so as to dam the stream and thus cause a lake above the dam. Such a lake would owe its existence to ice action and hence would be a glacial lake. It is likely that Devils and Stump Lakes were formed in this manner. Jim Lake and Arrow Wood Lake in Stutsman County were formed by the partial filling of the channel of the James River by the drift so that the river is compelled to spread out above the obstructions till the water rises high enough to flow over.

The lakes of North Dakota vary in size from tiny ponds only a few rods across to those several miles in diameter. Devils Lake, the Lake Superior of North Dakota, is forty miles in length, measured in a direct line, and it is more than three hundred miles around its shore. Des Lacs Lake in Ward County is nearly thirty miles long, while only from a quarter to a half mile wide.

Sometimes the depths of glacial lakes are very great in proportion to their sizes and sometimes they are large and shallow, broad, flat claypans filled with water. Sometimes the bottom drops suddenly to a great depth, and sometimes there is a gradual slope of the bottom from the shore toward the centre.

In a similar manner, on "glaciated" land surfaces hollows are sometimes deep with their sides abrupt and steep, and sometimes a broad "flat" merges gradually into surrounding hills. The deeper and steeper sided hollows in glaciated regions have been called "pots and kettles." The broad and more shallow ones might as properly be called "pans." "Pots and kettles" are very common in terminal moraines, and "pans" are common on rolling prairies between moraines.

Exactly the counterpart or opposite of the "pots and kettles" are the steep, rounded knobs or knobby hills of terminal moraines. Pots and kettles and knobby hills wherever seen are a pretty certain indication of a terminal moraine. A gently undulating prairie with shallow depressions generally indicates a ground-moraine.

The great irregularity of the shores of many lakes in North Dakota is due to the fact that they are hemmed in by knobby hills, and if the lake is large there may be several "pots" covered by the water of one lake, the water being very deep where are the pots and quite shallow between them, or knobs may rise up, forming islands.

Lakes may diminish in amount of water they contain during dry, hot seasons, or they may dry up entirely during the driest part of the summer. Such are often called "dry" lakes. Lakes may also be "dry" for a period of years when the summers are seasons of unusual drought, and become lakes again during a series of rainy seasons. If a hollow is not deep enough to hold sufficient water to form a lake but rushes and marsh grasses grow upon its bottom it will be a slough or bog. There are thousands of such sloughs in North Dakota, and they afford some of the most valuable "hay-meadows" in the State. Sometimes a stream flows from higher land onto a tract of land so nearly level that the water is unable to cross it and so spreads out and forms a marsh or swamp. Such marshes, also often making valuable hay-meadows, occur upon the bottoms of old glacial stream channels. Good examples of this kind are the flat bottoms of the old outlets of Lake Souris west of Balfour, and the Big Coulee, and very many over the great Missouri Plateau where glacial channels were cut by the waters from the melting Glacier flowing across to the Missouri River.

Since the walls which hem in the waters of glacial lakes are the materials dumped from the melting ice, and since these materials are often left in very irregular piles and ridges, the outlines or shores of glacial lakes are often very irregular, the shore-line of the lake winding around all the irregularities of the hills which hem in the waters of the lake. Sweetwater Lake, in Ramsey County, is a good example of such a lake having very irregular shore, though there are many hundreds of smaller lakes in the State which are equally good examples.

In the case of a lake formed by the damming of a river valley by the drift the shore-line will follow not only the windings of the stream course and the curves around the hills dumped into the valley, but will reach out into the tributary valleys forming bays. The very irregular shore-line of Devils Lake is probably due to all three of these causes.

CHAPTER THE THIRTEENTH.

SALT AND ALKALINE WATERS IN LAKES.

The Salts in Lake Waters.—The waters of many lakes are not only "salt," but they are often bitter. This is because there are bitter "salts" in the water. Our common table salt is what the chemist calls Sodium Chloride. This gives the "salt" taste to the water. There is also Sodium Sulphate and Magnesium Sulphate in the water of many lakes, and this is bitter to the taste and affects the digestive organs of animals that drink it. There are also other salts such as the Sulphates of Potassium and Calcium (lime), and the Carbonates of Magnesium, Potassium and Calcium. If common salt or Sodium Chloride is present in the water in larger quantity than any of the others the water is called "salt" water. If it contains a larger quantity of some salt which is bitter to the taste it is apt to be spoken of as "bitter" or "alkali" water.

Waters which are "hard" contain some kind of salt, usually Calcium Carbonate or Calcium Sulphate (gypsum). Rain water is "soft" because when water is evaporated the mineral salt is left behind, and when the vapor condenses into clouds and falls as rain it is free from any salt. Not all waters which contain salts are "hard," nor are all "soft" waters free from salts. The waters from the artesian wells at Jamestown and Devils Lake are "soft," but they contain a large amount of salts. These waters are not hard because the salts in them are not such as to give the water the character of "hardness." Hard water is not good for washing because the salt in it forms a chemical combination with the soap and a new "soap" is formed which will not dissolve in water. The soap thus formed floats on the surface of the water, forming a greasy "scum."

Hard waters are agreeable to the taste and are generally good for drinking if not too hard. Water which is hard from the presence in it of Calcium Carbonate can be "softened" or "purified" by boiling, which causes the limestone to fall to the bottom as a fine, white powder, or to collect in scales on the sides of the vessel in which it is boiled. This is called "temporary" hardness. Water which contains Calcium Sulphate or gypsum is "permanently" hard for it is not affected by boiling.

The Sources of the Salts and Alkalies.—The explanation of the origin of the salts in "alkali" waters lies in the fact that these minerals are in the rocks of the earth. The Cretaceous shales contain them, for they were present in the sea-waters at the time these rocks were deposited on the bottom of the ocean. We shall see in a later chapter that a great arm of the ocean once covered North Dakota and the rocks which underlie the drift were deposited as sediments on its bottom. The ice of the Great Ice-Sheet ploughed up these rocks and ground them into the fine soil, sand and clay which now covers the old land surface. What has been called in a former chapter "New North Dakota" has been made from the broken and pulverized top of "Old North Dakota." The till or drift earth which was thus ploughed up from the Cretaceous shales has given to the soil its alkaline character. The salts, Sodium Sulphate and Magnesium Sulphate, are among the minerals in the soil, but other salts which dissolve in water, such as Potassium Sulphate and Sodium Carbonate, also occur, and altogether make up the "alkali" which distinguishes the soils and the waters of this region from those of the northern states farther east.

The minerals or salts which make the water "hard" are Calcium Carbonate (limestone) and Calcium Sulphate (gypsum). These have been derived also from the Cretaceous shales. Pure limestone is the mineral Calcium Carbonate, and the drift which has come from a limestone region contains this rock pulverized in the soil, and so this becomes a cause of hardness of the waters. In the Red River Valley and also farther West the drift contains a large amount of this rock which has been ground to powder, and this adds greatly to the productiveness of the soil.

These salts are therefore seen to be in the soil and when the rain falls upon the ground it dissolves them and becomes "hard" or "salt" again, and as the waters flow down the coulees or streams into the lakes and there again are evaporated the lakes become "salt" or "alkali." If the lakes have outlets then the salt is carried on in the water which flows out of the lakes and away to the ocean, and as the ocean cannot have an "outlet" the waters of the seas become salt.

Salt Beds on Dry Lake Bottoms.—Sometimes a large inland lake becomes so salt from the long continued evaporation of the waters, a little salt being generally present in the waters of the earth's surface, that the lake becomes a great tank of brine, and after a while becomes so "strong" that it cannot hold any more salt in solution, and finally salt begins to fall to the bottom. Or if the lake is small so that it frequently becomes dry the salt left by evaporation upon the bottom may not all be re-dissolved when the waters again fill the basin. If but little mud or fine earth is carried into the lake by streams and the "salt" in the water is mostly "common salt," beds of salt will accumulate on the bottom of the lake. These may become of considerable thickness and may be almost pure salt.

Now, if for any reason a lake where this process has been going on for a long time should permanently dry up here might be salt beds of great value. Such salt beds occur in some of the Western States, where the dry salt can be shoveled from the ground in great quantities. It is said that salt has been shoveled up and hauled away in wagons for stock purposes from such salt lakes.

CHAPTER THE FOURTEENTH.

MAP STUDIES: DISTRIBUTION OF THE LAKES UPON THE LANDSCAPE.

Map Studies; The Lakes of North Dakota.—A map ought to mean more than dots and lines and shaded areas. We ought to be able to see in a map of the State a picture of the landscape. The "map studies" in our geographies do not sometimes mean as much as they ought to. Let us notice the distribution of the lakes of our State and see if we can make these have a meaning as landscape features.

In the light of the studies we have made in the preceding pages it will not be difficult to see that all the lakes in the State, while they are all "glacial" lakes and hence all belong in one great class, yet they fall into about a dozen groups, in each of which groups there is a meaning as a landscape feature.

The McLean County Group.—Look first at the group of lakes in McLean county. Does their position strike you as having any suggestion in it? Look at the Map, Figure 1, and you see that the great Altamont Moraine, the one called the First, or the outer one formed at the edge of the great Dakota Glacier of the ice-sheet, makes a turn or loop toward the big elbow where the Missouri River turns southward. Some of the highest and most rugged and stony drift hills in the State are here. You notice that these lakes are in chains or sort of crooked rows. This is more than accident. When the ice of the great ice-sheet had its edge here great glacial streams poured from it into the Missouri River, and cut large valleys in the drift which had been left from the melting ice. Some of them also were probably valleys before the ice came and were not entirely filled by the drift. These streams did not last long because the ice melted back so that the water ceased to flow through them. A short time though as used in geology is usually a good many years. Their bottoms were not in many cases made smooth by the streams, and when the ice had melted and the water was no longer compelled to flow through these channels the hollows remained and became filled with water and formed lakes. When the water is high in the spring it often overflows from one to another and may even pass to the Missouri River in some of these old channels. It may escape from Strawberry Lake near Dog Den Butte across by a long series of lakes and sloughs to the river, and in a similar manner from Brush and Pelican Lakes to the Missouri River.

About forty miles west of Fessenden is Pony Gulch, a broad valley extending for many miles across the great Missouri Plateau, the Coteau du Missouri. This is a valley in which probably a stream flowed eastward before the drainage systems were changed by the ice filling them, but when the ice-sheet lay over all the eastern part of the State, filling all the river valleys, a glacial river probably flowed westward into the Missouri River, which you will remember was not covered by the ice. The waters from Lake Souris were very likely carried across by this channel to the Missouri for a time, as we saw in another chapter. The hollow places along the bottom of this old channel are now beset with lakes.

The Kidder and Logan County Group.—In northern Burleigh, Kidder, western Stutsman, Logan, and northern McIntosh Counties is another group of lakes some of which also mark old glacial channels where the ice-waters surged over into the Missouri River. These lie in hollows among the hills of the First and Second or Altamont and Gary Moraines. These are all upon the top of the great Coteau, or Plateau of the Missouri, and hence are on the "Missouri Slope."

It is probable that the James River flowed across by the Hawk's Nest in southeastern Wells County by this group of lakes in Kidder County to the Missouri River at the time of the formation of the Third or Antelope Moraine, for at this time the ice-sheet covered the land as far west as Carrington, and its edge lay upon the plateau to the south, so that the river could not follow its present course southward.

The Chains of Lakes.—Another group consists of the lakes in Foster, eastern Stutsman, and western Barnes Counties. The James River flows for nearly thirty miles along the course of the Fourth or Kiester Moraine. The river probably begun to cut its channel here when the moraine was being deposited from the melting ice and the river flowed along the edge of the ice. Sometimes the materials from the moraine were dumped into the channel of the river so that its waters were dammed up and lakes were formed. Such lakes are the Jim and the Arrow Wood, in northern Stutsman.

The Spiritwood Chain of Lakes and four other chains of lakes which cross or lie near to the Northern Pacific Railway between Valley City and Spiritwood station, lie in deep channels which were the places of large glacial streams during the time the ice-sheet was melting back from the position of the Fourth or Kiester to the Seventh or Dovre Moraine. Lake Eckelson lies in one of these old channels which is five miles long extending south to Walker Lake. Another lies about two miles west, and the old channel is six miles long. Another also about six miles in length is just east of Sanborn, and there is still another extending south from Hobart.

These lakes are along the bottoms of channels forty feet below the general land surface. These channels may mark the places of old valleys on the pre-glacial landscape which were not filled by the drift so but that the flood waters from the melting ice flowed in their courses and cut these channels in the soft drift which partly filled them.

A Picturesque Group in Griggs County.—One of the prettiest groups of lakes in the State and surrounded by the most picturesque morainic hills is that in Griggs County, and extending also north into Eddy County. The group consists of Lakes Jessie, Addie, Sibley, Clear, and Red Willow, besides many small ones, and also the North and South Washington Lakes in Eddy County, and Free People's Lake, on the Indian Reservation north of the Sheyenne River. From Devils Heart Hill across the Sheyenne at the Morris ford to McHenry and Cooperstown is a continuous series of lakes and hills. West of Cooperstown are the high, steep, rounded knobs of the Dovre Moraine, rising seventy-five to one hundred and fifty feet above the surrounding prairie, covered often thickly with large granite and limestone boulders, and among these hills are the silvery sheets of water of the lakes named. The Washington Lakes in Eddy County are walled in between the hills of the Elysian and the Waconia (Fifth and Sixth) Moraines. These lakes are interesting as having old forests with their stumps still standing below the water along shore, showing that the water has been much lower in them at some time. The cut banks or cliffs on the sides of these and others of the group show that the water has also been considerably higher than it is now.

The Devils Lake Group.—The long series of lakes extending from the small sheets east of Stump Lake for more than 100 miles northwest nearly to the Turtle Mountains, including from the east the two small lakes east of Stump Lake, Stump, Devils, Ibsen, Hurricane, Grass, Island, and Long Lakes, as has been explained before, probably were all formed in the valley of an old or pre-glacial river by the partial filling of this valley with drift. These lakes, therefore, have a quite different meaning as landscape features from those in the Griggs County group just described, which are "morainic lakes" pure and simple.

The Group North of Devils Lake.—North of Devils Lake is a group of lakes which are cut off from draining into Devils Lake by the range of morainic hills which lies between it and them. These lie in broad flat hollows or "pans." This range of hills, which belongs to the Itasca (Tenth) Moraine, lies close along their southern shores and holds their waters from escaping into Devils Lake, their waters pushing up into the hollows between the hills forming many small bays.

Quite a large area to the north is drained into these lakes, and in times of high water or during periods of years when the amount of rainfall is greater, these lakes increase in size, rising and spreading out in area, and become connected by sluggish streams. They may thus at times become connected with the Mauvaise Coulee and so drain for a time into Devils Lake. Sweetwater Lake has sometimes risen high enough so that its waters overflowed the rim of its basin and discharged directly across to the south into Devils Lake.

If the position of these lakes in relation to Devils Lake is noticed it will be seen that the three larger, Sweetwater, Dry, and the Twin Lakes (Lake Irwin and Lac aux Morts or Lake of Death), lie directly north of the three large bays or arms of Devils Lake. It has been suggested already that Devils Lake probably lies in the hollow of an old partially filled valley and that its larger bays or arms may be due to tributary valleys entering the old main valley. The position of these lakes, with the moraine forming a barrier to prevent their draining into Devils Lake, suggests that they may lie in the same tributary valleys in which the three large arms of Devils Lake lie, and that the moraine which crosses these tributary valleys in an east and west direction dammed their courses and so caused the lakes to gather above where the valleys are filled.

This suggestion of valleys in the old or pre-glacial landscape of this region is further strengthened by the fact that wells which are dug or drilled about the City of Devils Lake and in the surrounding country vary very much in depth within short distances, but all penetrating down below the drift to the old land surface, the Cretaceous shale.

Along the International Boundary.—A number of lakes lying near the International Boundary and east of the Turtle Mountains are good examples of a class of lakes which owe their existence to the action of the ice-sheet, and hence are "glacial" lakes, but which are not morainic. They lie in shallow pan-like depressions in the region between moraines. Their basins often have their bottoms and sides in glacial clay of till, but they may also lie in hollows which were scooped out in the Cretaceous shales by the moving ice. There are many such lakes in the State. Those here described lie between the ranges or belts of hills of the Itasca (Tenth) Moraine.

It has been before explained that the Itasca Moraine extends across the northeast corner of the State in a northwest and southeast direction. It is a compound moraine, being made up of several ranges or belts lying between Devils Lake and Pembina Mountain. Lying between the belt or wide range of hills which extends from the shore of Lake Agassiz west of Inkster northwest to the International Boundary in the northeast corner of Towner county, and the moraine lying upon the top of Pembina Mountain which was formed on the east side of the Dakota Lobe or Glacier, are Rose Lake, six miles east of Langdon, Rush Lake, near Hannah, a small lake near Mt. Carmel, east of Hannah, and a fourth about five miles north of Osnabrock. Between the range which lies west of these lakes and the next large range still farther west, which extends from north of Lakota to the east of Cando and to the Turtle Mountains, lie Lac des Rochés, near the International Boundary in Towner county, which has been before spoken of as lying in the line of outlet of old Lake Souris, and Rock Lake, about four miles west of Lac des Rochés.

All these lakes have inflowing streams or small coulees feeding them. The four first named are drained by outlet streams, Rose Lake being drained by the Tongue River, Rush by the Pembina River, Mt. Carmel by the Little Pembina River, and Osnabrock by Park River. All these streams have cut deep channels into the Pembina Mountain highland, for in flowing down its steep front their currents become swift. They have worked back and "tapped" these lakes since the ice-sheet melted, that is, since the close of the Glacial Period. In a short time—short as time is measured in geology—these lakes will have been drained and become meadows, for their outlets will be cut down and their waters will be drawn off.

But with Lac des Rochés and Rock Lake the case is different. No stream has worked back so as to tap them. Streams have worked back from their basins into the higher land which surrounds them and now bring water to them but this only makes them spread out the more. The old channel along the course of Mauvaise Coulee is almost up grade till after it crosses the belt of morainic hills to the south. When the flood waters of Lake Souris came this way it forced a passage over the moraine after Lac des Rochés had spread out so that it and Rock Lake were probably united into one large lake.

The Turtle Mountain Group.—When it is remembered that this plateau rises about 600 feet above the surrounding prairie it will seem

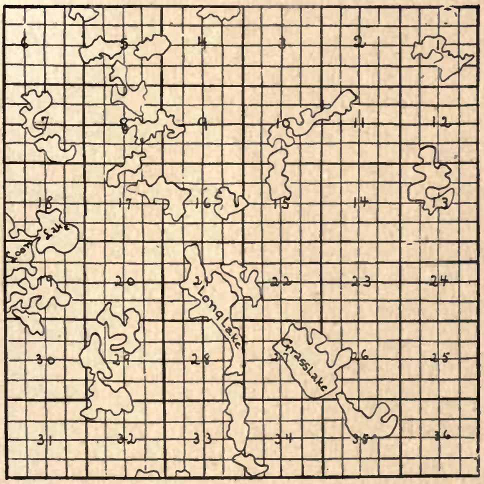


FIG. 60. Township 163, Range 74. Top of Turtle Mountain, showing the great number of small Morainic Lakes.

the more surprising that there are so many lakes on its top, for there are probably not less than 200 large enough to be shown on a map. Fish Lake, twelve miles north of Bottineau, its north end extending a little across the International Boundary, is one of the prettiest sheets of water in the State. Other lakes worthy of note are Kippax, Constance, Butte, Magog, Waukastian, Nemo and many others.

It will be seen from Figure 1 that a broad belt of the Itasca Moraine crosses the Turtle Mountains, and many of the lakes are "morainic" lakes scattered amongst the rounded hills in little round and irregular hollows.

The Turtle Mountain Plateau is about forty miles long and twenty-five miles wide in its widest part, lying mostly in North Dakota. Its top is forest covered, and very much broken and rolling due to the drift hills of the moraine just spoken of, and also to the fact that the plateau was cut up by creeks and coulees before the ice-sheet pushed across it, and many of these hills were too large to be entirely leveled down. In the hollows among the old, that is, the pre-glacial, hills, which are often only partially filled with drift, occur many of the lakes.

The Big Coulee Group.—Buffalo and Girard Lakes and a series of small lakes in Pierce county lie in the valley which was the outlet of Lake Souris before the time of the outlet by Lac des Rochés. These lakes differ in character from the great number of small lakes which are scattered among the hills in that neighborhood which are morainic lakes. These which lie along the bottom of the old channel are formed by the water which collects there from rains, and which cannot escape because there is not enough water to flood the old channel so as to cause a current. The water, therefore, stands upon the bottom in the low places, forming lakes and sloughs. "Big Coulee" Creek is a small stream lying in the valley, one of the head streams of the Sheyenne River, but it is a mere little pool which soaks along the bottom of the great wide valley. As the Sheyenne cuts its channel deeper and lowers the mouth of the Big Coulee Creek this creek will become more swift at its mouth and drain the lakes which lie upon the bottom of the old channel.

A Group of Typical Morainic Lakes.—The great number of lakes in western Benson, Pierce, and eastern McHenry Counties are morainic lakes,—small and larger basins, or "pots and kettles," of water hemmed in by the steep, irregular, and knobby rounded morainic hills.

Many of these hills are sandy, from the ground-up sand-rock of the Fox Hills Sandstone (one of the Cretaceous formations) which is the underlying rock south of the Turtle Mountains. Some of the lakes in this group lie among the sand blown hills (dunes) of the Lake Souris bottom. These hills, which were dumped into the lake as moraines. were not entirely leveled by the waves of the lake, but the sand of the hills on its southeastern shore was washed and assorted by the waves, and this is now blown by the winds into dunes, sometimes filling the lakes which lie in the hollows. The lakes are sometimes entirely filled, just as trees are buried by the drifting sand.

The "Alkali Flats."—South and west of Balfour, Anamoose, and Harvey, lying along the foot of the high front of the great Missouri Plateau, are what are known as the "Alkali Flats." Many broad flat bottoms are occupied by shallow lakes or sloughs. The water is strong of alkali, as are all the lakes farther west which have no outlets. The headwaters of the Sheyenne River have a sluggish beginning in this region, but there is almost no fall toward the Sheyenne in the flat surface from Dog Den Butte to western Wells County. A coulee from Pony Gulch and others from off the high front of the plateau flow out upon the "flats" and spread out as lakes. The shores and dry bottoms of the lakes are white from the "alkali" salt left by evaporation during the dry season of summer. These salts dissolve again in the water when the wet season returns.

When either a natural or an artificial system of drainage shall carry away the surface waters from these regions "the flats" will become valuable lands. They are rendered nearly valueless now by the accumulation of alkali by evaporation of the waters.

The "Alkali" Lakes in the Far West.—The lakes in western Ward and Williams Counties which lie upon the top of the high northern portion of the great Missouri Plateau, are among the most strongly alkaline, if not the most so, of any in the State. This is because the rock strata of which the plateau is composed, known as the Laramie formation (Cretaceous), are even more alkaline than those rocks which underlie the drift in the central and eastern portions of the State. Many of these alkali lakes lie in hollows in the underlying rock, which is covered by only a thin mantle of drift. The water of some of these lakes is a bitter brine.

The River of Lakes.—Another group of lakes in Ward County is of more than usual interest. This is a group nearly forty miles in length which lies in the old glacial river valley which once brought the waters of Lake Saskatchewan from far north in Canada, and also the waters from the edge of the melting ice all along its course, to Lake Souris.

There are three lakes in this series, the one farthest east and south being a small, pretty sheet of water one or two miles long. This is followed by a marsh and low meadow which separate this from the next lake, which is about three miles long. Then a marsh and a meadow again follow for a mile or two, and then a continuous and beautiful sheet, or silvery ribbon, of water extends to the northwest for thirty miles, having a width of about half a mile, its northern end extending about two miles into Canada. Des Lacs River, which drains (?) these lakes is a small, narrow ditch winding back and forth across the flat bottom of the broad and deep valley, and enters the Mouse River at Burlington, about five miles west of Minot.

Salt Lakes From Artesian Springs.—A remarkable group of lakes lies upon the level prairies in Grand Forks and Walsh Counties, between the city of Grand Forks and Grafton and north of Grafton. These are salt lakes which owe their origin and the saltness of their waters to the same causes as those which produce artesian wells in the Red River Valley. Springs which furnish salt water burst out upon the level prairie, the water having the same source far west of the Red River Valley as the water which is obtained by drilling artesian wells on the Red River bottom lands. In fact, these springs are natural artesian wells, the water being forced up through gravelly veins in the drift or till which fills the valley, and having its "head" or source in the high lands which flank the Rocky Mountains. These springs make the streams which start upon the highlands which formed the western shore of Lake Agassiz streams of salt water. There being not enough fall to the almost level prairie to cause drainage into the Red River their waters spread out into marshes and lakes, and the water which comes to the surface in the region of the lakes in springs adds to their volume, and hence the salt marshes.

CHAPTER THE FIFTEENTH.

LAKES AS A LANDSCAPE FEATURE.

The Meaning of Lakes on a Landscape.—Lakes as a landscape feature mean "youth," that is, the landscape is young in the sense that there has not been time for river systems such as were described in the first chapter to be developed. The landscape is as yet largely undrained by streams. A comparison of that portion of the State lying west of the Missouri River with the great portion east of it will show the difference between an "older" and a "younger" landscape.

We have noticed already the many lakes scattered over that part of the State which is east of the Missouri River. West of the river we see none marked on the map, for there are none. If there were once lakes there they have been drained. All of the hollows have outlets, and are valleys. East of the river most of the hollows do not have outlets, and are basins. The landscape west is therefore "older;" that east is "younger." West of the river drainage systems have become established, and streams have cut the landscape into hills, and these hills are being worn down and carried to the sea. East of the river few streams mark the landscape, and the cutting of the prairies into hills has just begun. West of the river the hills have been carved upon the face of the landscape. East of the river the hills are mostly "dumped" hills, or heaps and irregular ridges piled upon the landscape.

What has been the cause of these marked differences we have already seen. It was the great ice-plow which leveled down the hills and filled the valleys of the original landscape and piled these hills on the surface as it melted away. As this great ice-sheet reached only to the Missouri River the region west of this river has not been ploughed down and leveled and covered with dumped hills. There the landscape is "older" because the processes which carve and fashion all landscapes have been going on longer than east of the river, where they had to begin all over again after the Glacial Period.

The rocks are not any older in years west of the river than they are east of it; in fact, the oldest rocks in the State, as to the time they have been in existence as rocks, are in the eastern part of the State, as we shall see in a later chapter. It is the form of the landscape which is older. When the hills west of the Missouri River have all been washed away, or nearly so, so that there are no high, steep, flat-topped hills, and the whole region is worn down to base-level, then the landscape will have reached its *old age*.

In all the State east of the Missouri River drainage systems are just getting started. These are the "coulees" which, starting from the river valleys, old channels and lakes, have pushed back upon the landscape. Wherever there is a low place water collects from the falling rain and little streams begin to work back into the surrounding land. In time larger streams will become established and their heads will work back into the surrounding land and tap the lakes. The lakes will be drained by the cutting down of their outlets, and so in time there will cease to be any lakes, and the prairies will have been cut up into hills.

The rapidity with which river systems get started in any particular region depends upon the mouths of the streams. If the streams pour their waters into a deep basin, or if they fall suddenly down from a highland or plateau upon a considerably lower plain, they will cut their channels down and push their heads back rapidly, and the highland will become soon dissected into hills. The landscape may be said to "grow old" rapidly. But if the whole region is low, that is, if there is no place which is quite a good deal lower into which the waters can discharge, then streams will push back upon the landscape and cut their channels very slowly, and the rain which falls upon the land will lie upon its surface and in the soil till evaporation removes it.

Nearly perfect examples of landscapes which are "growing old" rapidly are the plateau top of Pembina Mountain, and the top of the Turtle Mountain Plateau. Of those which are lingering long in the youthful stage are the almost perfectly flat plain of the Red River Valley, and the region of the group of lakes north of Devils Lake. To the latter class, however, belongs most of the State east of the Missouri River.

All these regions began their "infancy" nearly at the same time, which was after the close of the Ice Age, or the Glacial Period. But the region of eastern Cavalier and western Walsh Counties, and the top of the Turtle Mountains, will be cut up into hilly landscapes and be reaching "middle age" while yet the plain of the Red River Valley and the region north of Devils Lake, as also much of the State elsewhere, will still be in the age of youth.

This is because the Red River has so little fall that it cannot deepen its channel, and so the coulees upon the prairies cannot lower their mouths, and the water which falls upon the broad level prairies stands in sheets until removed by evaporation. In the Devils Lake region the fall in any direction is so slight that only the faintest beginnings of drainage have been developed. Mauvaise Coulee enters Devils Lake from the north, but it cannot be said to drain the lakes with which it is connected. It is itself a long-drawn-out slough or pool which is broader at those places where it spreads out into lakes.

In the case of the Pembina Mountain top all the streams which fall down its steep front have cut deep channels. The Pembina River, the Little Pembina, the Tongue, the head streams or coulees of the Park, the Forest and the Turtle, have all cut deep channels down through the drift into the underlying shales. This is because of the fall from the top of the high plateau down to the low prairie. These same streams all become sluggish pools after they get upon the valley plain and their channels become long, puddling ponds. The high prairie upon the plateau top of Pembina Mountain will become cut up into hills while the Red River Valley still remains almost undrained. All the larger lakes upon this plateau have already been tapped by the head coulees of the streams named.

The Turtle Mountain Plateau is being cut into by the coulees which push their heads back from the prairie up the steep slope of the high front. All around the mountain on any good map streams are shown which are pushing their heads back onto the higher land. The old valleys which were partially filled with drift, many of which were dammed, forming the small lakes, will be cut out anew, and the lakes which are scattered among the hills in the hollows will be drained. Fish Lake and the series of lakes lying near it are in an old valley which was partly filled by drift. Oak Creek has cut a deep coulee into the side of the mountain and already draws away water from several small lakes in the series. When these have been drained by the deepening of the channel it will later draw off the water of Fish Lake, and finally the whole valley will be re-opened something as it was before the great ice-plow moved across the mountain's top.

A good illustration of the tapping of a lake by the cutting down of a coulee channel and the pushing back of its head is furnished by Rush Lake, on the Pembina Mountain highland near Hannah.

It will be seen in Figure 61 that it has two outlets. The lake is a shallow clay-pan of water only a few feet deep. The north outlet is the old outlet, one which was established when the water from the melting ice-sheet made the lake larger than it is now. Pembina River,

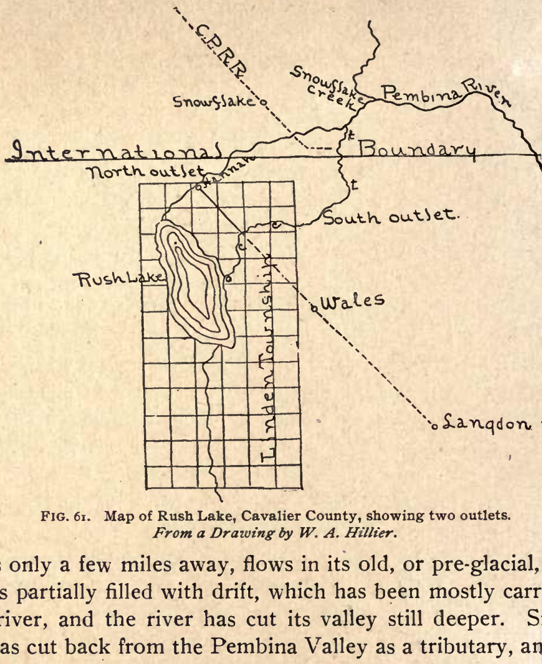


FIG. 61. Map of Rush Lake, Cavalier County, showing two outlets.
From a Drawing by W. A. Hillier.

which is only a few miles away, flows in its old, or pre-glacial, channel. This was partially filled with drift, which has been mostly carried away by the river, and the river has cut its valley still deeper. Snowflake Creek has cut back from the Pembina Valley as a tributary, and it, too, has cut a deep gorge or channel, because its mouth is made low by the deep gorge of the Pembina into which it empties.

Now, it chanced that a low place in the land surface caused a small tributary, *t*, to cut back from Snowflake Creek at the fork where the two outlets now meet. Snowflake Creek at first had its source in Rush Lake through the north outlet. But this little tributary has cut down more rapidly than the north outlet owing to the fact that more water falls over its sides, it being in a slight depression, and so it has pushed its head rapidly back.

It happened that a coulee, *c*, leading into the lake at *o* marked a little valley. This had its head about where the bend in the south outlet is now. At length the little tributary coulee from Snowflake Creek pushed back and began to draw the water of the little coulee the other way. So the little coulee which at first flowed into the lake was reversed and its channel became a part of the new south outlet.

This is just about the stage in which the two outlets are now. The north outlet is still the main outlet of the lake, that is, it carries a little more water from Rush Lake to Snowflake Creek than does the newer south outlet. But the south outlet at *t* has a deep gorge and it is rapidly cutting this gorge back so that it will soon lower the channel of *c*, and this will then become the principal outlet, and soon the north outlet will cease to carry away water from the lake entirely. Because the channel of Pembina River is deep Snowflake Creek is able to cut deeply its channel, and soon the rim of Rush Lake at *o* will be cut down and the waters of the lake will be drawn away, and its bottom will become a meadow.

CHAPTER THE SIXTEENTH.

THE BAD LANDS.

Bad Lands to Travel Through.—No part of North Dakota is perhaps more widely known or less understood than that part of the State styled the "Bad Lands." Probably about no part of the State are there more mistaken notions than about this region.

In the first place the lands are not "bad" for the purposes for which nature has fitted them, viz., for stock-raising. This is claimed by those who ought to know to be one of the best parts of all the State for profitable cattle- and horse-ranching. The region was called by the early French travelers who crossed the country in wagons "Bad Lands to Travel Through," which is a very fitting and appropriate title. The lands are not, in fact, so "bad," but they are bad to travel through. The whole region is so much cut up by deep valleys with steep sides that it is almost impossible to travel there with wagons. And the tourist who attempts to travel on horseback without a guide is very likely to "get lost."

Mistaken Notions About the Cause of the Bad Lands.—Many strange stories have been invented by travelers to explain how the lands of this region came to be so very rough. They are often described as having been made rough and jagged by great volcanic upheavals or earthquake shocks! There is scoria in the hills or "buttes," and this has given color to the notion that great volcanic fires have raged here, and the high crags and rugged hillsides with deep, narrow valleys appear to those who have keen imaginations like great rents or fissures in the rocks caused by earthquakes. Then there are many veins or beds of coal in the region and some of these are burning, and this has given rise to the idea that great fires have burned out the chasms, or that the coal has burned out underneath and the rocks overlying have then fallen in, causing the steep-sided, ragged gullies.

But careful observation and study will show that none of these causes is the true one. The earth has not been formed in the way we now see it by sudden changes. Great upheavals of the earth's crust forming mountain ranges and volcanic outbursts causing floods of lava to pour out upon the surface from the depths of the earth, have occurred in many parts of the earth, and the form and appearance of the earth have been greatly changed by such processes. But these are not the causes which have made the landscape features of the Bad Lands, nor of any part of North Dakota.

The Real Cause of the "Bad Lands."—The agent which has fashioned the landscape in the "Bad Lands" is the same as that which has been working ever since the solid crust of the earth first appeared above the seas, and dry land began to receive rainfall and to be worn away by it. The "Bad Lands" have been cut up into "Bad Lands to Travel Through" by the action of running water, just as the plateau top of Pembina Mountain is being cut up into hills by the action of streams. The buttes or flat-topped hills of this remarkable region, the deep valleys or gorges which surround the buttes, often so steep that neither man, horse nor wild beast can cross them, have been made by the eroding action of running water. The same processes of valley cutting which were studied in Chapter One are the explanation of the "Bad Lands."

The "Bad Land" Region.—A belt of country from ten to twenty miles wide in North Dakota along the course of the Little Missouri River is deeply intersected or cut into by this river and its tributary streams. The channel of the Little Missouri has been cut by the river deeply into the landscape so that the streams which flow into this river have steep bottoms, that is, they descend rapidly, and this causes them to erode or cut down their beds rapidly. Their sides, therefore, become steep and rugged. These tributary streams push back their heads into the land, as has been explained before, and often their heads work back into the plain so that they meet, and so a portion of the prairie becomes cut around by the streams forming a table-land. If this bit of land thus surrounded by deep valleys is large it is called a plateau or a "mesa." If it is a small area so that it is simply a flat-topped hill it is called a "butte."

Buttes and mesas are flat on top because the original plain or prairie was flat. The sides of the valleys or coulees are steep and rugged because the streams which form them cut down rapidly, and we have seen before that swiftly flowing streams erode their bottoms much more rapidly than do streams having slow currents.

In the spring when the snows are melting, and during seasons of heavy rainfall these streams are swollen and flow very swiftly. The rocks which make up the landscape are clay and sandstone and shale, and such rocks erode very easily under the cutting action of swift currents of running water. During the hot months of summer the coulees become mostly dry, the clays become "baked" and cracked by the sun's heat, and the sandstones and shales become crumbled. Then when the rains come and the snows melt the rocks are easily broken and carried away by the waters. Grass and other vegetation do not have time to get much foothold on the steep sides of the buttes because the earth wears away too rapidly, and so the sides of the buttes are generally naked of vegetation, except in crevices where the washing is less. The layers of clay, sandstone, shale, and often of lignite coal, are seen in parallel series one above the other just as they were laid down on the bottom of the ocean.

Different Forms of Buttes.—The sides of the buttes are worn away year by year as the rains continue to wash their sides, and the sun shin-

FIG. 62. Pyramid Butte. *Photograph by Prof. W. E. Johnson.*

ing upon their unprotected sides, and the frosts of winter, crack the clay and crumble the sandstone and shales, and the areas of the flat tops become smaller and smaller. By and by the flat top is entirely worn away and the butte "comes to a peak," and then the peak becomes lower and lower as the wearing process goes on. Thus there may be large mesas and small mesas, the small mesas grading in size into large buttes, and large buttes differ from small buttes only in the lesser areas of their tops. A large mesa may be cut up into smaller mesas or large buttes, and larger buttes may be cut into smaller buttes, by coulees pushing back and cutting up their tops. Finally the flat tops become rounded tops, and then the buttes begin to get lower, so that there are higher and lower buttes, and as the low, rounded buttes become still lower and smaller they in time wear away and become mere little naked, rounded hillocks or "bee-hives."

If there should be a harder layer of sandstone running through the butte the edges of this harder layer will not be worn away as fast as the rest of the softer materials, and so this layer will come to project out of the sides of the butte as a shelf. If the shelf is at or near the top of the butte then the butte will become a "table rock" or "capped butte." Sometimes a harder part of a sandstone layer or of lava forming a crag or jutting mass, stands out on the side or at the top of a butte, and so a "pinnacled" butte is formed.

FIG. 63. The Butte becomes a "Table Rock" or "Capped Butte."
Photograph by Miss Nellie T. Cruden.

Outside the Bad Lands.—The landscape about Dickinson, forty miles east of the Little Missouri River, is that of a broken prairie. The valleys are not so deep because the headwaters of the Heart River have to go a long way to the Big Missouri at Mandan, and this means that the "fall" is not so rapid so that the streams cannot cut their channels down so rapidly. If the headwaters of the Heart River did not have to travel the long journey of about 100 miles to the Missouri River, that is, if there were a place as low as the Missouri River at Mandan, only say ten miles east of Dickinson, the country about Dickinson would rapidly become "bad lands," for the streams would quickly cut down their channel bottoms and the prairie surface would soon become the tops of buttes.

This is what has happened thirty miles west of Dickinson at Fryburg, where the streams flow west into the Little Missouri, descending 530 feet in a distance of about ten miles.

About twenty miles north of Dickinson are what are called "the breaks." Here the gently rolling and grass-covered prairie changes suddenly to a much broken and rugged landscape with narrow valleys and buttes with naked sides. Here a stream with a deep valley and many tributary coulees, the Knife River, has pushed back into the landscape from the Missouri River at Stanton in Mercer County, and the development of "bad lands" has well begun. Farther north, after crossing the region drained by the Knife, there is rolling prairie again.

At a distance of about sixty miles north of Dickinson the prairie suddenly drops off, as abruptly as off the end of a bridge, into the valley of the lower Little Missouri at the bend where it turns east to enter the Big Missouri. Here the Little Missouri has cut its valley down like a great trough 400 to 500 feet into the prairie, and the side streams have cut the landscape on each side of the river into the most striking and majestic buttes anywhere to be seen in the North Dakota Bad Lands. The change from the grass-covered prairie to the steep and naked jagged buttes of the Bad Lands of the side of the valley-trough is as marked as stepping off from the edge of a plank platform. The traveler often has to go along the edge of the prairie for many miles before finding a coulee he can descend to the river, although the distance to the river in a direct line is less than four miles. There are only one or two places in a distance of thirty miles where it is practicable to get down to the river, ford the stream with its treacherous quick-sands, and get up again upon the prairie on the other side of the valley. Yet it is possible on a clear day to see across from the prairie on one side to the grass-covered prairie on the other, the distance across, which in this region represents the whole width of the "Bad Lands," being from seven to ten miles.

But the journey down from the prairie to the river is a most difficult one. Jagged, rough and steep, down into holes cut out by torrents of water, around slippery clay buttes, down deep and steep gorges, over hard crags of sandstone which have resisted the wearing action of sun, frost and water, passing sometimes a butte in the sides of which glisten countless crystals, passing with caution over a ledge under which burns a vast natural furnace of coal, till at length the bottom of the valley is reached, where roll the waters of the Little Missouri, yellow with their burden of sand and clay.

Halting at the hospitable door of a ranchman's log "schack," glad to rest and hear again the sound of a human voice, one may well gaze

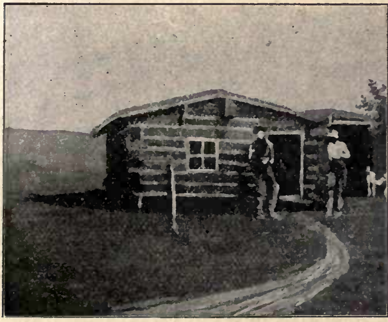


FIG. 64. "Halting at the Hospitable Door of a Ranchman's Log 'Schack.'"

back in awe and wonder at the lofty gray precipices which have been passed. "Bad Lands to Travel Through" indeed! But there is never a lack of a cordial welcome at the humble, thatched cottage of one of these ranchmen "cattle kings." True, there is nothing to drink but the warm water of the river, and this is so muddy from its sediment-laden current even in mid-summer that it is impossible to see the bottom of a spoon which is filled with it. But anything is good enough, and the best the ranchman has he deems none too good for the welcome traveler.

Here rolls the swift-flowing and sediment-laden Little Missouri, at once the cause and the explanation of the "Bad Lands." Its bed descends rapidly so that its waters flow swiftly, carrying a great burden of sand and clay, in some places little else than a great moving stream of quicksand creeping down the valley. Rolling on and on, bearing its mighty burden of sand and clay down its steep course to the Big Missouri, it adds to the muddiness of that great dirty river this pudding of rock, its waters stirred to a soup with clay, a burden which it has brought from all the coulees which girdle the buttes of all the "Bad Lands" from its long course in South and North Dakota.

The Structure of the Buttes.—One of the most striking things which the traveler observes in the Bad Lands is the arrangement of the rocks in the naked buttes in horizontal layers. So far from the region being one which has been rent and broken and upheaved by volcanic or earthquake action, so far from the rugged form of the hills being due to heat from eruptions of the earth, as has sometimes been said in descriptions of this region, the rocks are all horizontal in position and

FIG. 65. "One Layer above another like Boards in a Lumber Pile." Pyramid Park.
Photograph by Prof. W. E. Johnson.

one layer or stratum above another in as systematic order as boards in a lumber pile.

Rocks which have been upheaved and crumpled and melted in the processes of mountain making are upturned, broken, and bent, and the character of the rocks themselves changed, so that what had been soft clay or shale has been changed into slate, and sandstone into quartzite in which the grains of sand cannot now be distinguished. But no such changes have occurred in the Bad Lands. The rock-layers are in horizontal position just as they were laid down as sediments on the bottom of the sea long ages ago. The layers of clay are still clay, and the sandstone strata are sandstone now, made up of the same grains of sand as they were when the waves of the sea washed them.

All these layers of rock belong in what is called the Laramie formation, the highest in the series, or latest formed, of the Cretaceous rocks.

That these layers of rock, these sandstones, shales, and clays, were formed on the bottom of a great body of water there can hardly be doubt, for nothing but water can form clay or fine sand into such layers.

Follow along any particular layer in the side of a butte and then look across to the other side of the valley and the same layer occurs there at the same height. Follow it on and it has the same position in all the buttes. There are the same layers above it in all its course, and those layers which are below it can be seen below it in all the buttes. The edge of a particular layer as it is seen in the side of the hill is like a great ribbon stretched along the side of the valley. It keeps just the same thickness from one butte side to another as far as it is followed, till it finally plunges into the ground below the level of the stream bottom, if it is followed up-stream, or rises a little toward the surface or top of the side of the valley if it is followed down-stream. This is what would be expected if the layer itself is horizontal, for the stream bed at the bottom is not horizontal but rises up-stream, and so the layer *seems* to come down to meet the bottom of the valley, though really the stream bottom rises to meet the layer. The flat land at the top of the buttes has a slope down-stream or else the stream would not have been started, and so the layer tends to rise more and more toward the top when followed down-stream.

The only explanation of layers of rock so extensively horizontal is that they have been deposited in water upon the bottom of an ocean.

Veins, or beds, of lignite coal occur along with the layers of clay, sandstone and shale. They are of various thicknesses from less than an inch to eight feet or more, and these can be followed along the naked sides of the hills or buttes like the other rock layers. Now if lignite coal, while under the great pressure of the weight of the rocks above it were to be greatly heated, as it would be if volcanic action or earthquakes had caused great upheavals and rents in the earth, it would be changed to anthracite coal and cease to be lignite. The fact that there are beds of lignite coal all through the Bad Lands, therefore, is a proof that heat from earth eruptions was not the cause of the Bad Lands.

In many places in this region clay has been heated by the burning coal mines so that it has been baked into brick, and sometimes also it has been melted so that it looks much like lava. Where the sides of the buttes have crags of this melted rock projecting in great masses the region has sometimes the appearance of having been rent by volcanic eruptions.

Natural brick, which has been baked by the heat of burning coal mines that have smouldered in the bosom of the hills during centuries, and

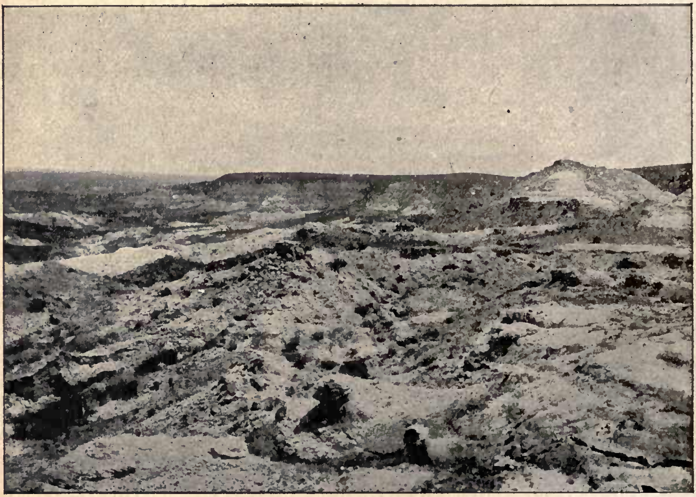


FIG. 66. "Masses of Scoria lie upon the Surface, forming Crags and Pinnacles." *Photograph by Miss Nellie T. Cruden.*

scoria, which is melted clay, are extensively used on the Northern Pacific Railway as ballast for the road-bed, and also at many of the ranches for making walks and the floors of stables.

Six miles east of Medora at Scoria the buttes look as though they had been deluged with blood, and immense masses of the hard scoria lie upon the surface crowning the buttes, and forming huge ragged crags and pinnacles. Many outcroppings of scoria and burned-clay brick occur also south of Medora in the buttes along Custer Creek and other small streams entering the Little Missouri River, shown by the red color which extends down over the lower rock layers, having washed from the red layers above.

Some Places of Interest.—The Northern Pacific Railway crosses the Little Missouri River at Medora. This is often spoken of as "the heart of the Bad Lands," though it is not in fact so "bad" here as at the point described farther down the river, for, as the valley is deeper farther toward its mouth, the buttes are higher and the chasms deeper. Medora is an interesting spot, and the traveler who wishes to see and study the Bad Lands will find no more favorable place so easily accessible.

It was at Medora that the French nobleman, the Marquis de Mores established his once famous stockyards and slaughtering houses, intending to make this a shipping point for dressed beef from this great cattle-raising district. The name Medora was given to the town in honor of his wife, who was an American lady. The baronial residence, the Mores Castle, still stands on a beautiful bluff overlooking the river and the town. The buildings which were intended to be used for the slaughtering and packing industry are still standing.

About two miles south of Medora is the old trail by which the ill-fated General Custer led his army across the Bad Lands in the famous

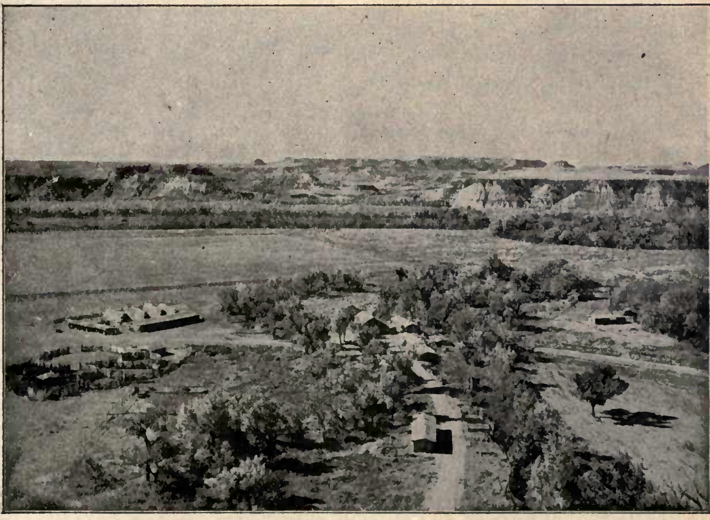


FIG. 67. "Custer Trail Ranche" is a good place from which to see the "Bad Lands."
Photograph by J. J. Freeman.

campaign against Sitting Bull in 1876. The buttes on which the picket guards were stationed while the army was encamped here are pointed out, and the marks of the trail made by the wagon wheels, and also the marks of the tent-pins at the camping place, are still visible.

Custer Trail Ranche, two miles south of Medora, named from its location on the line of the old Custer trail, is an unique place, and worth the tourists' time to visit, both because it is a typically ideal ranche, and because it is a good place from which to see the "Bad Lands." The ranche buildings, mostly made of logs, constitute a picturesque villa standing upon the plain where Custer Creek enters the Little Missouri, and surrounded by an amphitheater of buttes. The proprietors, the Eaton Brothers, are three gentlemen, and tourists will find here everything needed for their convenience for study or recreation. A carload of saddles and riding equipage, and all the things which go to made up the accessories of an ideal ranche headquarters, comfortable quarters, good food, congenial company, in fact, everything except the unpurchasable ability to ride a "broncho," are at the service of guests. A herd of riding horses of all degrees of docility, from the wild and unbridled broncho to the placid "old stager," which is suited to the novice, who may wish to see the Bad Lands, are "rounded up" early each morning from a pasture which is enclosed by twenty-eight miles of wire fence, into a corral built of logs so high and strong that the wildest deer, buffalo, or untamed broncho could neither scale it nor break through it.

A few miles farther up the river stands the log "schack" which was once the headquarters and home of President Roosevelt.

It has been stated before that the Northern Pacific Railway crosses the Little Missouri River at Medora. The railroad descends from the divide, or watershed, between the Heart and the Little Missouri Rivers at Fryburg, creeping down the steep bottom and between the jagged sides of Sully's Creek. The brakes upon the wheels of the great rolling city of parlor cars creak and grind as the train follows the curves of the track down the steep grade of more than fifty feet to the mile.

At length the porter calls out the poetic name of Medora. Stepping upon the platform of the little station the great nearly perpendicular wall of a large butte meets the gaze, its ribbon-marked side standing like a great curtain 300 feet high behind the town. The top of the butte appears to be perfectly flat, as though the upper part of a great mountain had been sawed off and taken away and this great massive base left. The ribbon-like marks across the steep side are the horizontal layers of the outcropping clay, sandstone, shales, and coal, of which the butte is composed.

After crossing the river the railroad suddenly bends northward or down the river, hugging closely against the bank at the foot of the overhanging buttes till the mouth of a coulee is reached, when it winds its laborious way up the steep path of the coulee to the prairie beyond the Bad Lands, that is, to the level of the tops of the buttes at Medora.

A View from the Top.—If the tourist secures a saddle-horse,—and there is nothing else, for there is little use in this country for wheeled vehicles,—he may go by a winding course around to the top of a butte. There he finds a level grass-covered prairie, as fine a field for a base-ball ground as college student could desire. Away down there in the valley—not away *off* there but away *down* there—is the muddy Little Missouri, houses, the railroad, the bridge! He is now on the top of the same butte which was first seen from the depot platform. Now he is looking down the face of the same wall from the upper edge, and not looking against it from near its base.

Look off toward the horizon and the scene is that of a great prairie cut up by little grooves or scratches, for the eye cannot see down into the valleys, and only the edges of the flat tops of the buttes tell where the valleys are. The other buttes are like this one, they are all little segments or blocks of prairie separated by deep and jagged valleys. Looking away across the distant landscape there spreads out over the tops of the buttes the vast prairie, the great Plateau which embraces all of western North Dakota and extends west to the Rocky Mountains. But look at the nearer landscape and it is deeply cut up by valleys. Go down into a valley and the traveler is lost to the world. He sees only the edges of the little prairies which are on the tops of the buttes. It is not the butte tops which are high, it is the valley bottoms which are low. They have been sunken down into the earth. They are furrows or troughs cut deeply into the bosom of the prairie.

Let us look off once more to the far distant horizon. Away to the south rises a huge dark mass higher than the general level. To the southwest is another dark mass, and against the western sky two other great blocks can be seen above the general horizon. These are higher buttes, buttes standing on the shoulders of buttes, as it were. They are so far away that they do not appear so very high upon the horizon, but when we approach nearer to them they are seen to stand 400 to 600 feet above the surrounding landscape, that is, higher than the tops of the buttes on the shoulders of which they stand.

On the Map of the State (Figure 1) it will be noticed that there are buttes or hills scattered over the southwestern portion of the State. These are higher buttes standing considerably above all the surrounding landscape. The Killdeer Mountains, forty miles north of Dickinson, are high buttes of this class. They are more than 700 feet above the surrounding prairie, their sides steep and ruffled with crags, their top a broad level meadow.

These higher buttes, the Killdeer Mountains, Camel's Hump, Sentinel Butte, Square Butte, Round Butte, and the many in the southwestern corner of the State which are higher than the surrounding landscape, tell an important story of the history of this region. Westward in Montana are many such high buttes. The story in brief is that the whole vast region extending west to the Rocky Mountains was once lower than it is now, that is, its elevation above sea-level was not as great. The land had been worn away by erosion till there were left only scattered patches of upland. The region had all been reduced to base-level except these few remaining parts.

"Base-level" means that the general level of the landscape has been lowered by the streams till it is so little above sea-level that erosion has practically ceased. The high hills, these highest buttes, are, therefore, vestiges of a former landscape, higher places which were not worn away, just as the Turtle Mountain Plateau was left during the long ages preceding the Glacial Period as a fragment of an older landscape which was nearly all carried away. The general level of the tops of the buttes in the Bad Lands is the old base-leveled plain, such a plain as was the great region of the Mouse Valley, and the central part of the State which is now crossed by the James and Sheyenne Rivers, before the ice-sheet swept over the landscape.

Now, this whole region was uplifted. This is what is called an epeirogenic movement of the crust of the earth. When the uplifting of this region occurred erosion began actively again, and then began to be formed the coulees by which the Bad Lands are dissected into buttes. All the "Bad Lands" along the Little Missouri River, therefore are the result of erosion since the region was uplifted. It is this uplift which gives the steep gradient to the Little Missouri and so makes the deep cutting of its channel and those of its tributaries possible.

Thus the Bad Lands are a new feature. They represent the "second childhood," or a beginning of the development of a new landscape from one which had become old. They have not always been "Bad Lands to Travel Through!" The region was once a great broad prairie lowland. The level meadows which are now left in patches on the tops of the buttes are fragments of the old base-leveled plain of a former time.

It should be said that the "Bad Lands" are not really so bad after all. They are, indeed, "bad to travel through," but it would be difficult to convince the ranchmen who have become wealthy grazing herds of cattle and horses here that they are "bad." They claim that these lands are better for grazing, area for area, than the smooth and unbroken prairie. The coulee bottoms yield excellent pasturage, for here the grass grows abundantly, and the deep valleys furnish protection for the animals in winter, and the snows which gather in the winter protect the grass so that more grows than there are cattle enough to eat. The burning coal mines also have their advantage, for these act as great furnaces warming the air near by them, and the cattle congregate about them in the cold weather to enjoy the warmth.

The Petrified Forests.—Another chapter in the history of the past is revealed in the "Petrified Forests," the remains of which are scattered over the landscape, or still stand as stumps in the places where they grew. Huge logs, looking so much like natural wood as to be easily mistaken for it, occur in great numbers. Many stumps still stand with their "roots" buried in the earth just where they grew.

We have seen before that beds of lignite coal occur in the rocks of the region. These were formed from the forests which grew during the times when these rocks were being formed. The "petrified forests" are trees which grew upon the landscape but which were not buried under such conditions as to form coal. They have become "petrified," or "stone trees."

When a tree dies in the forest, but remains standing, it does not become dry or "seasoned," but takes up water from the ground and becomes "sap-soaked." Such trees dry out by the action of the sun and wind, as do all trees, but they continually take up more water from the earth and so do not become dry or seasoned. The water which was taken up by the trees which become "petrified trees" contained mineral matter in solution. This mineral matter cannot evaporate from the tree with the water and so it is left behind in the pores or cavities of the wood. As this process went on for a long time the tree trunk, and sometimes the larger limbs also, became slowly filled with the mineral matter. Logs which lay upon the ground or became buried in the soil absorbed water which contained mineral matter, and these became "petrified" also.

The wood did not change into stone; this is not what is meant when it is said that the trees became "stone trees" or the log became a "petrified log." The wood decayed and particles of mineral matter were left in place of the wood, and so the tree trunk or log came to be replaced by stone having exactly the form and the structure of the original tree trunk or log. It thus happens that a log or piece of "petrified wood" can sometimes hardly be told from actual wood till it is examined closely. It is no joke that travelers on the western plains where no trees now grow, have been deceived by the petrified logs into thinking that they had found fuel; for such logs, falling to pieces under the action of frost and sun, so closely resemble slivers and pieces of a log of wood that only handling shows them to be stone.

When a block of petrified wood has been polished, or when a thin slice is examined with a microscope, the grain of the wood or the cell-structure can be seen just as it was in the original tree. In this way it is possible to tell what kinds of trees grew on the landscape long ages ago. And in the same way the kinds of trees which make up the coal in the coal beds can be found out.

CHAPTER THE SEVENTEENTH.

THE COAL BEDS OF NORTH DAKOTA.

The Early Landscape.—One of the great sources of wealth with which North Dakota has been endowed by Nature lies beneath the surface, and so is not exactly a landscape feature, yet it is so directly related to the landscape, and to the resources which belong to the surface, that it can hardly be omitted from a study of the landscape geology of the State. Its bearing upon the development of the wealth of the soil is so direct that it becomes a part of our subject. This is the great wealth of coal which lies buried beneath the surface of the western half of the State.

To understand the formation of the great deposits of coal we need to go back to an earlier chapter in the story of the rock formations of our State, to a time long before the present landscape was formed, and before the landscape which has been called "Old North Dakota," or the pre-glacial landscape, was formed, back to a period whose history is only known to us through the rocks which were then deposited. In fact the "date" of the history we now study goes away back to the great Middle Time of the progress of the North American Continent, and of the World, to a time when a great Inland Sea or arm of the ocean covered nearly half of the continent, and the rocks which are now the shales and sandstones underlying the drift formations were being deposited. This is the period in the earth's history known as the Cretaceous Era, the closing part of the great Mesozoic, or Middle Life, Period of the earth's history, known also as the Age of Reptiles.

The beginning of the landscape of North Dakota, as of all landscapes, was beneath the sea. The continents were first sea-bottoms and afterward became the dry land. The rock layers which are passed through in drilling an artesian well are the old mud-floors of the ancient oceans, and the different kinds of rock in these layers and the plant and animal remains they contain tell the history of the time in which they were formed. The Map, Figure 75, shows the portion of North

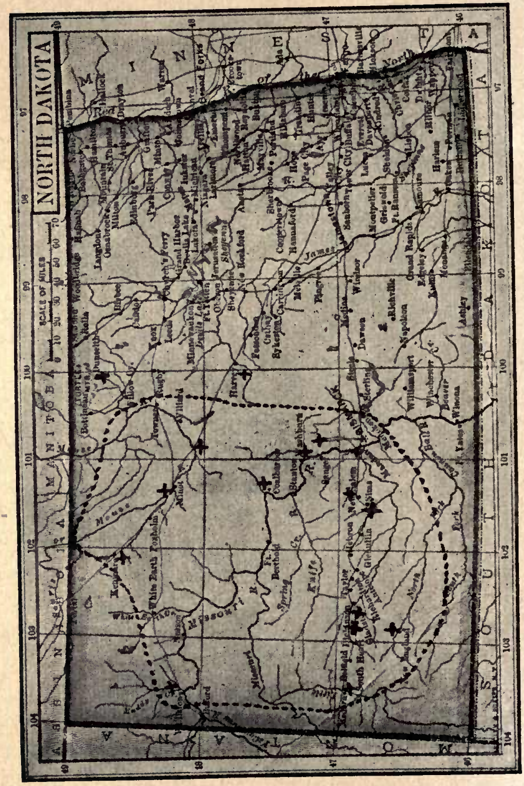


FIG. 68. Coal Deposits in North Dakota. ------ Within the area marked with the dotted lines coal may be found. X Coal is mined at the places marked X. *State Geological Survey of North Dakota.*

America in which North Dakota is embraced, and the shaded parts show the regions covered by the sea during the Cretaceous Era.

The sea was shallow and the crust of the earth underneath, as also the land areas of the continent, rose and sank. When an uplifting of the region of the sea occurred the waters withdrew and the mud at the bottom became the soil in which great forests grew. When the region sank again these forests were submerged and were in turn buried in the sediments deposited over them. It is to this rising and sinking of the crust of the earth, the elevation and subsidence of large areas, that we owe the fact of our great coal beds. When a region was elevated a little above the level of the sea this then became a great marsh, or moist lowland, and trees grew rapidly, forming dense forests. Then when the region became low enough so that the sea covered it again muds were deposited on top of the fallen trees and vegetable matter. In the clay-beds under the coal are sometimes found the stumps of trees standing apparently where they grew, and the trunks from such stumps have been found above in the coal seam as coal, though still in the form of the original tree trunk.

The fossil stumps of trees have been found in the rocks of the coal formations of Pennsylvania in the clay under the coal, their trunks running into the coal bed where this part has been formed into coal, and the top extending up into the rocks over the coal as fossil or "pet-

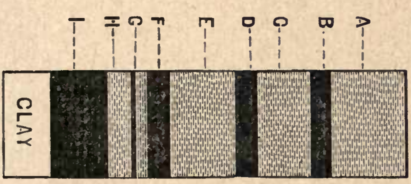


FIG. 69. Old Sims Mining Company's Mine. A—Clay and gravel. B—Thin layer of coal. C—Clay and gravel. D—Coal, one-half foot thick. Probably 30 feet above the thick layer I. E—Clay. F—Coal, about one foot thick. Probably 10 feet above the thick layer I. G—Sand and clay. H—Compact clay. I—Thick layer of coal—the one worked. *State Geological Survey of North Dakota.*

rified" wood. In the clays or rocks which are under and over the coal beds logs and leaves of fern plants such as grew during that time are sometimes found in such abundance as to make up a large part of the mass of the rock.

The coal beds of North Dakota have a layer of clay below, and very commonly one above also. These clays are often called fire-clays, because some of them are valuable for pottery and earthenware, and the manufacture of fire-brick.

How the Coal Beds Were Formed.—When the sea covered any part of the earth this region received deposits of mud and other sediments. If the lands next to the sea were not very high the streams flowing from them would not carry very coarse materials to the sea. Clay and shale are composed of very fine sediments. The waves of the sea caused by the winds and the tides would wear the bottom and shores, and the materials so worn would become spread over the sea-bottom as sandstones. The finer materials brought in by the rivers and the finest parts, worn by the waves, would be carried farther out and deposited as clay or shale.

Now the changes from below sea-level to above sea-level, or the changes by which the land became covered by the sea, or the sea-bottom was lifted up so as to become dry land, went on very slowly. A change of a few inches may have occupied hundreds of years. When the region became just a little above the level of the sea and was covered with a forest of trees together with a great variety of smaller plants, we should think of these growing and shedding their leaves season after season, some of them falling over by storms and their trunks becoming covered with leaves and debris, and this as going on for a very great length of time, as we measure time in years. But if during all this time the land was sinking slowly, so slowly that the tree trunks and leaves added to the land just about as fast as it sank, and the soaking of these with water prevented them from decaying, then after a great lapse of time there would be a layer of vegetable matter of considerable thickness all over this region, a layer of tree trunks, stems, and leaves. If in time the sea crept in and covered this region again, that is, if the sinking down, or subsidence, became great enough so that the sea came in and covered it, and streams from the adjoining lands brought their waters and sediments into it, then all this accumulation of vegetable material would be covered with mud or sediments. It might be covered with such sediments as form clay or shale, and the waves and currents might wash in more sandy materials forming a sandstone deposit. Coal beds are found to be made up of vegetable matter such as we have imagined in the case just described. Logs and stumps and leaves are found in the coal beds, changed from wood into coal; and pieces of coal which show no likeness to wood to the naked eye, when viewed with a microscope in very thin sections, show the structure of wood.

How the Wood Was Changed into Coal.—We shall now try to see how, in the long lapse of ages since it was covered by the mud and water, the accumulation of vegetable matter became changed into a coal bed.

Wood is composed principally of three substances, known as elements, and it may help us to better understand coal if we remember their names. They are Carbon, Hydrogen, and Oxygen. When wood is burned, or when it rots in the forest, the elements of which it is composed are separated, or, as the chemist would say, it is decomposed. When it is burned in our stoves the hydrogen and oxygen are separated from the carbon, and the former go up the chimney as water in the form of steam. This is a part of the "smoke." Oxygen from the air combines with the carbon and forms what is known as carbonic acid gas. This gas goes up the chimney also as smoke.

When a tree decays in the forest it "burns up" in the same way as in the stove except that the process is very slow. But the same amount of heat is given off, and the water and carbonic acid gas are formed by this slow burning, just as in the stove, the gases escaping into the air. But when wood is buried under a great weight of mud and water it is kept from decaying or burning up the way it would if it were lying on the top of the ground. It is in this condition of being entombed deep under the water and mud, shut away from the air, under the pressure of the overlying mud (which in time has become hardened into solid rock), and heated by the heat from the depths of the earth, that the wood becomes transformed into coal.

By a slow process the hydrogen and oxygen are driven off from the wood leaving most of the carbon. This carbon is the coal which we obtain from the mines. Not that all of the hydrogen and oxygen are driven off and all the carbon is left, for this is not exactly the case. Some of the carbon is driven off in combination with some of the hydrogen, in the form of oils or gases, but the carbon which remains is the black coal. Petroleum or "coal-oil," from which kerosene and gasoline are obtained, is carbon and hydrogen which have been driven off under similar conditions from animal remains entombed in the rocks.

The Different Kinds of Coal.—Different kinds of coal are formed according to the conditions under which the wood is changed. In the purest and hardest anthracite coal all the hydrogen and oxygen have been driven off and there is left the pure carbon, except such "impurities" as were in the wood in the form of mineral substances, for there is some mineral in wood which forms the "ashes" when wood is burned in the stove. Bituminous coal, or "soft coal," such as is used in steam engines and in blacksmith shops, contains a good deal of hydrogen in combination with carbon in the form of oils. This is what makes it so "dirty" to handle and causes the black sooty smoke in burning. Lignite coal (from Lignum, meaning wood) is a good deal more like the original wood. It has been changed much less than has bituminous coal, and peat has been changed still less.

There are all stages or degrees in the process of change in the coals found in the different parts of the world. Peat is dead vegetable matter which has become water-soaked and buried away from the air at the bottom of a slough or "bog." Lignite may be so little changed that fibers of the wood can still be seen, and knots and branches remain in the form in which they grew. There is also lignite which is more like bituminous coal, more oily, and not showing very clear traces of the woody fiber. Bituminous, or soft coals, have many degrees of "softness," that is, some contain more and some less of the volatile oils of carbon and hydrogen. (Volatile means flying away, because these oils quickly pass off in the form of gas when heated.) Those which contain less oil are more like anthracite, and so also there are grades of anthracite ranging all the way from the harder bituminous grades, which contain a little oil, to the hardest "diamond anthracite," which is nearly pure carbon.

The essential difference, therefore, between the various grades of lignite, bituminous, and anthracite coal lies in the extent to which the processes of change by which the volatile oils have been driven off have gone. Peat might be transformed into lignite, lignite into bituminous, and bituminous into anthracite, if the proper conditions of heat and pressure, away from air, could be supplied. The anthracite coal deposits are in the regions where mountain upheavals have occurred. The heat, which attends the upheaval of mountains, produces the change in the coal which is deeply buried beneath a great weight of overlying rocks. There is no anthracite coal in North Dakota because no mountain-making upheavals have occurred within the region of this State.

Thus we see that there is a long series of varieties, or kinds, of coal, all formed from vegetable matter which has been changed from its original condition as wood by a slow transforming process of decomposition under heat and pressure, and sealed up from the air. The woody stems and leaves falling upon the ground and becoming water-soaked, or carried upon ponds as "floating islands" and finally sinking as peat in bogs, forests building up accumulations of trunks and twigs many feet in thickness over the surface of the low marshy ground, these are the beginnings of the long series of coal formations in which North Dakota lignite represents one of the stages, and following this the many varieties of bituminous coal which include all degrees from the higher grades of lignite to bituminous and semi-bituminous, and the lower grades of anthracite, and finally the hardest diamond anthracite.

The "Western Coal Measures."—The rock formations in which the great western coal fields of North Dakota, South Dakota, Montana,

FIG. 70. An Outcropping of Coal on the Missouri River.
State Geological Survey of North Dakota.

Wyoming, and Colorado occur have been called the "Western Coal Measures" to distinguish them from the older "Coal Measures" of Pennsylvania and the eastern states, which belong to an earlier Time in Geological History. The rocks in which the western coal deposits occur belong mostly to the Cretaceous Era, whereas the eastern coal fields belong in the rock formations of the Carboniferous Era.

There is some question whether the North Dakota coal beds are buried in rocks which were deposited during the closing portion of the Cretaceous Era, the Age of Reptiles, or whether they belong to the earlier part of the next later era, the Tertiary, or Age of Mammals. The rocks are known as the Laramie Formation, and this is generally considered to belong with the Cretaceous, though the Laramie Formation seems to mark the transition, or crossing over, between the Cretaceous and the Tertiary Eras.

The highland in the western part of the State, the great Missouri Plateau, the Coteau du Missouri, embracing the western one-third of the State, is composed of the strata or rock layers of the Laramie group. Just how far these rocks extend east of the foot of the great plateau front into the basin of the James River we do not know with certainty, for they are mostly covered with drift so as not to be easily seen, but they probably extend east nearly to a line dividing the State into east and west halves.

Coal beds which are profitable for mining occur in the Turtle Mountains, and very extensive mines are worked on the upper Mouse River at Burlington and on the Des Lacs River at Kenmare, in the great valley which lies between the Turtle Mountains and the eastern edge of the Missouri Plateau. The Mouse and Des Lacs Valleys are cut down considerably below the drift, and the tunnels to the mines are made from the hillsides along the valleys.

The occurrence of mines in these valleys would seem to show that the "Coal Measures" extend across the broad valley from the Missouri Plateau to the Turtle Mountains. The opening of profitable mines near Harvey, in Wells county, indicates that the rocks in which the coal beds occur extend as far east as the upper James River.

Lignite coal has been found in some of the lower groups of rocks of the Cretaceous. The Fort Benton formation has furnished coal in some of the states farther west, but this formation is deeply buried in North Dakota. The formations lying next above the Fort Benton and below the Laramie, are the Niobrara, the Fort Pierre, and the Fox Hills. These formations are marine or sea-bottom formations, for fossils of sea-animals are found in the rocks. It seems, therefore, that North Dakota was covered by water too deep for the formation of coal beds from the accumulation of vegetable matter during the time these rocks were being deposited.

The Laramie rocks at the top of the Cretaceous series are mostly fresh water formations, with beds of coal, formed when North Dakota, or at least its western half, was just emerging from its long burial under the sea during the time in which the marine, or salt-sea formations, the Fort Benton, the Niobrara, the Fort Pierre, and the Fox Hills, were being formed. The beds of coal were formed when the land was being alternately lifted a little above and then sinking a little

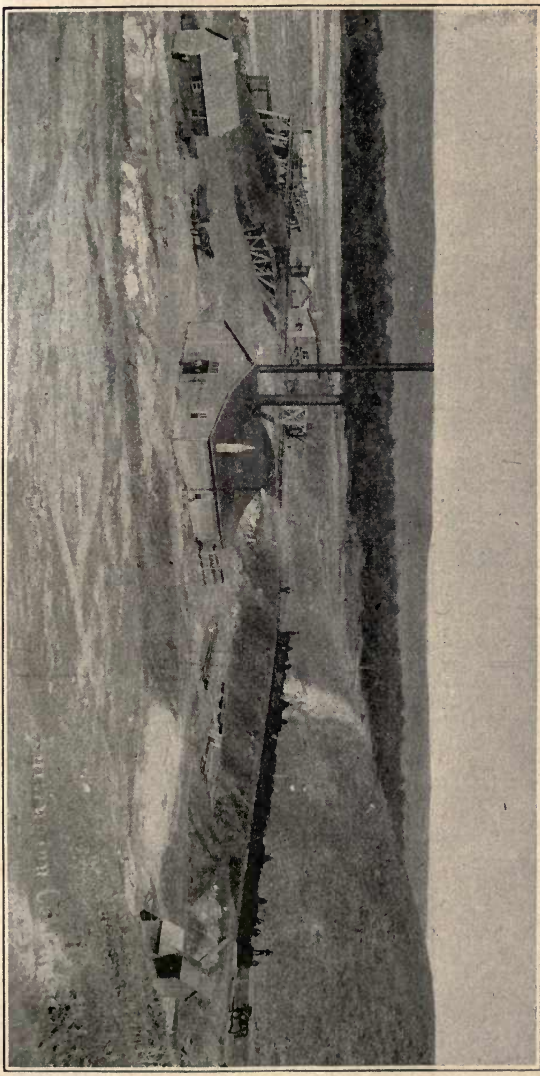


FIG. 71. Mouse River Lignite Coal Company's Mine, near Minot. *State Geological Survey of North Dakota.*

below sea-level. The conditions for the gathering of thick layers of wood, and leaves, and stems of small plants, were favorable during the Laramie epoch (an epoch is the time during which a formation is being deposited). The marshes remained marshes for a long time, and the peat-bogs continued to gather woody materials during long periods, before being buried beneath sediments. The gathering of the woody matter in broad shallow lakes, forming peat-bogs, explains why beds of coal are often not continuous for long distances, but occur in beds which are thicker toward the center and thin out toward the edges.

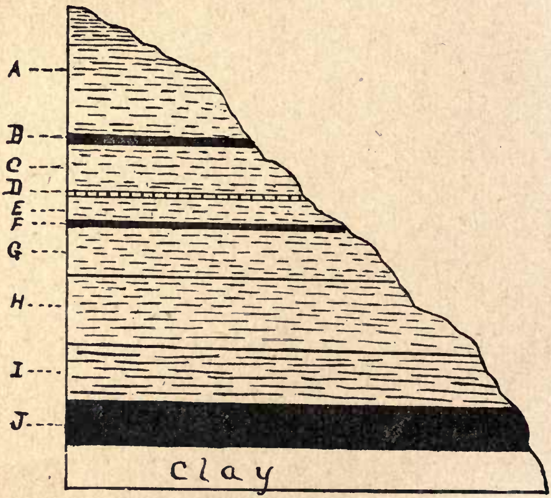


FIG. 72. Mouse River Lignite Coal Company's Mine. A—Prairie boulders, sand and yellow clay, 30 to 60 feet. B—Coal, one foot. C—Sand and clay, D—Sandstone, E—Sand and clay, about 20 feet. F—Coal, one and one-half feet. G—Sand and yellow clay, about 15 feet. H—Gray clay, 20 feet. I—Blue clay, 15 feet. J—Coal, 10 feet.
State Geological Survey of North Dakota.

This also explains why there may not be the same series of coal beds one above another in different regions. The beds run out horizontally, and so there may be more or fewer seams or beds in a vertical section in one place than another. It explains also why there may be differences in the quality of coal from different sections, and from different seams, or beds, in the same section. It would seem likely that not only higher and lower beds would be struck in different parts of the State, as well as in the same section, but different beds might be at nearly or quite the same level, though many miles apart. Fifteen to twenty seams or beds varying from an inch to twenty-six feet in thickness have been found to occur in a vertical distance of 1,000 feet in this formation in the states farther west. The thickness of the Laramie formation is much greater farther west than in North Dakota, but it is estimated to be about 1,000 feet in thickness in this State.

Sections showing the coal beds and rock layers above and below at several mines are given in the accompanying figures.

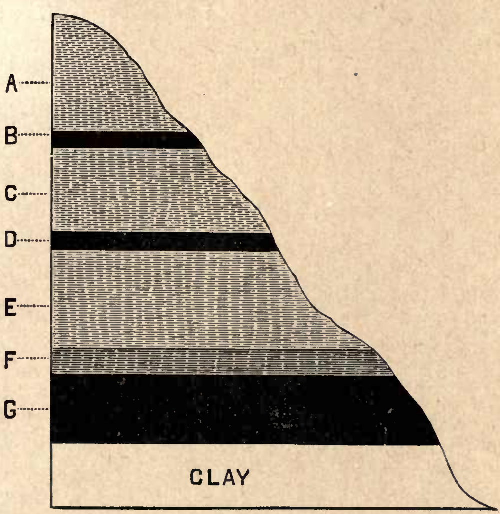


Fig. 73. Section at Lehigh Mine. A—About 25 feet clay and gravel. B—About one foot coal. C—About 25 feet clay, etc. D—About two feet coal. E—About 30 feet clay, etc. F—About three to five feet compact (gray) clay. G—About 10 to 15 feet coal. *State Geological Survey of North Dakota.*

The following table shows the elevations above sea-level of railroad stations nearest to several mines in different parts of the State. These figures do not show the exact elevations of the coal beds, but they give some suggestions of the vertical range of the coal beds of the State. The openings leading into the mines are in most cases near the stations.

Stations.	Elevations Above Sea-Level.
Harvey	1,596 feet.
Davis (near Minot)	1,573 "
Burlington	1,590 "
Kenmare	1,799 "
Williston	1,859 "
Bismarck	1,668 "
Wilton	2,158 "
Sims	1,958 "
Lehigh (near Dickinson)	2,342 "

The accompanying Map of the State shows the area where coal has been mined, and where there is not much doubt but that it can be found wherever a stream cuts deeply into the rock layers, or wherever a shaft may be sunk.

In the Bad Lands.—In the Bad Lands where the streams have cut deeply into the strata, coal beds are frequently seen in the sides of the buttes. They range in thickness from an inch or less to six or eight feet, or even more. It is a common thing for the ranchmen in this part of the State to have coal mines on their own lands or within short distances of their houses, so that they haul their fuel supply directly from the mines, shoveling it at first hand into wagons, just as in the eastern states farmers go to the woodlands on their own farms for loads of wood. Sometimes a coal bed is cut across by a small stream on the bank of which stands the house, so that coal is brought directly from the mine in the coal-pail and put into the stove! The writer has stopped at a ranche for dinner while traveling in this part of the State, and when fuel was wanted for the kitchen stove a small boy was despatched to the coal mine in the back yard to get the coal! It is not a joke that in digging a cellar for a house a coal bed may be dug into only a little below the surface, so that in the winter the owner of the house may go to the coal mine after a scuttle of coal without even going out of his own house!

A point of advantage the western farmer has over his eastern cousin lies in the fact that in the west the fuel comes from a forest which lived and flourished thousands of years ago, and the land at the surface, over the coal bed, may be cultivated, or used for grazing, while at the same time the coal forest underneath furnishes the supply of fuel. But in the east the woodland occupies a special preserve so that the land cannot be used for farming purposes!

CHAPTER THE EIGHTEENTH.

THE BEGINNINGS OF NORTH DAKOTA.

The Sea Bottom on Which the Rocks Were Deposited.—The great Inland Sea in which the rock formations of North Dakota were laid down as sediments extended from eastern Minnesota over North Dakota and Montana to Idaho and Washington, and south to northern Texas.

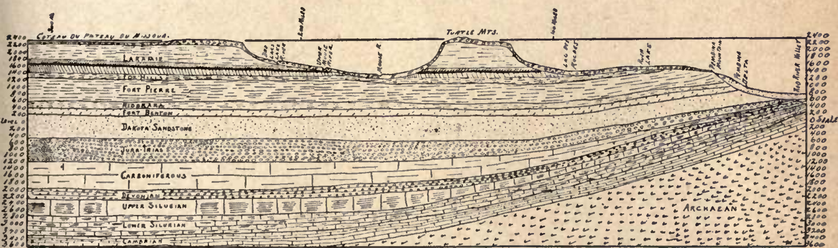


FIG. 74. Generalized Section across Northern Portion of North Dakota, showing the Formations.
From a Crayon Drawing by Miss Bessie M. Willis and the Author.
Re-drawn by Prof. Thomas H. Grosvenor.

Into this great sea were borne the sediments from the surrounding land areas, and the waves of the great shallow sea beat upon the shores and eroded the rocks into sand and mud and distributed them over its bottom, forming the rocks which now make up the sandstones and shales of the Cretaceous series, or system. North Dakota was then all under water.

The Cretaceous system, or series of rocks, is divided into Lower and Upper, the basis of this separation being the different conditions of the sea bottom during the earlier and later times of the Cretaceous Era. The Lower Cretaceous rocks do not, so far as we know, occur in North Dakota. The division into Lower and Upper is, therefore, made from the rocks in other states. The Upper Cretaceous, or what will here be called simply the "Cretaceous" series of rocks, is subdivided into several formations, each distinguished by certain characteristics which separate it from the others. The lowest of these formations, the Dakota Sandstone, is at the bottom of the series, so far as we have got down to the "bottom" in North Dakota. The other formations follow in the order in which they were deposited from below up, each formation being described as "shale" or "sandstone," etc., according to the kind of rock most common in that formation. A "shale" formation often contains some sandstone, however, and a "sandstone" formation often has layers of shale. Clays occur also in nearly all the formations. The thickness so far as it is known is given for each formatioı

	The Geological Formations.	Thickness.
6.	Laramie Sandstone, Shale, and Clay, with Lignite Coal	1,000 feet.
5.	Fox Hills Sandstone......................	100 "
4.	Fort Pierre Shale, with Beds of Clay.......	600 "
3.	Niobrara Shale, Calcareous (Lime)........	150-200 "
2.	Fort Benton Shale........................	200 "
1.	Dakota Sandstone, with Lignite Beds......	600 "

The Fort Benton and Niobrara formations are together called the Colorado formation, and the Fort Pierre and Fox Hills formations are together called the Montana formation, in the western states, but in North Dakota it seems more convenient to use the names and divisions here given.

The total thickness of all the Cretaceous series in North Dakota is thus seen to be nearly 3,000 feet. These formations, however, are thinner toward the east. The artesian wells at Devils Lake and Jamestown passed through about 1,400 feet from the upper layers of the Fort Pierre Shale to the Dakota Sandstone.

When, in speaking of the rocks which come to the surface, or outcrop, at any place, any one of these names is given to the rocks, it shows in what part of the Cretaceous series it belongs, and hence whether it is older or more recent than some other of the series. The lowest was deposited first, and, therefore, is the oldest, and so on up through the series.

The lowest and oldest, the Dakota Sandstone, and the highest and most recent, the Laramie Sandstone, are fresh-water or brackish formations, that is, they were deposited as sediments either in ponds and pools of fresh water, or else upon the bottom of a very shallow sea in which the water was only slightly salt, or brackish. The land now embraced in North Dakota was slowly sinking, and the sea was creeping upon the land when the Dakota Sandstone was being formed. The land was rising, and the sea was drying off from the bottom when the Laramie rocks were deposited and the great forests grew which formed the coal beds. The other formations, those formed after the Dakota Sandstone and before the Laramie, are marine or sea formations deposited when the whole region of North Dakota was a sea bottom.

It is to the fact that the rocks of the Fort Benton, Niobrara, Fort Pierre, and Fox Hills formations are salt sea sediments that the water of the lakes and streams of a large part of the State contain so much salt and alkali. The salt and alkaline substances were in the sea water, and so, as the sediments were deposited, they were saturated with salt and alkali water, and when the sea dried off from the mud and sand of the bottom, and these became the shales and sandstones of these formations, they contained the salts and alkalies which now dissolve out into the waters of the lakes and streams.

The highland which formed the western shore of Lake Agassiz, extending from the Pembina Mountain on the north to the Coteau des Prairies on the south, called the Manitoba Escarpment, is an outcropping of the edges of the horizontal layers, mostly of the Fort Pierre formation. This outcropping was caused by the erosion of the great pre-glacial valley in which now lie the level prairies of the bottom of Lake Agassiz.

We have seen how this great valley was filled with the ice of the Great Ice-Sheet, and how as the ice melted this basin came to be filled with water because the course of the river to the northward was blocked by the ice, and Lake Agassiz came to occupy the great valley, its western shore being the escarpment, or cut off edges, of the Fort Pierre, Niobrara, and Fort Benton formations. We are now studying a much earlier period, when the rocks were deposited in which the valley was afterward cut.

The "Manitoba Escarpment."—The great Inland Sea during the Cretaceous Era spread over all of North Dakota and a large part of Minnesota, although all of Minnesota, and probably a little of the eastern edge of North Dakota, had before been raised above sea-level so that it had been dry land. But the Dakota Sandstone was deposited over a large part of western Minnesota, showing that the sea not only

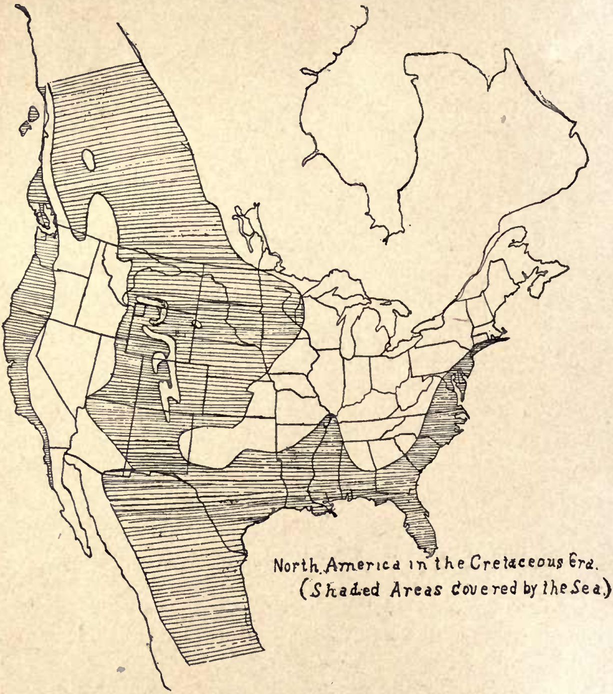


FIG. 75. *After Dana.*

covered North Dakota and the states west to where the Rocky Mountains are now, but extended east, covering much of Minnesota. So the sea-bottom formations, the Fort Benton, Niobrara, Fort Pierre, and probably the Fox Hills, were deposited over all of North Dakota and western Minnesota, but during the long period following the Cretaceous Era, known as the Tertiary Era, and before the time of the

Glacial Period, the great valley of the Old Red River of the North was eroded, carrying away the sediments which had been deposited over eastern North Dakota and western Minnesota, so that the outcropping edges of these formations now occur along the west side of the Red River Valley.

The strata, or layers, which are at the top of this highland underlying the drift in its northern and higher portion, the Pembina Mountain, and extending south more than half way across the State, and also the outcropping edges along the northern half of the highland, are Fort Pierre shales. The Niobrara and Fort Benton formations outcrop lower down on the old valley wall, but they are deeply buried by the drift so that we do not readily see them. About ten miles east of Lisbon, below the Big Bend, just after the Sheyenne River enters upon the plain of the Lake Agassiz bottom, this river has cut a deep gorge in the Fort Benton shale. This formation is also penetrated in drilling artesian wells in the southeastern part of the State, lying beneath the drift.

The Dakota Sandstone forms the floor of the old valley beneath the great depth of drift in the part of its course lying between Grand Forks and Larimore and southward to Casselton and Fargo, though patches of shale, which are probably Fort Benton, were struck by artesian wells at Fargo and Mayville. These probably represent the tops of higher places or low hills on the old (or pre-glacial) valley bottom. Farther south in the higher part of the old valley the floor of the valley is probably the Fort Benton shale. This shale is struck by artesian wells in the vicinity of Wahpeton. In the lower (northern) portion of the valley the floor is older rock than the Dakota Sandstone, the artesian well at Grafton passing through the drift into limestone belonging to the Lower Silurian, which is much older than the Cretaceous. The section through the formations of the northern part of the State (Figure 74) will make this more clear.

West of the Manitoba Escarpment, in the central portion of the State, the eroded surface of the Fort Pierre and Fox Hills formations underlie the drift. The Sheyenne, James, and Mouse Rivers have cut down their channels in many places so that the strata of these formations have been cut into. The deep valley of the Sheyenne River has cut into the Fort Pierre Shale through much of its course from Devils Lake south to the Big Bend east of Lisbon, and a large amount of shale was added to the Sheyenne Delta, eroded along the course of this valley during the time of the glacial flood waters. The Valley of the

James is not nearly as deep, and is cut through much of its course in North Dakota in the Fox Hills Sandstone.

The Fox Hills Sandstone extends east underneath the drift probably nearly to Devils Lake. From the fact of this sandstone being the surface rock from the vicinity of the Turtle Mountains south across the State, comes the sandy character of the drift hills, and the tracts of sand dunes along the eastern side of the old Lake Souris bottom, the soft sand-rock being easily ploughed up by the moving ice-sheet, and dumped in the lake by the melting of the ice.

The Missouri Plateau.—Farther west rises abruptly the great hill-country known as the Plateau du Coteau du Missouri, or the Plateau of the Missouri Hills. This highland is composed of Laramie rock-strata, and the sudden rise from the lower land of the James and Sheyenne Valleys of 300 to 400 feet is due to the erosion of the eastward continuation of these rocks, just as the Fort Pierre, and the formations below it, in the eastern part of the State, were eroded by the pre-glacial Red River of the North, forming the Manitoba Escarpment.

The Turtle Mountains, on the International Boundary about midway between the Coteau du Missouri and Pembina Mountain, is a plateau of Laramie strata, surrounded on all sides by great wide-spreading prairies, the old valley bottoms of the rivers which eroded the interior portion of the State, and carried away the upper part of the Fox Hills and Fort Pierre formations, in the region east of these mountains, and the Laramie strata west to the highland of the Coteau du Missouri. Thus the Turtle Mountain Plateau is a fragment of the great Missouri Plateau which was not carried away by the erosion which lowered the whole country round about it.

Dog Den Butte, the Mauvais or Big Butte, south of Church's Ferry and Leeds, and probably Devils Heart and Sully's Hill south of Devils Lake, are fragments of the Laramie strata of the great Missouri Plateau which have not been entirely carried away by erosion.

All the great plateau country to the westward is Laramie. The Bad Lands along the Little Missouri River, and the Yellowstone in Montana, are Laramie rocks, made up of sandstones, shales, and clays, with beds of coal and lava. This great upper part of the Cretaceous series or system of rocks extends westward to the Rocky Mountains. It extended once much farther east than now also, and it probably covered all the State. At least it reached farther east than the Turtle Mountains, for the form of this plateau shows that the rock layers once

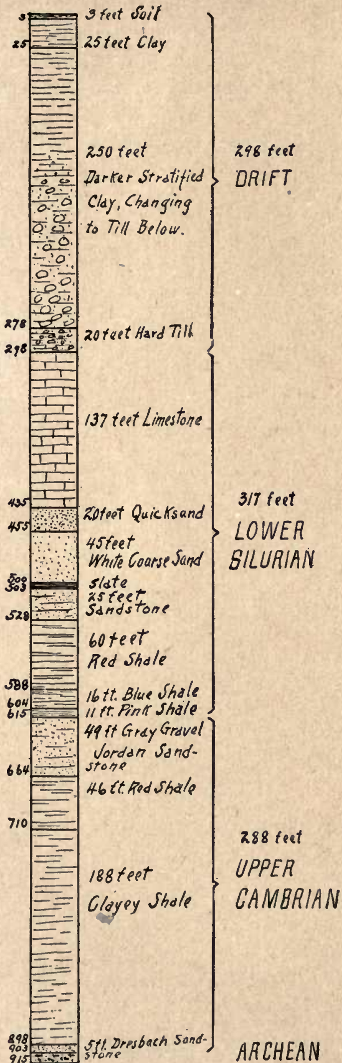


FIG. 76. Section showing the Rock Formations passed through by the Artesian Well at Grafton. *After Upham.*

extended farther east. This broad valley between the Turtle Mountains and the Missouri Plateau was eroded during the same time that the Old Red River Valley was being formed farther east.

The Older Rocks Underlying the Eastern Portion of the State.—Below the Dakota Sandstone in the Red River Valley are still older rock formations. The Jura-Trias, the Carboniferous, the Devonian, the Silurian, the Cambrian, and finally the oldest of all, and the oldest in the world, the Archaean, lie one below another under the rocks of the State, and their thinner eastern edges extend along the eastern portion of the State. These are shown by borings for artesian wells. An artesian well at Grafton, 915 feet deep, after passing through nearly 300 feet of drift penetrates several older formations, into the granite at the bottom,—which may indeed be called "the bottom," for it was the first formed and hence the oldest of all the solid rocks of the earth.

This oldest Archaean granite comes to the surface in Minnesota about Lake Superior, and northward in Canada. It was the old, first beginning of the Continent, being at first an island raised above the sea. Other formations lie all around it and flank or lap upon its sides. The ice of the Great Ice-Sheet ploughed its way across it and broke off huge masses, which are the "hard-head" boulders now scattered over the prairies.

West of Winnipeg in Canada the Silurian, which is a limestone formation, is the surface rock, and from it were broken off and carried away limestone fragments by the great ice-plow, and these were ground up to make the fertile wheat lands of our State. Many of them are scattered over the prairies, not having been entirely ground up by the ice-mill. Boulders of the softer and more easily crumbling shales and sandstones were soon broken and pulverized into clay or ground into sand.

How Old Is North Dakota?—It is natural to ask how long ago it was that the great Inland Sea covered North Dakota, and how long it has been since the forests grew which have become the coal beds. It is a fair enough question, and one which any thoughtful person is bound to ask, in his mind at least. But it is one which the most learned scientist cannot answer with accuracy, as time is measured in years. We do not know how long it is since civilization began upon the earth because we have not a written record from the beginning. We can only infer from the marks left in buildings and implements and other things which show man's handiwork. So we can only infer from the great handiwork of Nature how long the time has been that geologic processes have been fashioning the earth. We do not know how long the time has been since the Glacial Period, or Ice Age, but we know that it is only a little while as compared with the time since the coal beds of North Dakota were formed.

Many attempts have been made to get a basis of comparison by which the time since the Ice Age could be measured in years, but no conclusion which can be considered as fact has been reached. Nothing more than estimates can be said to have been made. A method of studying the problem is this: The gorge of the Mississippi River from Fort Snelling to the Falls of St. Anthony has been formed since the closing stages of the Ice Age. This is known because the River was forced out of its old channel by the drift which filled its valley, and when the river re-entered its old channel at Fort Snelling a "falls" was formed. The falls have been "moving back," by cutting the rock ledge over which the water passes, ever since that time. The gorge at Niagara Falls, New York, has been formed in a similar manner, the gorge having been cut back from Lewiston to the present cataract. Now it would seem a simple matter to see how far the falls cut back in one year, and then by measuring the length of the gorge (from Fort Snelling to the falls at Minneapolis, or from Lewiston to the Niagara cataract), divide this distance by the amount of cutting in one year. This would give the time in years since the close of the Ice Age. But the problem is not as simple as it may at first appear. Geologists have reached estimates ranging from 6,000 to 10,000 years (Upham) to more than 30,000 years (Gilbert). So that the result at best is only an estimate.

But suppose we assume a rather low estimate of 10,000 years for the time since the close of the Ice Age, then how long has it been since the coal beds were formed during the closing stages of the Cretaceous era? How long was North Dakota under the sea after the Dakota Sandstone had been deposited, while the salt and alkaline sediments, which now make up the shales and sandstones of the Fort Benton, Niobrara, Fort Pierre and Fox Hills formations, were being deposited? Attempts have been made to estimate the length of geologic periods by measurements of the rate of accumulation of sediments on the sea bottom at the present time, but these estimates are quite as variable as those of the time required for the cutting of the gorges referred to. Without considering the methods of computing by which the estimates have been made we may think of the time of the Ice Age, that is, the length of time that the cold of the Glacial Period continued, as five to ten times as long as the time since the ice finally melted, or the time during which the gorge of the Mississippi River below Minneapolis, and the Niagara gorge from the Falls to Lewiston, were being cut, or 50,000 to 100,000 years (Upham, Prestwich). The time since the formation of the coal beds in North Dakota would be from fifteen to twenty-five or thirty times as long as that which has passed since the beginning of the Glacial Period, or nearly 300 times as long as the time since the ice finally melted away and Lake Agassiz began to drain toward the north and the present Red River Valley began to appear as dry land.* This would make the age of the shales and sandstones and coal beds of North Dakota nearly 3,000,000 years, and the time during which the salt-sea sediments which occur between the Dakota Sandstone and the Coal Measures, the Fort Benton, Niobrara, Fort Pierre and Fox Hills formations were being formed, may have been 1,000,000 years.† Of course, no one knows how long it has been. These figures are only estimates, but they will at least serve as a suggestion that *time is long*. They should not be taken by the reader as settled facts, for they are not. But that geologic time is immensely long as compared with human standards of years we may safely admit.

Perhaps a better idea of the great length of geologic time may be gained from this, that the greater part of the Rocky Mountain region was under the sea during the Cretaceous era and perhaps till after the depositing of the rock strata of the Laramie formation with its coal beds in North Dakota. In fact, it is likely that the great uplift by which the Laramie rocks in North Dakota were raised so that the region became dry land was a part of the beginning of the great movement by which the Rocky Mountains were heaved up. And since the Laramie strata were deposited and the coal beds were buried the region of the Colorado Cañons has been elevated from 10,000 to 11,000 feet, and erosion has cut down 10,000 feet (Dutton). And in British Columbia it is estimated that an elevation of 32,000 to 35,000 feet has taken place since Cretaceous time, and cañons 5,000 to 6,000 feet deep have been eroded (G. M. Dawson).

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* Based on Walcott's estimate of the length of Cænozoic Time, and Upham's estimate of the length of Glacial and Post-Glacial Time.

† Based on Walcott's estimate of 27,240,000 years for the whole of Mesozoic Time.

CHAPTER THE NINETEENTH.

THE WATER SUPPLY.

Conditions Necessary for Artesian Wells.—In a prairie country more than in a broken or hilly country the water supply for men and animals comes from wells. In a prairie country there are generally few streams and these are apt to be small and often sluggish so that their waters are not good for drinking, and there are not usually many springs. In North Dakota a large part of the water supply for towns and cities as well as farms comes largely from wells. This condition makes the possibility of obtaining artesian wells over a large part of the State a very fortunate thing. An immense saving to the people of North Dakota results each year from the fact that the water flows from the depths of the earth without being pumped.

Artesian wells have been in use for hundreds of years, but the fact that they have been long known does not make it possible to obtain them in every place. It is only where the structure of the earth deep below the surface is such as to cause an upward pressure of the water that an artesian well can be obtained.

The word "artesian" is borrowed from France from the province of Artois, because such wells were first known there. When flowing wells began to be found in other parts of the world they were called Artois wells or Artois-ian wells, and by usage the word has become "artesian."

Artesian wells differ rrom common wells in that the water flows from them naturally, that is, without being pumped. They are often deep, but there are many wells not artesian which are much deeper than some artesian wells. Sometimes artesian wells are a mile or more in depth, and there are many in North Dakota which are less than fifty feet in depth. There are even natural artesian wells, in which the water rises to the surface as springs, but yet the flowing of the water is due to the same causes as those which make the flow from a boring.

The reader will be able to understand the conditions which are necessary for an artesian well from Figure 77. The section shows the relation of the underlying rocks from the Red River Valley westward to the Rocky Mountains. The source of the water supply is the region along the base of the Rocky Mountains where the rain which falls upon the ground soaks into the soil and travels underground along the porous gravel and sand of the Dakota Sandstone. The water follows this layer at first for the same reason that it flows down hill on the surface. It fills all the little cavities or spaces in the loose rock because of the pressure due to the weight of the water.

Now, if a boring is made from the surface down through the overlying rock layers the water will rise in this opening and there will be

FIG. 77. Section showing Water Supply of Deep Artesian Wells. *After Upham.*

a flowing well. How rapidly the water will rise above the ground and flow out at the surface or how high it will rise depends upon the pressure or "head" which the water has, for the same reason that the height of the tower on which the water tank stands in a city determines how rapid a stream of water can be poured from a hose in time of fire, or how high a stream can be thrown, or how high it can be made to run in pipes in the houses.

Not taking into account the friction of the water in its passage in the rocks it will rise as high as the source or collecting ground along the foot of the mountains from whence it comes. But it will not actually rise nearly as high because of the friction, but we may think of the flow from an artesian well being determined by the "head" or height of the land where the rainwater soaks into the ground, and if this is a good deal higher than the surface where the well is the water will flow out with considerable force, but if it is not much higher and is a long distance away then the water may rise only part way in the boring and not flow out at all.

There must be a layer of clay or shale or some rock through which water does not pass readily both above and below the gravel and sand layer or else the water would soak away into the other layers of rock and so would not rise in the boring and flow out at the surface. There are, therefore, certain conditions necessary for an artesian well; there must be, firstly, a collecting ground higher than the surface where the boring is made; secondly, there must be a layer of rock both above and below the layer from which the water flows through which water cannot readily pass; and, thirdly, there must be enough difference between the height of the collecting ground and the place where the boring is made to overcome the friction or resistance to the passage of the water.

Deep Artesian Wells West of the Red River Valley.—The artesian wells at Devils Lake, Jamestown, Ellendale and Oakes, and a large number in South Dakota, obtain their water supply from the Dakota Sandstone by deep borings through the overlying formations. The borings vary in depth from less than one-fifth of a mile at Oakes to more than one-third of a mile at Devils Lake and Jamestown. These pierce through the Fort Pierre, Niobrara and Fort Benton formations, which are mostly shale and through which water does not readily pass.

From the section showing the formations of the State (Figure 74) it will be seen that the top of the Dakota Sandstone in the northern portion of the State is nearly at sea-level. The depot at Devils Lake is 1,468 feet above the level of the sea, and the surface about the well is six or eight feet higher. The depth of the well is 1,511 feet. The boring penetrates eighty feet into fine white sand. The top of the Dakota Sandstone is, therefore, at this point about forty-five feet above sea-level.

The depot at Jamestown is 1,395 feet above sea-level, and the well reaches a depth of 1,476 feet, penetrating into the top of the sandstone. The surface about the well is about eight feet below the depot. The upper part of the Dakota Sandstone beneath Jamestown is therefore about eighty-nine feet below sea-level.

Ellendale is 1,449 feet above the sea and the well penetrates the Dakota Sandstone at a depth of 1,087 feet, so that the upper portion of the Dakota Sandstone at this place is 362 feet above sea-level. At Oakes the elevation is 1,322 feet and the Dakota Sandstone is reached at a depth of 944 feet, so that the Dakota Sandstone beneath the surface at Oakes is 378 feet above the sea. Farther south in South Dakota the sandstone is reached at still less depths, showing that its upper portion is nearer the surface southward. At Vermilion in the southeast corner of South Dakota the sandstone is reached at 323 feet below the surface, or 818 feet above sea-level.

It would, therefore, seem that artesian wells may be expected to be obtained anywhere over the central and eastern portion of the State, and much farther west, by penetrating to the depth necessary to reach the Dakota Sandstone. It is not always possible, however, to get a flow of water even when the general conditions are such as to warrant the expectation. Sometimes the sandstone is pierced in a place where from some local cause, such as an unusually hard place in the sandstone rock, the water is not able to pass readily through the rock and so cannot rise in the boring with force enough to cause a flow.

The artesian well at Grafton penetrates through the drift to a depth of 298 feet, but instead of entering the Dakota Sandstone passes next through 137 feet of limestone belonging to the Lower Silurian forma-

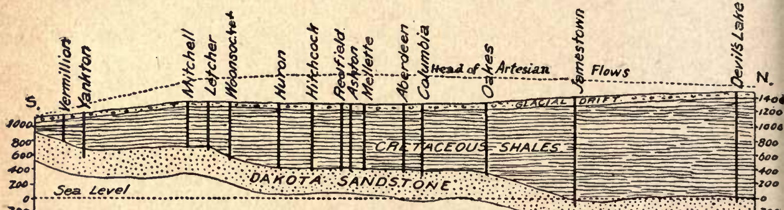

FIG. 78. Section showing the Series of Artesian Wells from Devils Lake and Jamestown southward to Yankton and Vermilion. Horizontal scale, 90 miles to an inch. *U. S. Geological Survey.*

tion, and obtains its flow of water from a sandstone layer still lower in the Lower Silurian series. The well had a depth of 915 feet when first drilled, a small flow of very salt water being obtained at a depth of 898 feet, from a sandstone layer next to the Archaean Granite. The boring was filled, however, below the sandstone layer which yields the very large flow of brackish water.

A section of the rocks passed through by the boring is shown in Figure 76. It is interesting to note that the Dakota Sandstone was not struck at all, showing that this sandstone does not, in this part of the Red River Valley, extend as far east as this.

Artesian Wells in the Red River Valley.—In the Red River Valley there are many artesian wells which range in depth from 250 feet to 400 feet, and which, like the deep wells at Devils Lake, Jamestown, Tower City, Oakes and Ellendale, derive their water supply from the far-distant foothills of the Rocky Mountains.

From Blanchard north to southern Manitoba most of the artesian wells are of this class. The source of the water is the same as that of the deep wells farther west, that is, the Dakota Sandstone. To obtain an artesian well, therefore, it is needful to penetrate through the mass of drift. The greater part of the material of the deeper portion of the floor of Lake Agassiz consists of boulder-clay or till. Water cannot pass through clay much more readily than through a porcelain dish. The glacial clay has, therefore, to be drilled through, and when the sandstone is reached a flow of water usually results. This is not always the case, for sometimes the sandstone is hard and compact, so that the water is not able to soak through it readily, and so it is not always possible to obtain an artesian well.

The drill penetrates through a few feet of soil and fine silt and soon enters blue clay. Occasionally there are layers of sand and gravel, and large boulders are sometimes struck. But always a harder layer of clay known to the driller as "hard-pan" is found at the bottom of the clay, and then beyond this is the water-bearing sandstone. This bottom "hard-pan" is the part of the drift which is next to the underlying rock, and is always passed through in drilling or digging wells either in the Red River Valley or west of it wherever the drift lies upon the surface. Several wells in the vicinity of Mayville and Blanchard, and northward, range in depth from 300 to 400 feet, water being obtained from white sandstone just below the hard-pan.

Mineral Substances in the Water of Artesian Wells.—The water from artesian wells in North Dakota generally contains some mineral matter. That from some wells is very salt, that is, it contains the kind of salt we use in our food, or "common salt." Other wells contain a greater amount of salt, but do not taste "salty" or like brine; they contain other kinds of salt. Some of these give a bitter taste to the water, and sometimes the water is a bitter brine, and still other salts give a sparkling and pleasant taste such as those of "hard" waters in limestone regions. Hard limestone waters are sometimes called "pure" because of their clear and sparkling character. Such waters are far from pure though they may be good for drinking and general uses. Some wells furnish water that is soft so that it is good for washing. It is "soft" because it does not contain those salts which make it "hard," though it may contain more salts of other kinds. The water from the deep well at Devils Lake contains seven times as much common salt (Sodium Chloride) and three and a half times as much Glauber's salt (Sodium Sulphate) as the water from the Jamestown well, and yet the water from the Devils Lake well is called "soft."

The salts which are in the lake water of Devils Lake are much the same as those which are in the water of the artesian well at Devils Lake city. The waters, therefore, which soak into the ground and become the source of the artesian well 600 or 700 miles away dissolve the salts from the rocks through which they pass, in a similar manner as the rains falling upon the ground dissolve the salts from the soil and carry them into the lake.

It should be remembered that the rocks in North Dakota, the Cretaceous formations, were deposited in a great inland sea or ocean, and ocean waters are always salt. Our artesian waters are, therefore, much like the sea water of the ancient oceans.

The water from all the wells is not the same because it does not all pass through the same kind of rock. Wells, therefore, in different localities furnish water differing in quality. Different rock layers contain some more and some less of a certain kind of salt. The rain water soaking into the ground and passing slowly through it dissolves out different kinds of salt.

Another Class of Artesian Wells.—There is another class of artesian wells in the Red River Valley in which the source of the water supply is probably not the same as that of the deep wells west of the valley and the wells which yield salt water in the valley. They are obtained at depths of even less than forty feet and from this up to 250 feet. Sometimes within a distance of only a few rods flowing wells are obtained at depths varying greatly, and the water in the wells of this class is gen-

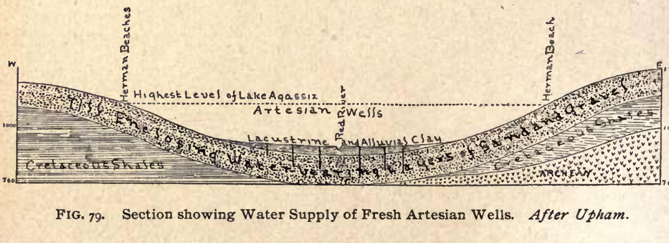

FIG. 79. Section showing Water Supply of Fresh Artesian Wells. *After Upham.*

erally fresh. These three facts distinguish this class of wells from those we have been studying: they are not as deep as those just described; they vary much in depth within short distances, and the water contains generally very little of any kind of salt.

These wells do not derive their water supply from the Dakota Sandstone, but from layers of sand or gravel in the drift. The mantle of drift, as we have seen, covers the underlying rocks over most of the State like a great blanket, but much thicker or deeper in some places than in others. Upon a large part of the Red River Valley it is 300 or more feet deep, while on the higher lands outside the valley it is often not more than fifteen to twenty-five feet deep. We have seen before that the drift is made up of a variety of materials—boulders, gravel, sand and clay. Wherever the surface is sandy the rainwater soaks in readily. If sandy and gravelly layers extend for long distances beneath the surface then water soaking into these loose beds may follow along them for long distances. Thus it happens that water which falls upon the sandy hills and rolling prairies may be carried along belts of gravel

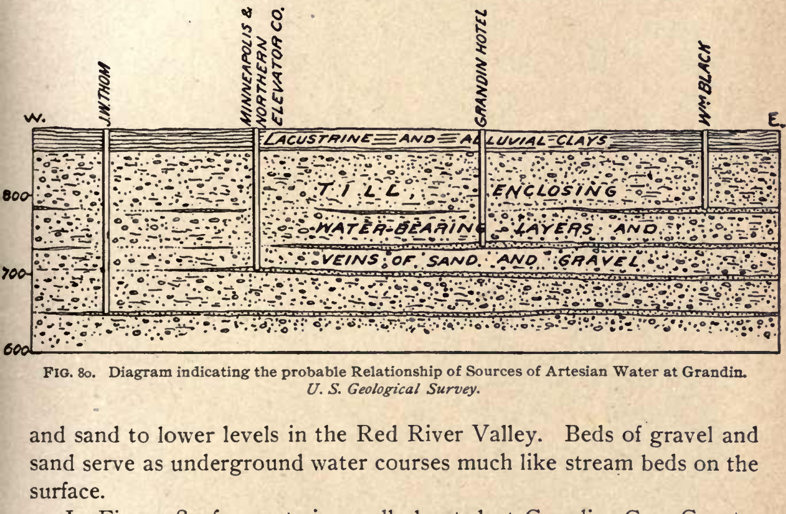

FIG. 80. Diagram indicating the probable Relationship of Sources of Artesian Water at Grandin.
U. S. Geological Survey.

and sand to lower levels in the Red River Valley. Beds of gravel and sand serve as underground water courses much like stream beds on the surface.

In Figure 80 four artesian wells located at Grandin, Cass County, are represented which have depths of 105 feet, 158 feet, 187 feet and 248 feet. These wells are only a few rods apart, and the water from them is fresh, containing but little of any kind of salt. It is good for drinking or for any purpose. The water of these wells, as of many other shallow artesian wells in the Red River Valley, has probably come from the higher land west of the valley not so very far away where the soil is sandy or gravelly, and it has followed the loose layers of sand and gravel which extend between beds of clay, down to the lower valley, and thus a head is given which causes the flow when these "veins" are tapped by the drill. These veins are probably long, narrow beds of gravel or sand, but in some parts of the valley wells are obtained at about the same depths, showing that the beds are in some places not long, narrow strips of gravel or sand, but wide sheets. Such shallow artesian wells yielding plenty of good water are found over a large part of the southern and eastern part of the Red River Valley south of Blanchard, and north to Crookston in Minnesota.

The waters are fresh because they have not passed through salty rock layers for any great distance. Waters which flow underground for long distances and through different kinds of rocks which contain salts are salty or alkaline because there are many salts and alkaline substances in the Cretaceous formations, and the waters in passing through these slowly dissolve the mineral substances from them.

Common Wells.—On the whole, North Dakota has an abundant supply of good, wholesome water. Almost anywhere west of the Red River Valley, which means nearly the whole State west of the eastern tier of counties, the supply of water from surface wells is abundant and of good quality. The mantle of drift over the underlying shales is not so deep but that it is an easy matter to dig or drill through it, and plenty of water is generally obtained as soon as the overlying drift is passed through at depths of fifteen to seventy-five feet. The writer thought on a hot afternoon that he had never tasted better water than the clear, sparkling liquid which he drew from an old-fashioned chain pump at a rancher's cottage in the hill country south of Dog Den Butte in McLean County, and many such wells dot the prairies in the great interior portion of the State.

CHAPTER THE TWENTIETH.

SOILS AND RESOURCES OF NORTH DAKOTA.

Geology a Practical Science.—The geological features of any region of country have much to do with the industries of that region, and determine in large measure the value of the lands. A farmer may or may not understand the geology of his farm, but if he is a successful farmer he is controlled very largely in his methods of farming by those agricultural principles which have their explanation in geology. A farmer knows in a very practical way that certain crops do well upon certain soils, that others cannot be raised to advantage upon those soils. Oftentimes this knowledge is painfully practical, because he has learned it at the expense of much toil and labor. The best knowledge in the world is often gained by experience, that is, by experiment. It is because of this that experimental stations or laboratories have been established for the study of soils, and experiment in the best methods of cultivation of crops, looking toward a better knowledge of the natural resources of the land. The laboratory of the landscape geologist is the field. The farmer has to do with soils, rain and sunshine, and hence his laboratory is also the field. He must be a geologist. He may not know it; he may not believe in "science;" he may know nothing of geology as such, but he is a practical geologist, nevertheless. In buying a farm the geology of that farm is of much interest, not for the sake of the geology, but because this determines for all time certain points of value about the farm. A landscape is a more complex thing than is often thought, and more things enter into its character and so into the quality of the fields determining their use and value than is by many supposed.

The Character of the Lands.—That there is a large variety of types of landscape and a great diversity of soils in North Dakota is apparent from what has been said in the preceding pages. The diversity in kinds of soil as well as in forms of landscape adapts the State to a diversity of farming interests. Few states offer a greater range of opportunities for agricultural pursuits than does North Dakota. The richest wheat lands in the world, the most profitable flax and oat fields, ranges for grazing herds of horses, cattle and sheep, of immense extent, vast areas of meadow, fuel in inexhaustible supply, clays suitable for brick for building purposes unlimited in extent, make any forecast except that of permanent prosperity, under the judicious management of an intelligent population, seem absurd.

Let us briefly pass in review some of the things worth remembering about the landscape of North Dakota.

The landscape owes its present form in a large measure to the fact that the Great Ice-Sheet spread over the State and leveled down the

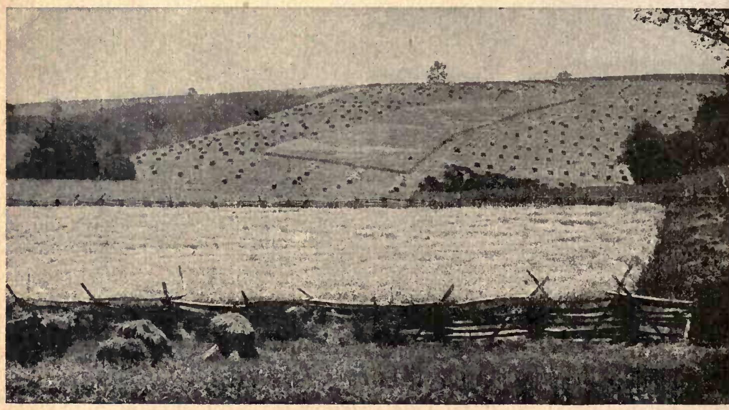

FIG. 81. In the East the Farm is cut up into Fields containing Acres!
Photograph by McCormick Harvesting Machine Co.

hills and filled the valleys, and left the surface in the form of level, undulating, or rolling prairies. The fertility of the soil is due in large part to the grinding and pulverizing of the rocks by the Great Ice-Sheet, forming the finest of rock-flour. No long, high, sweeping hillsides such as are common in the Eastern States, formed by the wearing of streams during long ages, greet the eye in North Dakota. No long stretches of clayey hard-pan hillsides off from which the fertile soil is annually washed into the rivers, enter into the farm scenes in this Northwest land. The land is mostly free from stones in the fields because the rocks which were ploughed up by the Great Ice-Sheet were mostly soft rocks which were easily pulverized into fine rock-powder and soil. It is estimated that not more than one-twentieth as many boulders strew the fields in North Dakota as in the Eastern States which were passed over by the Great Ice-Sheet. The soil is good in North Dakota because the old sea-bottom sediments of the Cretaceous formations contained those mineral "salts" which are needed for the growth of wheat, flax and oats, and other cereal grains. The same "alkali" which sometimes renders the water not good for drinking, when present in small quantities distributed through the

FIG. 82. In North Dakota it is One Big Field containing Sections!
Photograph by McCormick Harvesting Machine Co.

rocks, helps to make the great fertility of the soil. The limestone which is the surface rock in portions of the Canadian Provinces lying to the north, and off from which the great ice-plow broke vast quantities, which was carried over into this State and the sister state of Minnesota, when ground into rock-powder forms the most fertile wheat soil in the world. From the circumstance of great bodies of water standing upon portions of the State in glacial lakes of large extent, which have now disappeared and their bottoms become dry land, there is spread out the most nearly level and among the most productive large areas of land in the world. These lands are level because the waves and currents of the lake waters distributed the earth materials evenly over their bottoms. They are the richest lands known because the finest of rock-powder was carried by the waves and currents and distributed in layers over their bottoms, and the gathering of vegetable remains upon the bottoms of these lakes added the black matter which gives the final touch of fertility to the soil and makes it the strongest crop-producing soil known. These lake bottom lands are not confined to the eastern portion of the State known as the Red River Valley, but the Mouse River Valley, embracing more than one-third of a million acres of land within the State of North Dakota, and the area covered by Lake Sargent, embracing most of Sargent County and a portion of Ransom County, and Lake Dakota, covering a portion of Dickey County, are like the Red River Valley in their geological character, viz., old lake bottoms. The even character of the bottoms of these lakes leaves almost the entire area suitable for cultivation in crop raising and meadow. Less "waste land" exists in these portions of North Dakota than in almost any equal areas in any of the Northern States, being estimated over large areas not to exceed one-fiftieth of the whole.

Mineral Resources.—The geologic situation of the State makes possible the obtaining of abundant flows of artesian water over most of the entire eastern half if not, indeed, over the whole State, and in all parts of the State water is obtained in unlimited supply from common wells at moderate depths.

An inexhaustible supply of coal underlies the surface of the western half of the State, making abundant and cheap fuel within reach of all citizens of the State. Railroads traverse the State so that a never-ceasing fuel supply is available at small cost to the eastern half of the State from the vast coal fields in the western half.

Clays suitable for the finest quality of building brick, and for fire-brick and tile purposes, and also for the finer processes of cement and pottery manufacture, lie but a little beneath the surface, and within easy reach of fuel for the manufacturing processes.

Natural forests of growing timber abound along nearly all the stream courses, and experience has demonstrated that groves of any extent desired may be grown by suitable cultivation upon prairie lands remote from the larger streams.

The Stockman's Paradise.—Stock raising finds a paradise in the vast pastures of natural prairie grass, and hay in almost unlimited quantity can be cut, during dry seasons on the bottoms of the sloughs and marsh-lands, and in wet seasons on the higher lands, which yield more grass by far than there is stock of any kind to eat during the grazing season. The coulees or deep valleys in the western portion of the State furnish protection to animals from the storms of winter so that the expense for the construction of stables for horses and cattle, which attends stock farming in the East, is largely saved to the ranchman farmer in North Dakota.

That the occurrence of storms and severe weather will bear favorable comparison with other Northern States farther east is shown by the statistics of the U. S. Weather Bureau extending over the decades since accurate records have been kept in the Northwest.

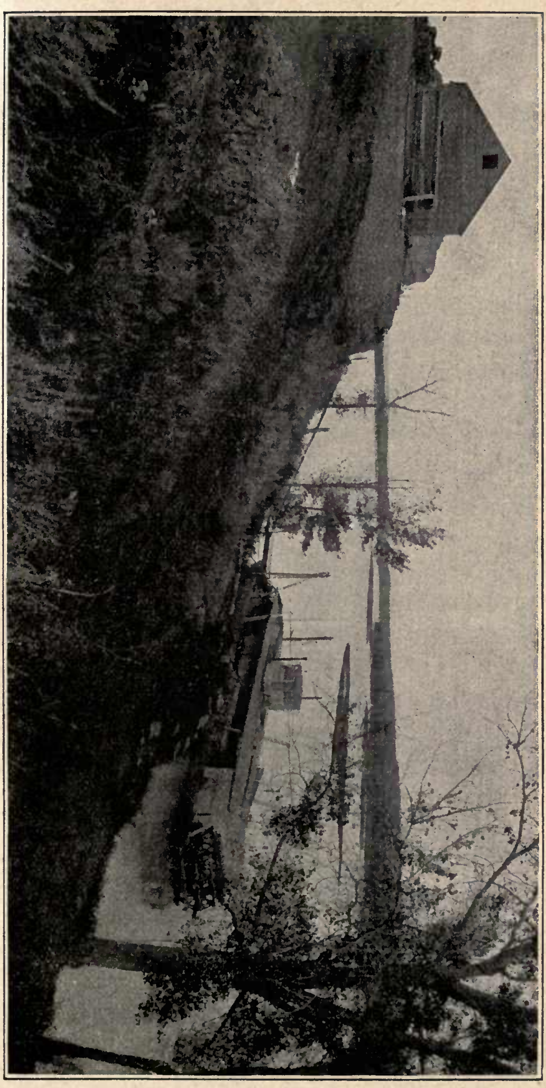

FIG. 83. Banks of Missouri River—Underlain by Ten Feet of Coal. *State Geological Survey of North Dakota.*

The Question of Rainfall.—That the rainfall in North Dakota is sufficient in amount and distributed over the growing months of the year so as generally under good cultivation to produce reasonably sure returns in bountiful harvests is shown by the records of annual and monthly rainfall for many years past.

The question of rainfall is an important one in any agricultural district. To all appearances North Dakota has almost unlimited resources in the matter of fertility of soil. Records of the amount of rainfall have been kept for many years. A study of the U. S. Weather Bureau records will show that failure in farming, if failure there be, is due more largely to careless or unscientific farming than to either quality of soil or amount of rainfall. If any one has labored under the impression that the Northwest is subject to drought and hence is not adapted to profitable farming, a study of the climatic records will tend to dispel that idea. The idea has gained acceptance that these lands have good soil but that the rainfall is insufficient. Statistical figures compiled from official sources tell their own story of the amount of rainfall, and largely outweigh the notion that the rainfall is scant.

Thirty years ago a vast region lying west of the Mississippi River embracing what are now portions of Kansas, Nebraska, South and North Dakota and Minnesota—and some of the best parts of those now great and wealthy states—was considered a great arid waste unfit for cultivation and not capable of supporting an agricultural population. In fact, many citizens of those states whose heads have silvered a little as they approach the latter half of life, remember when they studied about the "Great American Desert" in the geography lessons in the little schoolhouse on a clay hillside in the East, and were taught that it was a great arid waste—a vast wild and irreclaimable buffalo range, best adapted to gophers, badgers, wolves, wild horses and red men!

It is said that Horace Greeley, while traveling across the barren desert plains of Arizona and New Mexico, said to a friend, with characteristic dry humor, that "all that that country needed to make it a desirable place to live was good people and plenty of water." "Yes," remarked his facetious friend, "all that hell needs to make it a desirable place to live in is the same two things!"

Western North Dakota has been thought of by those who know the West only through fanciful tales as needing good people and plenty of water. That the State has room for more good people, thrifty, industrious people, and that there is a large amount of land waiting for settlers, none will deny, but the water it seems to have. The geology of the region shows that the character of the soil is such as to be capable of a high degree of productiveness, and the records bear out the statement that the rainfall is sufficient under proper cultivation and with intelligent attention to scientific farming, with stock raising and crop rotation, to insure large harvests and profitable returns from general farming.

The Days of the "Great American Desert" No More.—So far as the great Northwest is concerned there is no more "Great American Desert." The phrase has given place in modern geography to "The Bread Basket of the World." It is beyond our purpose to traverse the history of the development of the great Northwest, but the writer wishes herein to record his modest prediction that before another thirty years shall have rolled around the vast domain known as Western North Dakota will be occupied by bona fide settlers, will be owned and occupied by somebody, railways and highways will intersect it, schoolhouses and churches—always an accompaniment and mark of American civilization—will stand in different parts of all the counties; where are now small towns will be larger towns; what are now prairie postoffices at the intersections of trails will have grown to be agricultural and shipping centers. When this region becomes settled with an industrious and intelligent people who shall take advantage of the conditions as they are and adapt the mode of cultivation to the character of the lands, this will become a great and prosperous part of a vast commonwealth. Diversified farming will be made successful. These lands are capable of sustaining a great population. A great population will occupy them. Here will be the homes of successful and well-to-do farmers, as is now the case in the greater portion of those states which were once considered to be irreclaimable desert wastes.

CHAPTER THE TWENTY-FIRST.

GEOLOGY FROM A CAR WINDOW.

Prefatory Note.—The pleasure and the benefit to be derived from travel are not always measured by the cost of the journey, the distance traveled, or the great cities passed through. A journey of a hundred miles may afford more real pleasure to the lover of nature than a thousand miles of travel to one who simply endures the time till he arrives at the end of his journey. There are people to whom a tour across the continent is a matter to be wished soon over because there is nothing to do but to ride and ride and wait for the miles to roll by. There are others to whom every mile reveals something new, to whom the changing view is a continuous panorama of delight from the beginning of the journey to the end of it.

One who cannot enjoy pictures and statuary does not care to visit the art gallery. To one who does not enjoy the beautiful in architecture and mural decoration a cathedral is a no more fitting place to worship than a hay-barn. To one who does not enjoy the beauty of the landscape, or who does not know the meaning of landscape gardening, who does not recognize nature's handiwork in the fashioning of landscapes, does not derive the fullest value he pays for when he buys a railroad ticket.

Just as a guide-book is an indispensable requisite to the tourist abroad, so it is thought a word about what may be seen by the way, a description made from the car window, will help to make more real what has been known in a general way before. Just as a catalogue of the pictures and statuary in the art gallery is helpful to the visitor, so the traveler on a business trip or the tourist in search of health or pleasure may get more from his journey if he has pointed out to him some of the simpler things of the landscape, so that there is added meaning in the hills and valleys, the forests and prairies, the sand-plains and lakes, a meaning which includes much more than merely seeing the things.

The notes which follow have been gathered from observations actually made from the car window, the rear platform, the cupola of the "caboose," or the top of a box car. This does not mean that the "geologizing" which made the notes possible was all done from the moving train. Many days of field work have been necessary to make it possible to interpret what could be seen from the passing train. But to make the notes valuable for their purpose, and that they should not include what could not be actually seen by the passing traveler, the author has journeyed over all the lines of railroad here described and made the notes from first hand observation. It is hoped that the reader will find these observations helpful as furnishing particular illustrations of what has been said in the text. The notes are intended not only for the tourist and the traveling citizen who may be interested in knowing what he sees at the time when he sees it, but it is hoped that they may serve to give local touch and color to the descriptions in the body of the preceding pages. As teachers and all other persons who may read these pages travel more or less it is hoped that such notes may have a value in pointing out local examples of landscape features and that the teacher will find some assistance in local geography lessons in the facts which are here compiled.

The figures following the names of stations indicate the number of miles from the point where the Red River is crossed by the particular line of railroad. The figures in parenthesis indicate the number of miles east from the point where the line leaves the State, unless otherwise specified. The figures representing feet show the altitude of each station above sea-level. All the figures representing distances and altitudes are taken from the official surveys of the several railroads. The population of all incorporated cities, towns and villages, census of 1900, is also given. County seats are distinguished by **black faced type**, and the station which is nearest to the boundary line of any county traversed by the particular road is indicated.

THE GREAT NORTHERN LINES.

Grand Forks.—(Grand Forks County.) Distance from St. Paul (via Crookston), 324.1 miles; distance east of Montana line, 350 miles. Altitude, 835 feet. Population, 7,652.

Grand Forks, on the Red River of the North, is surrounded by the level black plain of the axis of the bottom of Lake Agassiz. The prairie from here to the International Boundary, eighty miles north, falls only a little more than seven inches to the mile. At the time of the highest stage of Lake Agassiz, *i. e.,* when the highest Herman Beach was being formed, the water was probably more than 300 feet deep where the city now stands.

OJATA.—Distance from Grand Forks, 11.1 miles. (Distance east of the Montana line, 338.9 miles.) Altitude, 864 feet.

Level prairie, with alkaline marshes. Two miles west the prairie becomes broken into irregular hummocks six to eight feet high. These mark the place of the lower Ojata Beach. The shore sand has been piled by the wind into small dunes. A little farther west the upper Ojata Beach rises about twenty feet, sloping at first, then rising quite suddenly.

EMERADO.—15.6 miles. (334.4 miles.) Altitude, 910 feet. Population, 236.

The Emerado Beach is crossed one-fourth mile east, about ten feet high. Hillsboro Beach, two miles west, just after crossing Hazen Creek. The east side of the beach rises as a beautiful slope, falling again a little west of its crest.

ARVILLA.—21.0 miles. (329.0 miles.) Altitude, 1,022 feet. Population, 199.

The front of the Elk Valley Delta rises distinctly to view, from south window of car. Within a mile east of Arvilla two conspicuous beaches are crossed, the McCauleyville and the Campbell, lying near together. The railroad makes a deep cut in crossing these. A gravel pit has been opened north of the track from which beach sand and gravel are taken. The McCauleyville Beach rises eighteen feet, falling a little west of its crest, then the Campbell Beach rises twenty-five feet, falling about one-third of this west of its crest, to the level prairie. A fine view of the delta front is afforded from the south window, and the deep valley of the Turtle River from the north window.

The Tintah Beach is crossed two miles west, where it runs along the delta front. The railroad here ascends upon the delta-plain by a heavy grade. Farther west, long, low hills represent the Norcross Shore-Line, the beach sand having been piled into low dunes by the wind.

LARIMORE.—27.7 miles. (322.3 miles.) Altitude, 1,138 feet. Population, 1,235.

Larimore stands upon the crest of the Elk Valley Delta, the plain of which is here about eight miles wide. The highest Herman Beach is four miles west, skirting the highland. Two lower Herman Beaches pass near the city, skirting its eastern suburbs. North of the city these beaches are crossed by the Turtle River, beyond which they rise as a long, low hill.

Traveling westward it will be noticed that a broad, level plain extends to the north. This is the mouth of the Elk Valley, and was the bed of the great glacial Elk River, which formed the delta in Lake Agassiz. On the western side of this valley is the Herman Beach, marking the highest shore of Lake Agassiz. An extensive gravel pit has been opened in this beach near the railroad. As the ascent is made up the face of the highland to the west a fine view is afforded of the mouth of Elk Valley, "The Ridge," which forms its eastern side, north of McCanna, and the Norcross Shore-Line south of the Ridge. A ride on the rear platform is here worth while, for a few miles.

NIAGARA.—41.7 miles. (308.3 miles.) Altitude, 1,444 feet.

In a distance of eight miles an ascent of more than 300 feet is made, to Niagara. This is the Manitoba Escarpment, the southern continuation of the Pembina Mountain Highland. Rounded, irregular hills, very different from anything which has been seen in the Red River Valley, occur on both sides of the track. These are morainic hills, and belong to the Ninth, or Leaf Hills, Moraine. Many granite boulders are noticed, and sloughs and ponds such as are common among the hills of a terminal moraine, are frequent.

PETERSBURG.—(Nelson County), 47.9 miles. (302.1 miles.) Altitude, 1,527 feet. Population, 182.

MICHIGAN CITY.—53.7 miles. (296.3 miles.) Altitude, 1,523 feet. Population, 309.

In the distance north the higher knobs of the Itasca (Tenth) Moraine can be seen. Many small lakes and grassy sloughs dot the prairie,—glacial "pans" which show the undrained character of the landscape. A belt of high rounded knobs is crossed a little west of Michigan.

MAPES.—58.4 miles. (291.6 miles.) Altitude, 1,531 feet.

One of the principal ranges of the Itasca Moraine lies north one mile. Same seen in distance north of Michigan City. Crosses line of railroad near Lakota, and continues to the Odessa Narrows of Devils Lake.

Lakota.—64.0 miles. (286.0 miles.) Altitude, 1,520 feet. Population, 576.

The Itasca Moraine is about a mile wide where crossed by the railroad, just west of Lakota. It is a fine example of a morainic "range." It is followed by undulating prairie again farther west. Before reaching Bartlett another range of low hills of this moraine is crossed.

BARTLETT.—(Ramsey County), 68.0 miles. (282.0 miles.) Altitude, 1,536 feet.

Many small shallow lakes dot the prairies between the moraines. In summer these are often "dry" lakes, with sheets of white alkaline salts covering their bottoms. The rounded knobs of another large range of the Itasca Moraine can be seen in the distance north. A branch connecting the moraine north with the one which was crossed at Lakota, lies in north and south direction across the line of the railroad east of Sidney station. West of Sidney is another similar range.

CRARY.—77.9 miles. (272.1 miles.) Altitude, 1,490 feet. Population, 284.

East of Crary a finely developed range, another branch connecting the two principal moraines mentioned. West of Crary a few miles is another range, with fine rounded hills, and little basins filled with water. These hills and hollows continue west of Keith station. The hills and hollows have the appearance of having been formed by the dumping of giant loads of earth from gigantic wheelbarrows! This is a good example of a terminal, or "dump," moraine.

Devils Lake.—88.5 miles. (261.5 miles.) Altitude, 1,468 feet. Population, 1,729.

Along the line for fifteen miles approaching the city the high hills south of Devils Lake can be seen against the sky. Devils Heart, the highest of all, holds its summit 175 feet above its base, and 290 feet above the level of the water of the lake. Eight miles west, and about nine miles south of the city, is Sully's Hill, rising 275 feet above the lake. Fine groves of oak, elm, linden, and cottonwood grow on the bluffs about the lake. In one of these groves, on a morainic swell on the north shore of the lake, the North Dakota Chautauqua grounds are located, one of the prettiest places in the State.

The City of Devils Lake stands upon the low hills of a moraine, one of the branches of the Itasca Moraine. The hills of one of the principal ranges of this moraine are seen about two miles north of the city.

GRAND HARBOR.—95.8 miles. (254.2 miles.) Altitude, 1,460 feet.

The large morainic range seen north of Devils Lake is crossed at Grand Harbor, the town being built upon the rounded knobs of this moraine. The railroad crosses another branch half way between Devils Lake and Grand Harbor. The bluffs which indent the lake, and which are generally tree-covered, are the ends of these smaller moraines which are too high to be covered by the waters of the lake.

PENN.—101.7 miles. (248.3 miles.) Altitude, 1,473 feet.

Gently undulating prairie, enclosed in a wide loop of the moraine which was crossed at Grand Harbor, the western side of the loop being crossed two miles west of Churches Ferry.

CHURCHES FERRY.—107.4 miles. (242.6 miles.) Altitude, 1,464 feet. Population, 264.

Splendid level prairie, among the finest in the State and the northwest. The Mauvaise Coulee (meaning "Bad Valley") is an old glacial drainage way which now connects the lakes to the north with Devils Lake in time of high water. This was the outlet stream of Glacial Lake Souris when that lake drained into Devils Lake and the Sheyenne River.

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ST. JOHN BRANCH.

Cando.—(Towner County), 15.4 miles north of Churches Ferry. (43.5 miles south of International Boundary.) Altitude, 1,488 feet. Population, 1,061.

Cando is located on the broad and fertile prairie which extends from the loop in the range of hills south of Grand Harbor and Churches Ferry north and west to the Turtle Mountains. About eight miles north and east lies one of the ranges of the Itasca Moraine, about five miles in width, which extends northwest across the Turtle Mountains, and southeast nearly to Lakota, thence northeast along the highland west of Conway and Inkster.

Rolla.—(Rolette County), 47.4 miles. (11.5 miles.) Altitude 1,823 feet. Population, 400.

About six miles south of Rolla the railroad crosses the moraine referred to. About six miles northwest, the plateau of the Turtle Mountains rises suddenly against the horizon, having a height here of 300 to 400 feet above the prairie.

St. John.—54.8 miles. (4.0 miles.) Altitude, 1,950 feet. Population, 168.

City located on eastern slope of the Mountains. Deep coulees intersect the sides of the plateau. Morainic hills, of the range crossed ten to twelve miles south, three miles west. Mountain top clad with forests.

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Leeds.—(Benson County), 119.0 miles. (231.0 miles.) Altitude, 1,516 feet. Population, 349.

Big Butte, or Mauvais Butte, rises with broad sweeping outlines six or seven miles south. This immense hill is about ten miles in length, rising 150 to 200 feet above the surrounding prairie at its eastern end, and 250 to 300 feet in its western portion. This is an old hill, *i. e.*, it was a hill before the Ice Age, as is shown by the fact that morainic ridges cross its surface and many boulders lie scattered upon it. It belongs in the class of hills such as Devils Heart and Sully's Hill, south of Devils Lake.

Occasional morainic hills stand upon the flat landscape between the Big Butte and the railroad. A well marked, broad glacial drainage channel west of Leeds. Only a small stream in it now.

York.—125.3 miles. (224.7 miles.) Altitude, 1,619 feet.

The high western end of Big Butte rises in the southeast. Its surface is seen in the distance to be rough, and marked by coulees and morainic hills. The prairie between Leeds and York is undulating, with an occasional round, morainic knob standing like a great mound upon the generally flat landscape. A school house stands on the top of one of these knobs, just south of the railroad. Many fine hay-meadows occur in the shallow depressions.

Knox.—131.1 miles. (218.9 miles.) Altitude, 1,610 feet.

Fine example of moraine crossed east of Knox. Along the horizon in the west, the high knobs and ridges of the combined Fergus Falls (Eighth) and Leaf Hills (Ninth) Moraines, the town standing upon a beautiful, gently undulating prairie. A fine view of a moraine is afforded from the south window of the car, west of Knox. The higher rounded hills of another moraine seen in the distance north.

About two miles west is the highest point of the Great Northern Railway between the Red River of the North and the eastern slope of the Missouri Plateau, 1,660 feet. This is the "divide" between Devils Lake and the Sheyenne on the east, and the Mouse River on the west. It can hardly be called a *watershed*, for the land in this region is undrained by streams. Drainage courses have not had time to become established since the Glacial Period.

PLEASANT LAKE.—136.7 miles. (213.3 miles.) Altitude, 1,608 feet.

The change from the gently undulating prairie to the extremely irregular topography of the morainic belt which is here entered, is very marked. The hills are steep and rugged, and strewn with boulders. A typical morainic region. This belt of hills, the compound Fergus Falls and Leaf Hills Moraines, crosses the Indian Reservation south of Devils Lake, the two moraines continuing separately from the hilly region south of Devils Lake across Nelson, Steele, and Barnes Counties, and thence, after crossing the Red River Valley, where they are recognized only as slight undulations, they continue across Minnesota, and become a part of the great "Kettle Moraine" in Wisconsin, Illinois, Michigan, and Indiana, and extending east to the Atlantic Ocean near New York City. The higher hills, which lie along either side of the railroad, rise from fifty to one hundred feet above the hollows at their bases, and from 100 to 150 feet above the general level of the prairie outside the moraine. Scores and hundreds of lakes of all sizes, from small ponds up to lakes two miles in diameter, occupy the hollows between the hills. Which one of the great number which lie within a few miles is the most "pleasant" would be hard to say. South of Pleasant Lake station is Broken Bone Lake, named from the piles of broken buffalo bones which were left on its shores by the Indians, from the manufacture of "pemmican," in which the marrow of the bones was used.

Rugby.—(Pierce County), 145.7 miles. (204.3 miles.) Altitude, 1,567 feet. Population, 487.

Rugby stands where was the eastern shore of Old Lake Souris. The aspect of the prairie suddenly changes to the west. The rolling and hilly landscape gives way to a broad, gently swelling prairie. The hilly moraines stop abruptly at the shore of the old lake. The hills were deposited upon the lake bottom just as they were beyond its shores, but they were leveled down by the action of the waves. From Rugby to Minot the railroad crosses the bottom of Lake Souris in the same manner as the western half of the bottom of Lake Agassiz was crossed from Grand Forks to Larimore. High morainic hills are seen both north and south of Rugby. The region about the city was occupied by a bay of the lake. A long slough lying north of the railroad can be traced from the car window most of the way between Pleasant Lake and Rugby. This is the old channel of a glacial stream which flowed into Lake Souris from the melting ice at the time the moraine about Pleasant Lake was being formed.

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BOTTINEAU BRANCH.

WILLOW CITY.—(Bottineau County), 21.2 miles from Rugby. (36.9 miles south of the International Boundary.) Altitude, 1,478 feet. Population, 476.

The railroad runs near the eastern shore, on the Lake Souris bottom. The horizon line to the east is an irregular line, marked by the crests of the hills and ridges, and the deep intervening hollows. To the west the sky meets the earth upon an almost unbroken horizontal line, the nearly level surface of the old lake bottom.

OMEMEE.—30.4 miles. (27.7 miles.) Altitude, 1,545 feet. Population, 320.

East of Willow City and Omemee the undulations of the prairie rise often ten feet above the adjoining hollows. These swells are the morainic hills which were not entirely leveled down by the waves of the lake. The high and rugged hills of the same moraines beyond the lake shore show how much the action of the waves leveled the hills which were deposited in the waters of the lake.

Bottineau.—38.1 miles. (20 miles.) Altitude, 1,646 feet. Population, 888.

Bottineau stands upon the lake bottom, about four miles from where the waters washed the base of the Turtle Mountains. The Turtle Mountain Plateau rises 400 to 600 feet above the level of the prairie at Bottineau. The highest hills on the top of the plateau, Butte St. Paul and Bear Butte, rise 700 and 600 feet,[1] respectively, above the prairie at the foot of the plateau, or Mountains.[2]

SOURIS.—52.1 miles. (6 miles.) Altitude (about), 1,550 feet.

West of Bottineau is a group of morainic hills which seemed to be too large to be leveled by the waves of the lake. They probably formed an island, or a group of islands, during the receding stages of the lake. Souris is on the nearly level prairie of the deeper lake bottom.

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[1] Andreas' Atlas of Dakota.

[2] The U. S. Boundary Commission gives the highest point of the Turtle Mountains as 2,534 feet above sea level.

BERWICK.—(McHenry County), 157.4 miles. (192.6 miles.) Altitude, 1,487 feet.

West from Rugby the railroad grade falls rapidly from the shore of the old lake toward its center. From the north window, or better, from the rear platform, the ends of the high moraines can be distinctly seen along the shore, cut off abruptly by the waves of the lake. North, and south, of the railroad, ranges of low, broad hills, with gracefully curving outlines, are the continuation of the moraines south of Rugby, across the lake bottom. They all have a trend northwest by west, so that they appear to approach the railroad from the south, and diverge to the north. Fine nearly level prairies lie between these long ground-swells. A moraine of sandy hills is marked by *dunes* farther west.

Towner.—164.7 miles. (185.3 miles.) Altitude, 1,482 feet. Population, 331.

Towner is on the lowest part of the old lake bottom crossed by the Great Northern Railway. The *valley* of the river, *i. e.*, the trough cut by the river, is very small here compared with the broad and deep valley west of Minot. Here it is a small valley, cut since the lake disappeared. At Minot and westward the large valley was eroded by the great glacial river which emptied into Lake Souris.

DENBIGH.—173.4 miles. (176.6 miles.) Altitude, 1,520 feet.

Choppy sand hills, wind-drifted. High, ragged dunes, morainic hills of sand partly leveled by the waves of the lake, and modified by the action of the wind. Higher hills, grass covered, are more clayey, and so not affected by the winds. Medicine Lodge Hill, and Buffalo Lodge, seen from the north window, are morainic hills which were too large to be leveled by the lake. They were at one time islands in Lake Souris. Tracts of dunes, sparsely covered with scrubby timber, and alkaline lakes, lie along the course of this moraine.

About a mile north of the railroad, west of Riga station, is a high morainic hill, its crest irregular in form, grass covered, and abruptly cut off at its eastern end. This was an island in the lake, as is shown by the form of the hill, for its crest has not been made smooth by the waves. Its eastern end was washed away by the waves, hence the level plain surrounding it.

GRANVILLE.—185.1 miles. (164.9 miles.) Altitude, 1,516 feet.

Range of morainic hills west, their outlines smoothed and rounded by the waves, but not leveled much. Little bumpy dunes of sand, the sandy character of the hills being due to the ploughing up of the Fox Hills

Sandstone by the ice-sheet, and ground up and deposited as a moraine in the lake. Nearly level prairies lie in the broad tracts between the moraines.

NORWICH.—192.2 miles. (157.8 miles.) Altitude, 1,531 feet.

Town built on hills of moraine. Hills modified in outline by action of lake waters, giving them a beautifully curved contour. Moraine crosses railroad from southeast to northwest. Splendid prairie, nearly level, both east and west of this moraine.

SURREY.—(Ward County), 198.9 miles. (151.1 miles.) Altitude, 1,635 feet.

Steep slope of the western side of the valley of the Mouse River can be seen to the west, from south window. Prairie here intersected by coulees leading into the Mouse.

Minot.—206.3 miles. (143.7 miles.) Altitude, 1,562 feet. Population, 1,277.

Minot stands at the western edge, or shore, of Lake Souris, in a bay formed by the broad mouth of the Mouse River, where that great glacial stream emptied its waters, collected from the melting ice-sheet, into Lake Souris. The valley of the Mouse is here more than a mile wide, and its banks on either side are hills rising 150 feet or more to the level of the adjacent prairie. The valley is here many times larger than the same valley sixty miles farther down its course at Towner. Many coulees, or little tributaries, have cut into the valley sides giving a beautiful combed, or grooved, appearance. Viewed from the bottom of the valley the landscape on either side appears hilly. The coulees which mark the banks are little notches cut by the rains which flow into the valley from the prairie. Some of these have worked back into the landscape several miles.

About four miles west of Minot is the junction of the Mouse and Des Lacs Rivers. Both these streams are now small, but their valleys are broad and deep. They are glacial valleys, cut when the waters from the melting ice-sheet kept the streams at high flood. (See Tenth Chapter.)

DES LACS.—220.0 miles. (130.0 miles.) Altitude, 1,902 feet.

Railroad ascends by heavy grade to the high prairie west of the Mouse Valley, rising 339 feet in less than fourteen miles. A fine view of the broad Valley of the Mouse is afforded from the north window. The view from the rear platform will repay the inconvenience. A deep coulee is spanned by a high iron bridge four miles west, beyond which the grade rises through many cuts to the prairie at Des Lacs. Fine examples of coulees, or "young valleys," deep troughs with steep sides, are best seen from south window. The great Missouri Plateau rises against the western horizon fifteen miles distant.

BERTHOLD.—229.2 miles. (120.8 miles.) Altitude, 2,087 feet.

A vast evenly sloping prairie, rising quite rapidly toward the Plateau front, extends as far as the eye can reach, to the northwest and southeast.

TAGUS (or Wallace).—238.8 miles. (111.2 miles.) Altitude, 2,187 feet.

Here is the front of the Missouri Plateau, or Coteau du Missouri. The Outer or Altamont Moraine lies upon the eastern edge of the plateau. Rounded hills and many small lakes mark the rough morainic topography. A small lake having a distinct wave-worn cliff, and a shore-boulder chain at its foot, lies near the station.

DELTA.—245.4 miles. (104.6 miles.) Altitude, 2,263 feet.

Delta is on the top of the plateau, 700 feet higher than Minot, forty miles east. The high, steep, and boulder-strewn hills illustrate finely the landscape of a terminal moraine. Many small lakes and sloughs at different levels, without outlets.

PALERMO.—252.6 miles. (97.4 miles.) Altitude, 2,200 feet.

Station stands at western edge of the Altamont Moraine, which is here about ten miles wide. The landscape is a rolling prairie westward. No more morainic hills will be seen farther west, for here was the limit of the western movement of the great ice-sheet. Boulders and glacial gravels occur as far as the Missouri River, "over-wash" materials from the Outer Moraine, or else deposits from the older ice-sheet, which is often spoken of as the "Old Drift."[1]

STANLEY.—260.7 miles. (89.3 miles.) Altitude, 2,253 feet.

The vast upland prairie of the Coteau du Missouri. Many alkaline lakes in shallow basins. Fine grazing lands; hay-meadows dotted with stacks.

WHITE EARTH.—279.9 miles. (70.1 miles.) Altitude, 2,092 feet.

[1] By "Old Drift" is meant the materials left upon the surface by an older ice-sheet, which belonged to an earlier epoch of the Glacial Period. This earlier ice invasion extended farther west in North Dakota than did the great Ice-Sheet by which the moraines described in this book were formed. The Altamont Moraine, the outermost of those formed by the later Ice-Sheet, nowhere occurs west of the Missouri River, but the Older Drift extends as a thin mantle to a distance, as usually mapped, of 40 to 60 miles west of the river. The drift may have extended farther west, however, and have been carried away by erosion since the disappearance of the ice. The writer has observed what seemed to be drift pebbles 100 miles west of the Missouri River at Dickinson, and nearly 40 miles still farther west, 85 miles south of the Missouri River at Williston, on the tops of buttes in the valley of the Little Missouri River, 10 miles south of Medora, what appeared to be drift deposits occurred to a depth of 8 to 12 feet. rounded pebbles of quartzite and granite up to 5 or 6 inches in diameter being observed,

The Valley of White Earth Creek has been cut down 150 feet into the plain. Strata of whitish sandstone and clay exposed in the naked sides of the valley, hence the name. Springs, which burst out of the hillsides of this and similar deep valleys, are of much value to the ranchmen. Protection is also afforded for stock during the winter season in these deep valleys. The only town between Minot and Williston is this. All the other stations are names upon the map merely.

TIOGA.—(Williams County), 287.9 miles. (62.1 miles.) Altitude, 2,237 feet.

The high prairie again reached, after traversing the course of a side coulee of White Earth Creek.

WHEELOCK.—305.4 miles. (44.6 miles.) Altitude, 2,380 feet.

Highest point of the Great Northern Railway in the State. The higher points on the prairie rise to an elevation above sea-level of 2,500 to 2,600 feet, which is more than 1,000 feet higher than the plain of the Mouse Valley where it is crossed by the railroad 100 miles east.

SPRING BROOK.—316.0 miles. (34.0 miles.) Altitude, 2,066 feet.

Railroad descends more than 500 feet in a distance of a little more than twenty miles, to the Valley of the Missouri River, crossing and recrossing the channel of Stony Creek.

Williston.—327.3 miles. (22.7 miles.) Altitude, 1,859 feet. Population, 763.

High, steep, naked butte-like hills south of the river. River channel meanders over a broad belt of changing sand-bars. Dense forest of red willows and heavy timber along the river, the favorite haunt of deer and other wild game. The city stands upon a terrace formed by a glacial stream which spreads as a belt of gravel and sand for a distance of more than thirty miles along the course of Little Muddy Creek. The bottom land of the valley is about thirty feet lower than the "bench" or terrace, and the Little Muddy flows in a small channel on the "bottom." So slight is the fall of this flat bottom that an irrigation ditch eleven miles in length is necessary to raise the water out of the small channel to the level meadow bottom-land at the mouth of the valley.

BUFORD.—348.0 miles. (2.0 miles.) Altitude, 1,950 feet.

Railroad follows the picturesque valley of the Missouri. South and west rise the naked walls of the buttes, cut in the high prairie by the mighty rivers, the Missouri and Yellowstone. The two rivers meet beyond the plain south of the station.

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FARGO TO GRAND FORKS AND NECHE.

Fargo.—(Cass County.) Distance from St. Paul, 242.0 miles. (Distance south of International Boundary at Neche, 159.1 miles.) Altitude, 900 feet. Population, 9,589.

The Great Northern Railway crosses the Red River of the North at Fargo, thence running down the Red River Valley generally at a distance of about ten miles from the river, to Grand Forks, and the International Boundary. The entire distance is over the almost level plain of the bottom of Lake Agassiz, broken only by beach ridges, or shore lines. The soil is the fine silt of the lake bottom, blackened by the accumulation of organic matter. Its fertility is unexcelled by anything in the world.

For fifteen miles out from Fargo the prairie is nearly level, and undrained. The plain is crossed by the Sheyenne River at Harwood, but this river can hardly be said to drain the land. It is the relic of a large glacial stream, but which has now but a very slight current. The stations of Harwood and Argusville are both lower than Fargo. The river would have to flow up hill to discharge its waters directly into the Red.

GARDNER.—Distance from Fargo, 20.7 miles. (Distance south of the International Boundary, 138.4 miles.) Altitude, 886 feet. Population, 266.

GRANDIN.—27.0 miles. (132.1 miles.) Altitude, 891 feet.

Hillsboro Beach, rising ten feet from the prairie, two miles west of railroad. With some difficulty distinguished from the passing train.

KELSO.—(Traill County), 33.2 miles. (125.9 miles.) Altitude, 897 feet.

North branch Elm River. Hillsboro Beach finely developed west, a typical shore-line of gravel and sand.

HILLSBORO.—38.9 miles. (120.2 miles.) Altitude, 902 feet. Population, 1,172.

Goose River, north of the city. The Hillsboro Beach rises fifteen feet from the level prairie, one mile west.

CUMMINGS.—46.7 miles. (112.4 miles.) Altitude, 904 feet

Two miles south of Cummings the railroad crosses the Hillsboro Shore-Line. This is here not a beach ridge but an eroded cliff eight to ten feet high. East of Cummings a few rods it is a well defined beach ridge of gravel and sand, rising ten feet on the east side and falling five feet on the back, or west side.

BUXTON.—52.8 miles. (106.3 miles.) Altitude, 931 feet. Population, 470.

North of Cummings the railroad runs upon the crest of the Hillsboro Beach for a short distance, then the beach diverges eastward. West of Buxton one mile is the lower Blanchard Beach. This is the high ridge which is crossed four miles west of Cummings, on the stage route to Mayville.

REYNOLDS.—(Grand Forks County), 57.6 miles. (101.5 miles.) Altitude, 910 feet. Population, 389.

The Hillsboro Beach is crossed again by the railroad one and one-half miles south of Reynolds. The beach is here about thirty rods wide, a large gravel pit having been opened in it. It is about eight feet high on the east side, falling six feet on the west side. The Emerado Beach is crossed one and one-half miles north of Reynolds, and three miles farther north the upper Ojata Beach is crossed. One mile north of Thompson the lower Ojata Beach is crossed. A mile north of Merrifield is the Gladstone Beach, which marks the shore of the lake when its southern point was where this beach crosses the Red River east of Buxton.

GRAND FORKS.—78.2 miles. (See page 198.)

SCHURMEIER.—84.3 miles. (74.8 miles.) Altitude, 833 feet.

Irregularly ridged surface, showing wave action at time of formation of Burnside Beach.

MANVEL.—90.7 miles. (68.4 miles.) Altitude, 827 feet.

The irregular surface of the Burnside Beach continues east of the railroad from Schurmeier, and extends through the west side of Manvel.

ARDOCH.—(Walsh County), 102.4 miles. (56.7 miles.) Altitude, 832 feet. Population, 298.

The Burnside Beach, a ridge two to three feet high, and thirty rods wide, crossed by railroad north of station.

MINTO.—108.8 miles. (50.3 miles.) Altitude, 828 feet. Population, 860.

Burnside Shore-Line about a mile west, but it is not easily traced on the level prairie. Cross Forest River.

Grafton.—117.7 miles. (41.4 miles.) Altitude, 834 feet. Population, 2,378.

Burnside Beach passes through east side of city. Gladstone Beach about four miles west, but neither beach is well marked. The region represents the almost perfectly level plain of the lake bottom. The black soil is unexcelled in fertility in the world.

St. Thomas.—(Pembina County), 131.8 miles. (27.3 miles.) Altitude, 847 feet. Population, 661.

The Pembina Mountain, or northern and higher portion of the Manitoba Escarpment, rises clearly on the horizon twenty miles distant.

Hamilton.—144.8 miles. (14.3 miles.) Altitude, 827 feet. Population, 224.

Burnside Beach is crossed by railroad one mile south.

Bathgate.—149.9 miles. (9.2 miles.) Altitude, 828 feet. Population, 756.

Cross the Tongue River. Burnside Beach about one mile west, not easily recognized. Two or three low ridges two to four feet high, marking the shore-line of Lake Agassiz during the Ossawa Stage, are about two miles east, and appear from passing train as slight undulations in the surface. Pembina Mountain rises high in the west, distant about twenty-five miles.

Neche.—157.7 miles. (1.4 miles.) Altitude, 837 feet. Population, 396.

Pembina River north of the town. In a journey of 160 miles from Fargo the traveler has seen the finest agricultural land in the world. His route has been along the axial line of the Red River Valley. The fine sediment of the lake bottom makes the soil of incomparable richness. Nowhere on the Western Hemisphere, if in the world, is there such an extent of so nearly level and so fertile land, with so little waste.

Winnipeg.—North of Neche, 74.5 miles. Altitude, 757 feet.

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WAHPETON TO LARIMORE AND HANNAH.

Wahpeton.—(Richland County.) Distance from St. Paul, 215.4 miles. (Distance south of International Boundary, 228 miles.) Altitude, 955 feet. Population, 2,228.

Bois des Sioux River crossed just above its junction with the Red to form the Red River of the North. The highest shores of Lake Agassiz are twenty-eight miles west, near Wyndmere, and seventeen miles east, in Minnesota. Lake Traverse is thirty-five miles south, lying in the trough of the southern outlet of Lake Agassiz. The Red (called also Otter Tail) and the Bois des Sioux meet to form the Red River of the North, which flows north along the axis of the bed of Lake Agassiz, 285 miles in a direct line, or about 700 miles following its winding course, to Lake

Winnipeg. At the time of the formation of the highest shore-line of Lake Agassiz the water was about 100 feet deep where the City of Wahpeton now stands.

DWIGHT.—Distance from Wahpeton, 6.9 miles. (South of International Boundary, 221.1 miles.) Altitude, 946 feet.

The front or edge of the plateau of the delta formed by the Sheyenne River in Lake Agassiz rises along the horizon eight miles west.

COLFAX.—20.1 miles. (206.9 miles.) Altitude, 951 feet.

South two or three miles the railroad crosses the lower McCauleyville Beach, which is broken into dunes of wind-blown sand five to fifteen feet high, the sand having been washed from the edge of the delta, which is about a mile west.

WALCOTT.—26.3 miles. (201.7 miles.) Altitude, 948 feet.

The delta front rises in the near distance west, so that the horizon is near. The horizon to the east is far out over the broad expanse of the level lake bottom. Low swelling dunes with beautifully curved outlines south. Dunes with ragged crests north. These are the wind-piled sands of the upper McCauleyville Beach. This beach was formed during the lowest stage of the lake while it yet discharged to the south. The delta was formed during the higher stages of the lake. The Campbell and Tintah Beaches cross the delta beyond view to the west, where their sands have been blown into dunes ten to thirty feet high.

KINDRED.—(Cass County), 34.2 miles. (193.8 miles.) Altitude, 932 feet. Population, 348.

The lower McCauleyville Beach turns westward between Walcott and the Sheyenne River. It is a large ridge broken into hills twenty to thirty feet high. A house stands on the top of one of these hills just west of the railroad. After crossing the river a fine view of the delta plateau is obtained from the level prairie south of Kindred.

DAVENPORT.—39.1 miles. (188.9 miles.) Altitude, 910 feet. Population, 245.

Crossing Fargo and Southwestern Branch N. P. R'y. The front of the delta can be seen from the west window as it extends away to the northwest.

DURBIN.—47.3 miles. (180.7 miles.) Altitude, 908 feet.

Two miles north of Durbin Maple Ridge rises ten feet above the level prairie, where it is crossed by the railroad. This is a beach ridge which was built out from the shore of Lake Agassiz as a "spit," or bar. It is a broad swell about fifty rods across, and follows the course of Maple River for twenty miles.

CASSELTON.—54.8 miles. (173.2 miles.) Altitude, 927 feet. Population, 1,207.

Crossing main line N. P. Ry. Prairie level as the floor of a house. An ideal landscape.

ARTHUR.—68.6 miles. (159.4 miles.) Altitude, 979 feet.

The Campbell Beach is crossed by the railroad south where it is a ridge rising ten feet on its east side. Just before reaching Arthur the beach west of the track appears to be double, one ridge being higher than the other, like stairs. The lower one is the upper McCauleyville, the higher the Campbell. The crest of the Campbell Beach lies close east of Arthur. This beach is again crossed north of Arthur as it turns westward, the railroad then running east of and near to the ridge for about ten miles. Marshy lagoons occur frequently west of the ridge.

HUNTER.—74.6 miles. (153.4 miles.) Altitude, 965 feet. Population, 407.

The upper McCauleyville Beach is a low bank, or cliff, east of Hunter. It can be traced from the east window for about two miles south, lying half a mile from the railroad. The Campbell Shore-Line is a well marked cliff half a mile west.

BLANCHARD.—(Traill County), 85.2 miles. (142.8 miles.) Altitude, 935 feet.

South of Blanchard a fine illustration of the development of a drainage system on a level plain is afforded. The prairie is intersected by the north fork of the Elm River, and tiny hills, just like the big hills in Pennsylvania and New York *except in size,* are separated by little coulees, or young valleys. (See Chapter One.)

MAYVILLE.—97 miles. (131 miles.) Altitude, 967 feet. Population, 1,106.

South of Mayville the rise toward the western shore of Lake Agassiz is clearly seen. The Campbell, Tintah, Norcross, and lower Herman Shore-Lines rise one above another, the crest of the last named forming the horizon line. The heights of these beaches, as shown in Figure 40, page 85, give an idea of the depth of the water of the lake where the City of Mayville now stands, at the time when these beaches were being formed. The Campbell Beach passes through the City of Portland, two miles west, as a wave-cut cliff. The Bruflat Academy stands upon its crest. North of Mayville half a mile the railroad crosses the upper McCauleyville Beach, which here has a nearly northeast course.

HATTON.—108.6 miles. (119.4 miles.) Altitude, 1,068 feet. Population, 430.

The elevation of the railroad from Mayville to Hatton, a distance of less than twelve miles, rises more than 100 feet. It may be observed also that the soil becomes more sandy. The sudden rise in the elevation and the more sandy character of the soil are due to the fact that the railroad here passes upon the plain of the Elk Valley Delta. This delta spreads over the lake bottom from the mouth of the Elk Valley north of Larimore south to Portland, its southern and eastern edge thence extending near Mayville north and a little east, crossing the main line of the Great Northern Railway about a mile west of Arvilla. The Norcross Beach crosses this delta plain at Hatton. It can be recognized south of Hatton where it is marked by small dunes of wind-blown sand.

NORTHWOOD.—(Grand Forks County), 116.8 miles. (11.2 miles.) Altitude, 1,101 feet. Population, 697.

From Hatton north is a beautiful prairie, the top of the delta being here but slightly undulating. The highland of the Manitoba Escarpment, the southern extension of the Pembina Mountain, rises clearly in view in the west. The highest, or Herman, shore-line of Lake Agassiz lies at the foot of this long hill.

LARIMORE.—129.5 miles. (98.5 miles.) Altitude, 1,138 feet. Population, 1,235. (See page 199.)

MCCANNA.—137.7 miles. (90.3 miles.) Altitude, 1,145 feet.

The broad level plain is the mouth of the Elk Valley. The highland west is the Manitoba Escarpment. North four miles and half a mile east of the railroad, rises the first of the series of hills locally known as "The Ridge." These hills were islands in Lake Agassiz. The Ridge formed the eastern side, and the Manitoba Escarpment the western side, of the Elk Valley. It was the Glacial Elk River, which once flowed in this broad valley, which formed the delta south of Larimore. North of this first island the railroad crosses a high beach ridge which extends between the first and second islands. The second island rises as a large hill west of the railroad after crossing the beach ridge.

ORR.—143.0 miles. (85.0 miles.) Altitude, 1,103 feet.

Fine view of the great plain of the bottom of Lake Agassiz, from east window, south of Orr. A few rods south of the station the railroad crosses the Norcross Beach, which is here a well defined ridge of gravel and sand.

INKSTER.—148.5 miles. (79.5 miles.) Altitude, 1,041 feet. Population, 376.

Two miles north of Orr the railroad crosses the Tintah Beach, which is well marked. West of the railroad it is double, the upper crest being two to five feet higher than the lower. Inkster stands upon the flat top of the Campbell Beach, which is here a wave-cut cliff, or bank, fifteen to twenty-five feet high. Half a mile east, on the level prairie, is the McCauleyville Beach, a gravelly and sandy ridge. The railroad crosses the latter north of Inkster near the crossing of Forest River, where it is a conspicuous ridge, its front rising eight feet from the prairie, and falling five feet on the west.

CONWAY.—(Walsh County), 154.5 miles. (73.5 miles.) Altitude, 993 feet. Population, 216.

From the crossing of Forest River north to Conway the McCauleyville Beach lies a few rods west of the railroad. A half mile west and parallel with it is the Campbell Beach. The first of "The Mountains"—the name locally applied to the large hills which are the northern continuation of "The Ridge"—rises high two and one-half miles west of Conway as a large long hill.

PISEK.—160.0 miles. (68.0 miles.) Altitude, 1,006 feet. Population, 132.

The wide southern end of the second "Mountain" rises three miles west. The crest of this "mountain" is 200 to 225 feet higher than the surrounding prairie, and seventy-five to one hundred feet higher than the highest point reached by the waters of Lake Agassiz.

PARK RIVER.—166.1 miles. (61.9 miles.) Altitude, 1,003 feet. Population, 1,088.

From two miles south of Pisek the railroad runs on the natural grade of the McCauleyville Beach. The Campbell Beach lies half a mile west, and is a massive beach rising twenty to thirty-five feet. The Mountain is hidden from view by the high crest of this beach. After crossing Park River the top of the Mountain is seen above the crest of the beach. About a mile north the railroad crosses the Campbell Beach by a deep cut. The prairie surface beyond is marked by hummocks, the irregular Tintah and Norcross Beaches, broken by the action of the waves beating upon the base of the Mountain, which now rises high to the west.

EDINBURG.—175.5 miles. (52.5 miles.) Altitude, 1,194 feet. Population, 286.

Edinburg stands at the north end of the Mountain. This "Mountain," which is a part of the great ridge which forms the eastern side of Elk Valley (called Golden Valley, or Pleasant Valley, in northern portion) should be clearly distinguished from the Pembina Mountain, which is a part of the Manitoba Escarpment, which formed the western shore of Lake Agassiz. "The Ridge" and "The Mountains" on the east side of Elk and Golden Valleys, are drift hills (moraines). The Manitoba Escarpment is a hill of the Cretaceous rocks. (See Seventh Chapter, page 69.) The higher part of the Manitoba Escarpment, north from about where the railroad passes upon it, is called Pembina Mountain.

MILTON.—(Cavalier County), 188.1 miles. (39.9 miles.) Altitude, 1,591 feet. Population, 384.

In the distance from Edinburg to Milton, a little more than twelve miles, the railroad rises 397 feet, the grade being forty-two feet to the mile for seven or eight miles. Here are many boulders of granite, and gravel and sand, and the irregular ridges and rounded hills which always indicate a terminal moraine. This is one of the ranges of the Itasca, or Tenth, Moraine. Boulders are especially abundant about Union. Deep cuts along the railroad show sections of drift hills, often with stratified sand, some of the excavations reaching into the shales of the bed-rock. Deep, jagged sided coulees, and forests of poplar trees, lend a picturesque grandeur to the scene. Magnificent panoramic views of the level plain of the valley bottom of Lake Agassiz are obtained at different points along the line. A fine example of a "young valley" occurs west of Milton,—one of the head streams of Park River. Its course can be followed for several miles (better traced when traveling east) from west of Milton, where it has its "head," growing deeper and wider down its course south and east; many small "tributaries" entering it.

OSNABROCK.—193.7 miles. (34.3 miles.) Altitude, 1,625 feet. Population, 228.

Fine undulating prairie, marked by occasional low morainic hills.

EASBY.—199.2 miles. (28.8 miles.) Altitude, 1,652 feet.

A small but noticeable range of morainic hills extends across the line of the railroad in a northwest by north direction.

Langdon.—205.4 miles. (22.6 miles.) Altitude, 1,615 feet. Population, 1,118.

Range of morainic hills east half a mile. Rolling prairie landscape, fine farming lands. Several low, gently rising moraines, belonging to the Itasca Moraine, lie in nearly parallel courses a few miles apart.

HANNAH.—226.5 miles. (1.5 miles.) Altitude, 1,568 feet. Population, 596.

Terminus of railroad. The vast plain comprising the top of Pembina Mountain is crossed by several small ranges of the Itasca Moraine. These diverge from the line of the railroad going north and approach it going south, from the right hand.

CHAPTER THE TWENTY-SECOND.

GEOLOGY FROM A CAR WINDOW—THE NORTHERN PACIFIC LINES.

Fargo.—(Cass County.) Distance from St. Paul, 251.5 miles. (Distance from Montana Line, 376.2 miles.) Altitude, 902 feet. Population, 9,589.

Fargo is situated upon the axis of the Red River Valley, surrounded by the almost perfectly level prairie of the bottom of Lake Agassiz, the great wheat belt of the Northwest and the world. The Northern Pacific Railway runs nearly due west across the State. For more than forty miles across the level plain of the lake bottom the track is without a curve, said to be the longest stretch of straight track in the world.

MAPLETON.—Distance from Fargo, 12.5 miles. (363.7 miles.) Altitude, 905 feet. Population, 322.

Prairie rises imperceptibly toward the west. At Greene, two miles west, the railroad crosses "Maple Ridge," which rises ten feet from the prairie to the east. This was an off-shore bar known as a "spit," built at the time of the Blanchard and Hillsboro stages of Lake Agassiz.

CASSELTON.—20.0 miles. (356.2 miles.) Altitude, 931 feet. Population, 1,207.

Crossing Breckenridge Division Great Northern Railway. Broad, level, fertile prairie; the finest wheat land in the world.

WHEATLAND.—25.6 miles. (350.6 miles.) Altitude, 992 feet.

Level prairie continues west of Casselton, till at Wheatland it rises suddenly fifteen feet onto a conspicuous gravelly ridge sixty rods wide, the Campbell Beach.

MAGNOLIA.—29.7 miles. (346.5 miles.) Altitude, 1,078 feet.

The watertank stands upon the Herman Beach, the highest shoreline of Lake Agassiz, and the western limit of the Red River Valley. The Tintah and Norcross Beaches were crossed between this point and Wheatland. Beach sand and gravel are taken from an extensive pit which has been opened in the Herman Beach.

BUFFALO.—35.2 miles. (341.0 miles.) Altitude, 1,204 feet. Population, 213.

Buffalo is 212 feet higher than Wheatland, less than ten miles east, and 126 feet higher than Magnolia, five and one-half miles east, at the highest shore-line of Lake Agassiz. This is the Manitoba Escarpment, the continuation of the Pembina Mountain highland, which formed the western side of the pre-glacial Red River Valley. (See Seventh Chapter.) The traveler can easily distinguish the heavy grade as the engine toils westward, or rolls with easy speed toward the east. At Buffalo a distinct range of low hills is crossed, the Fergus Falls, or Eighth, Moraine. The moraine makes a loop south of the railroad, being crossed again fifteen miles west near Alta.

TOWER CITY.—41.0 miles. (335.2 miles.) Altitude, 1,172 feet. Population, 468.

Scattered morainic "knobs" give a varied aspect to the prairie, outlying hills from the moraine just crossed.

ORISKA.—(Barnes County), 46.5 miles. (329.7 miles.) Altitude, 1,269 feet.

One of the ranges of the Fergus Falls Moraine is well shown east of Oriska about two miles. North of Oriska are seen broad, low hills differing in appearance from the "morainic" hills. These are "preglacial" hills, that is, they were hills before the Ice Invasion, and while they were passed over by the ice, yet were not leveled down entirely. They are therefore "veneered hills," being covered with a mantle of drift.

ALTA.—51.3 miles. (324.9 miles.) Altitude, 1,430 feet.

More hills of the Fergus Falls Moraine between Oriska and Alta. The elevation at Alta is 161 feet higher than at Oriska, five miles east. This rapid rise means that here was a hillside on the old, or pre-glacial, landscape. Broad hills with smooth surfaces north are veneered hills. Pilot Mound, seven or eight miles north of Alta, is such a veneered hill.

Valley City.—57.0 miles. (319.2 miles.) Altitude, 1,221 feet. Population, 2,446.

Crossing main line of Soo Railway. The railroad descends 209 feet from Alta to the bottom of the Sheyenne Valley, rising again 204 feet to Berea, five miles west. At the edge of the valley east of the city a fragment of the prairie has been cut around by coulees so as to form a flat-topped hill, or "butte." This is capped with drift to a depth of ten or twelve feet. The line of separation between the drift and the underlying Cretaceous shales can be traced by the difference in the vegetation above and below the line. A similar line can be followed along the sides of the coulee down which the railroad descends to the valley bottom from the east, and also along the sides of the valley of the Sheyenne. Large and small boulders are strewn upon the top and sides of the "butte," and also along the coulee. Outcroppings of the blue shale can be seen along the sides of the coulee, and in places in the steep sides of the Sheyenne Valley.

The Sheyenne Valley has a most interesting history. Here once rolled a mighty river, many times larger than the present small stream which occupies the great valley, because kept at flood by the waters from the great melting Ice-Sheet, during the closing stages of the Glacial Period. This glacial river carved its broad channel deeply into the Cretaceous shales which underlie the drift, and bore the materials thus eroded, together with sand and finer rock-powder from the melting ice, into Lake Agassiz, and there built up the great delta which bears its name. (See Ninth Chapter.)

SANBORN.—68.0 miles. (308.2 miles.) Altitude, 1,445 feet. Population, 259.

The hills of the Dovre, or Seventh, Moraine lie west of the Sheyenne River, and cap the hills which border the coulee up which the railroad rises to the prairie from Valley City. Once out upon the prairie numerous steep, rounded knobs are noticed. South of the railroad the hills of the Waconia, or Sixth, Moraine rise from fifty to seventy-five feet above the prairie. This moraine continues south of the railroad and nearly parallel with it for several miles. A long lake extends south from Hobart, and several lakes, one of which is crossed by the railroad a mile east of Sanborn, represent ancient watercourses, probably pre-glacial valleys, which were partially filled with drift.

ECKELSON.—74.4 miles. (301.8 miles.) Altitude, 1,464 feet.

The railroad crosses Lake Eckelson, which also lies in an old waterway. The hills surrounding the lake rise twenty-five to forty feet. Wave-worn beaches border the lake, and boulders are perched upon the shores, shoved up by the action of ice during winters. The Waconia Moraine is crossed by the railroad just west of Eckelson.

URBANA.—78.2 miles. (298.0 miles.) Altitude, 1,471 feet.

Between Eckelson and Urbana the railroad crosses another ancient waterway a fourth to a half mile in width, with hills rising forty feet on each side. This old valley is occupied by a lake north of the track, and by a slough south. More small lakes lie in the valley to the south and west.

SPIRITWOOD.—(Stutsman County.) 81.0 miles. (295.2 miles.) Altitude, 1,478 feet.

West of Spiritwood the railroad crosses a broad and deep valley having steep sides and a level bottom, extensive hay-meadows occupying the flat bottom. This is the valley in which lies the Spiritwood Chain of Lakes. These lakes lie along a course from five or six miles north of the railroad fifteen miles or more to the northwest. This also is an ancient drainage channel. East of Spiritwood station the low rolling hills are those of the Elysian, or Fifth, Moraine. West of the station are similar hills of the Kiester, or Fourth, Moraine.

Jamestown.—92.0 miles. (284.2 miles.) Altitude, 1,397 feet. Population, 2,853.

The buildings of the North Dakota Asylum for the Insane stand upon the west bank of the James River, seen from south window. A fine view of the deep James Valley, its sides serrated with coulees, is afforded as the approach is made to the city. The Valley of the James is not as deep as that of the Sheyenne, being from seventy-five to 125 feet deep, cut in the drift through most of its course, but in places having its bed in the Cretaceous rocks which underlie the drift. Like the Sheyenne Valley, it is a large channel eroded by the flood-waters from the melting Ice-Sheet. From Bloom, five miles east of Jamestown, the highest point between the James and Sheyenne Valleys, the railroad descends 101 feet to Jamestown. West the grade rises 132 feet in five miles, to the prairie. The coulee up which the railroad passes to the prairie to the west furnishes a fine illustration of the development of a river system. The coulee, itself a "young" valley, has its sides serrated with many smaller coulees, still "younger" tributaries. The prairie bordering the Valley is thus being cut up into hills.

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DEVILS LAKE BRANCH.

JAMESTOWN NORTHWARD.—The railroad follows the valley of the Pipe Stem River, and a coulee which enters this, to the general level of the prairie at Parkhurst, six miles from Jamestown.

The great plateau, the Coteau du Missouri, rises in the west six to ten miles distant, the railroad running at about this distance from the steep slope of its front for twenty-five miles to the northern boundary of Stutsman County. At times the horizon line is rendered broken and irregular along the top of the plateau by the morainic knobs and ridges which lie upon it. Deep coulees also intersect the face of the sloping front of the great highland. The prairie is a fine level expanse such as is common in the broad tracts between moraines. This gently undulating tract continues northward for forty miles, to Carrington.

MELVILLE.—(Foster County.) 33.4 miles north from Jamestown. Altitude, 1,602 feet.

From this point the railroad diverges from its course parallel with the front of the great plateau. Hawk's Nest, a large outlying hill belonging to the plateau, lifts its blue and hazy head on the horizon twelve miles west.

Carrington.—42.4 miles. Altitude, 1,579 feet. Population, 1,150. (See p. 236.)

New Rockford.—(Eddy County.) 58.5 miles. Altitude, 1,529 feet. Population, 698.

Cross the James River, here a small stream with sluggish current. A splendid expanse of gently undulating prairie extends fifteen to twenty miles both east and west. About two miles north the railroad passes upon a tract of morainic hills. Between this point and Minnewaukan, twenty-five miles north, the railroad crosses several morainic belts, which represent the Kiester, Elysian, Waconia, Dovre, Fergus Falls, and Leaf Hills Moraines. Between the broad belts of hills are tracts of nearly level prairie varying from two to seven miles in width.

SHEYENNE.—69.6 miles. Altitude, 1,470 feet.

A broad inter-morainic belt, traversed by the Sheyenne River. A fine illustration of river terraces is observed west of the railroad bridge, there being two distinct terraces, or "benches," one higher than the other. These are best seen from the west window, or from the rear platform.

OBERON.—(Benson County.) 78.3 miles. Altitude, 1,559 feet. Population, 217.

Oberon lies at the eastern end of the Antelope Valley, a fertile inter-morainic tract of gently undulating prairie, from five to six miles wide, lying between ranges of hills from one to three miles wide. No stream occupies this valley, nor is it a glacial drainage course. It is a nearly level belt of prairie between moraines,—an inter-morainic tract. Two miles north the railroad crosses a morainic range about two miles in width, then passes upon an inter-morainic tract, on which Lallie, or Fort

Totten Station, stands. This prairie is about eight miles long and two miles wide, and entirely surrounded by ranges of morainic hills.

Minnewaukan.—89.1 miles. Altitude, 1,461 feet. Population, 432.

One and one-half miles north of Lallie the railroad passes amongst the hills, which continue for six miles, to Minnewaukan, except for two small inter-morainic areas which are nearly level. Minnewaukan stands on the western shore of Devils Lake, at the northern edge of the great morainic region just crossed. A broad expanse of prairie lies north.

LEEDS.—107.3 miles. Altitude, 1,516 feet. Population, 349.

The railroad passes near to the eastern end of Big Butte, or Mauvais Butte, and along the west shore of Lake Ibsen. Big Butte is a large hill which belongs in the same series of hills as Devils Heart and Sully's Hill, south of Devils Lake, large pre-glacial hills which are covered with a mantle of drift, but are not themselves "drift hills." The western and higher end of the Big Butte is crossed by well marked morainic ridges, with many large boulders.

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ELDRIDGE.—99.0 miles. (227.2 miles.) Altitude, 1,542 feet.

After rising from the Valley of the James River, the great western plateau, the Coteau du Missouri, forms the blue and hazy horizon west. The Antelope, or Third, Moraine is crossed just west of E., the moraine lying along the foot of the great plateau. The engine will be noticed to toil heavily now, as the ascent is made onto the plateau. From three miles west of Eldridge the grade rises 277 feet in a distance of six miles to Windsor.

WINDSOR.—108.0 miles. (268.2 miles.) Altitude, 1,839 feet.

The slope of the plateau front is marked by many coulees, small lakes and marsh hay-meadows being numerous among the hills of the Antelope Moraine. The eastern edge of the plateau marks the "divide" between the James Valley and Missouri "Slope." The landscape is now a high rolling prairie, with hills rising fifteen to forty feet, and sometimes seventy-five to 100 feet. This is a splendid grazing country. Ranche buildings, and fine herds of cattle, horses and sheep may be seen upon the hillsides and prairies. What have been glacial lake bottoms are now the best of hay-meadows. Some of these flat bottoms show well defined wave-worn beaches around their margins, now nicely grassed over. Some of these lakes probably represent the bottoms of glacial drainage channels.

MEDINA.—120.5 miles. (255.7 miles.) Altitude, 1,794 feet.

Occasional high morainic hills, but the landscape generally is the "swell-and-sag" topography of glacial regions. Large granite boulders are frequent. Fine hay sloughs and alkaline lakes occupy low places. To the west the railroad crosses a channel in which lies a long lake, well grown with rushes, a long morainic hill of white sand lying in this lake. This is probably a drainage channel by which water from the melting ice-sheet escaped to the Missouri River.

CRYSTAL SPRINGS.—(Kidder County.) 128.8 miles. (248.2 miles.) Altitude, 1,796 feet.

The railroad passes amongst the hills of the Gary, or Second, Moraine, to the west. The main range lies south, but high hills also occur north. Hills rise to a height of 125 feet above prairie. The track runs for several miles along the course of an old glacial channel now occupied by a long irregular lake, and low, marshy lands.

TAPPEN.—136.7 miles. (239.5 miles.) Altitude, 1,765 feet.

Large hills of the Gary Moraine both north and south of railroad. West of Tappen another broad valley is crossed, having sloping sides and an extensive hay-meadow on its bottom,—another glacial drainage channel.

DAWSON.—142.0 miles. (234.2 miles.) Altitude, 1,746 feet.

Fine level prairie about the town. South are the high hills of the Altamont, or First, Moraine. High hills of this moraine are also seen north in distance. West the railroad makes a long cut through a range of hills belonging to this moraine, then suddenly comes into a broad shallow glacial channel, its bottom marked by lakes and hay marshes. This is Long Lake Valley, an old drainage course which extends south-west to Long Lake, and the Missouri River.

STEELE.—150.0 miles. (226.2 miles.) Altitude, 1,856 feet. Population, 185.

Fine level tract about Steele. Hills of the Altamont Moraine south. A small ridge crossed west. High rugged hills north. West of Steele a few miles a grassy lake bottom, probably a part of the Long Lake glacial drainage system. That this has been the place of a larger sheet of water is shown by the boulders perched high on its shore.

DRISCOLL.—(Burleigh County.) 161.0 miles. (215.2 miles.) Altitude, 1,873 feet.

Hills of Altamont Moraine south of railroad approaching Driscoll. West the train glides swiftly down to a broad, level, marshy meadow. In this valley lies a chain of lakes representing a large channel of glacial drainage which opens southwest into the valley of Apple Creek.

STERLING.—169.6 miles. (206.6 miles.) Altitude, 1,812 feet.

A deep cut is here made through the high crest of a ridge of the Altamont Moraine, the crest being eighty-two feet above the track, and the highest hill crossed by the railroad between Fargo and Bismarck. Many boulders, some of immense size, lie along the surface. Some of these knobs rise 200 feet above the prairie. Butte-like hills capped with the Fox Hills Sandstone can be seen in the distance. These are hills of erosion, and not drift hills. The last ridge of morainic hills, westward, has now been passed. At McKenzie a fine level hay-meadow is crossed, which belongs to the Apple Creek Valley glacial drainage system, leading to the Missouri River.

BURLEIGH.—180.0 miles. (196.2 miles.) Altitude, 1,722 feet.

Burleigh stands on a terrace plateau, the old flood-plain of the large glacial river in the valley of which now sluggishly meanders the small Apple Creek. About a mile west of Burleigh the "bottom" of the valley is crossed, about seventy-five feet below the old flood-plain on which Burleigh stands.

BISMARCK.—192.7 miles. (183.5 miles.) Altitude, 1,670 feet. Population, 3,319.

The State Penitentiary stands upon what appears to be a terrace about fifteen feet above the bottom of the creek to the east, and sixty feet lower than the terrace on which Burleigh stands. The depot at Bismarck stands upon another terrace-like plateau ten or twelve feet higher than that at the Penitentiary, and about two miles west the elevation is about the same as that at Burleigh.

The Missouri River is a majestic stream. Its broad sandy bottom spreads out in the distance south. Along its banks the Cretaceous rocks which underlie the drift are exposed in many places. A fine view of a section of these rocks is obtained at the east end of the railroad bridge which spans the river. The strata of shale extend up nearly to the top of the high bank, being capped with a thin mantle of drift. This shows that the broad valley east of Bismarck is really a valley cut in the underlying rocks, the drift merely forming a surface covering. North and east of Bismarck, along the line of the Bismarck, Washburn, and Great Falls Railway, many fine examples of butte-like hills may be seen, their flat tops capped with the Fox Hills Sandstone.* The extensive coal mines

* J. E. Todd.

at Wilton, and other points north, are in a higher series of rocks than the Fox Hills formation. The coal formation is the Laramie. This means that the shelves of sandstone rock which cap the hills would be found deep below the coal to the north. (See Eighteenth Chapter.)

Mandan.—(Morton County.) 199.5 miles. (176.7 miles.) Altitude, 1,644 feet. Population, 1,658.

Mandan is located on the broad plain at the mouth of the valley of the Heart River, near where that stream enters the Missouri. The city is picturesquely located among the hills, which have been formed by the deep cutting of the Heart River and its tributaries. The hills rise abruptly 300 to 400 feet above the bottom of the valley. Ascending the Heart Valley, shale and sandstone outcroppings occur in the sides of the drift-capped hills. Numerous drift boulders lie along the bottoms and sides of the coulees.

Sweet Briar.—214.8 miles. (161.4 miles.) Altitude, 1,799 feet.

The railroad passes up Sweet Briar Creek from the valley of the Heart River. A shelf of sandstone outcrops along the north side of the valley. Where the side of the valley is grown over with grass a mark on the hillside shows the edge of the sandstone shelf. Going up the valley the sandstone layer approaches the bottom, and other layers of rock are above. The layers do not become lower, but the bottom of the valley rises. Farther west many capped buttes are observed, and the layer of hard sandstone which caps these becomes lower in relation to the surface, and finally disappears beneath the surface.

Judson.—220.5 miles. (155.7 miles.) Altitude, 1,948 feet.

The railroad still follows the branching coulee, not yet having reached the general prairie surface. Many boulders lie upon the surface, and crags of sandstone project from the hills.

New Salem.—227.0 miles. (149.2 miles.) Altitude, 2,160 feet. Population, 229.

Here the high prairie is reached. The highest peak, which stands far above the surrounding landscape, shows outcropping horizontal layers of sandstone. Some idea of the amount of earth which has been carried away by erosion can be gained from this, for the projecting edges of this high peak are part of the horizontal layers which once extended over the whole landscape, and have been all carried away except this. Some of this rock is now the sand along the valley of the Missouri River, and some has been carried far down toward the Gulf of Mexico, and some may be resting on its bottom. Occasional large boulders lie upon the surface, but most of the finer drift materials has been carried away, the boulders remaining because too heavy to be transported.

SIMS.—234.2 miles. (142.0 miles.) Altitude, 1,959 feet.

West of Sims the railroad turns abruptly south and descends a coulee six miles, turning again to traverse another valley for twenty miles to the prairie surface west of Glen Ullin. About Sims are some small hills of drift thickly strewn with boulders, the last drift hills and large boulders observed, westward bound.* A projecting chimney from a coal mine shows that it is the Laramie formation that is now being crossed, a formation which lies *above* the sandstones and shales farther east, and in which are the North Dakota coal beds.

ALMONT.—239.1 miles. (136.3 miles.) Altitude, 1,914 feet.

North of railroad a fine "park" of sandstone-capped hills. The lower hills, those which have been eroded more, are rounded at their tops. Farther west a pretty row of beehive-shaped buttes, tipped with red from colored sandstone or clay. Two high, pointed buttes, the first genuine "Bad Land" *buttes* observed. Same range of hills becomes grass-covered farther west, as the valley becomes less deep and less erosion has occurred.

GLEN ULLIN.—265.6 miles. (119.6 miles.) Altitude, 2,067 feet. Population, 272.

Low flat buttes south. Some lofty peaks mark the higher level of an older landscape which has been mostly carried away. Eagles Nest is one of these, a few miles west.

HEBRON.—269.1 miles. (107.1 miles.) Altitude, 2,157 feet. Population, 182.

East of Hebron is the divide between streams tributary to the Big Muddy and the Heart on the south, and the Knife River on the north. The streams have not yet cut deeply, and the general landscape is an expanse of grassy prairie.

ANTELOPE.—(Stark County.) 278.5 miles. (97.2 miles.) Altitude, 2,405 feet.

The railroad here runs upon the divide between the Heart and Knife Rivers. Tributaries from both these rivers push up upon the prairie. This is therefore what may be called the high prairie. North of the railroad stands a pointed butte with naked sides, its crest reaching far above the general landscape. Another is south of the track, thinly covered with grass. These isolated peaks, standing alone on the landscape, their tops

* See footnote, page 207.

composed of horizontal layers of sandstone, show that a vast amount of erosion has occurred, for once the layers of sandstone were continuous over the whole region and the general level of the landscape was above where these tops now are.

TAYLOR.—289.5 miles. (86.7 miles.) Altitude, 2,484 feet.

Taylor marks the highest point of the railroad east of the divide between the Heart and Little Missouri Rivers.

GLADSTONE.—297.2 miles. (79.0 miles.) Altitude, 2,345 feet.

Well marked terraces are shown along the streams south and west from the railroad. West toward Lehigh two naked buttes stand south of railroad. One is nearly "worn out," being a mere thumb standing upon the prairie. The other is larger, and has hard sandstone shelves projecting from its sides which protect it from so rapidly wearing away. The flat tops and projecting shoulders of many buttes are thus explained.

LEHIGH.—304.0 miles. (72.2 miles.) Altitude, 2,343 feet.

The extensive Lehigh Coal Mines on south side railroad.

Dickinson.—308.6 miles. (67.6 miles.) Altitude, 2,401 feet. Population, 2,076.

Three broad table lands, or *mesas,* covered with grass, northeast. Northwest of the city the small hills are crested with sandstone crags. High, naked buttes south in distance.

FRYBURG.—(Billings County.) 334.3 miles. (41.9 miles.) Altitude, 2,761 feet.

Steadily ascending all the way from Mandan, the summit, or divide, between the Heart and Little Missouri Rivers has now been reached. Mandan is at the mouth of the Heart River, with an altitude of 1,644 feet; Fryburg is 117 miles (by section lines, 136 miles by rail) west, with an altitude of 2,761 feet, or 1,116 feet higher. Now, in a distance of twelve miles (by section lines, fourteen miles by rail) a fall of 500 feet is made into the valley of the Little Missouri. Then, in a distance of twenty miles the ascent is made to the high prairie again through a vertical rise of 750 feet to an altitude west of Sentinel Butte of 2,801 feet. Within this narrow but deep valley lies the famed "Bad Lands." And this deep valley is at once the cause and the explanation of the Bad Lands. The Little Missouri River has a steep bed, and it therefore cuts down rapidly. This gives to its inflowing tributaries a high gradient, and these in turn cut their channels rapidly. The result is that the landscape along the course of the Little Missouri is deeply intersected by streams. The flat-topped buttes are the hills which have not yet been worn away so as to make their tops round. The high table lands are fragments of the old prairie which has been thus cut up by the streams. The hard sandstone layers, such as were observed in the journey west from Mandan, give to the hills many of their remarkable features, just as they gave the jutting shoulders and projecting crags to many hills along the Heart River.

SULLY SPRINGS.—340.0 miles. (36.2 miles.) Altitude, 2,571 feet.

Just west of the station the railroad passes through the Petrified Forest. No shade is afforded by this "forest," and the trees have long since ceased to shed their leaves! These ancient monarchs of a "dead past," these giants whose branches once wafted in the breezes of the Cretaceous Age, have fallen, and their immense trunks now strew the ground. The stumps on which they grew still stand, buried in the rocky soil in which they grew, mutely testifying to a glory long past,—of a "forest primeval." Truly it may be said:

> "This was the forest primeval. The murmuring pines and the hemlocks,
> Bearded with moss, and in garments green, distinct in the twilight,
> Stood like Druids of old, with voices sad and prophetic,
> Stood like harpers hoar, with beards that rest on their bosoms.
> Loud from its rocky caverns, the deep-voiced neighboring ocean
> Spoke, and in accents disconsolate answered the wail of the forest!
> Filled was the air with a dreamy and magical light; and the landscape
> Lay as if new-created in all the freshness of childhood."

But this was long, long ago. What we see is the tomb in which the "Forest Primeval" was buried, the strata of rock which were deposited over them, and which have in later time been removed by erosion. On both sides of the railroad many stumps stand where they grew. Immense logs four feet in diameter lie near the track. Pyramid Park lies to the left (south), a magnificent view. Pyramid shaped buttes, large and small, white, naked walls of rock, flat topped tables and smaller rounded cones. Descending the valley the buttes become red on their crests, capped with lava. Rough crags of scoriaceous rock project from many sides. At Scoria the buttes appear as though dyed in blood. The small stream, Sully's Creek, has cut down through a lava bed which was spread over the ancient sea-bottom which was here "before ever the hills were formed."

Medora.—348.2 miles. (27.5 miles.) Altitude, 2,261 feet.

Medora lies in the "heart of the Bad Lands." The nearly perpendicular walls of rock rise 400 feet from the Little Missouri River to their tops, which represent the prairie level. The horizontal strata of the Cretaceous rocks are magnificently exposed to view. Sandstone, clay, shale, and lignite coal lie in alternate bands from base to top of the buttes.

SENTINEL BUTTE.—365.8 miles. (11.4 miles.) Altitude, 2,703 feet.

After crossing the river the railroad follows down its west bank to the mouth of Andrew's Creek, up which it passes to the high prairie. High rugged buttes rise steep on either side the narrow deep valley. A fine view of a group of haystack-shaped buttes is obtained from the north window, several miles west. Sentinel Butte stands high above the surrounding prairie six miles south of the station. The top of this butte is said to be the highest point in North Dakota. The butte gets its name from a pathetic incident in the campaign of the lamented General Custer against Sitting Bull, in 1876. The "pass" through the top, which may be seen from east of the station, was guarded by two soldiers during a night when it was anticipated an attack might be made by the Indians upon the army encamped upon the plain north of the butte. In the morning when relief was sent to the guards their bodies were found pierced with arrows. Their bodies were buried one on either side of the pass they had guarded, and their graves are marked by two large piles of stones.

STATE LINE.—376.2 miles. Altitude, 2,811 feet.

The highest point of the Northern Pacific Railway in North Dakota is reached at the instant of crossing the State line into Montana. The western boundary is almost exactly on the watershed, or divide, between the Little Missouri and Beaver Creek, the railroad then descending to the valley of the Yellowstone.

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FARGO SOUTHWESTERN LINE.

Fargo.—(See p. 218.)

The railroad crosses the level plain of the bottom of Lake Agassiz for twenty-five miles.

LEONARD.—Distance from Fargo, 28.0 miles. Altitude, 1,052 feet.

The railroad here passes from the level lake bottom upon the plateau of the Sheyenne Delta, rising more than eighty feet in a distance of two miles, and crossing the McCauleyville, Campbell and Tintah Beaches of

Lake Agassiz, which extend along the delta front. South the delta sand is in places piled into dunes by the action of the wind.

SHELDON.—(Ransom County.) 40.5 miles. Altitude, 1,079 feet. Population, 318.

Surface of the delta slightly undulating. The sand is piled into dunes, notably south. The western edge of the delta, and of the lake, is at Sheldon. The change in the landscape is at once seen toward the west, where the hills become the familiar drift hills, with occasional high knobs.

Lisbon.—55.3 miles. Altitude, 1,089 feet. Population, 1,046.

Deep valley of the Sheyenne River. A well marked broad terrace of the larger glacial river on west side of valley. Suburbs of the city built upon its top. Terrace seen also north of the city on east side of valley, from west. The Dovre Moraine lies along the western bluffs of the river. A cut in the gravelly terrace west of the city shows finely stratified sands. From the prairie west of the valley the broad outlines of White Stone Hill may be seen eight miles south. This is a pre-glacial hill rising 150 feet above the prairie and veneered with drift.

ELLIOTT.—62.8 miles. Altitude, 1,330 feet.

West of Elliott is another pre-glacial hill rising about sixty feet.

ENGLEVALE.—67.7 miles. Altitude, 1,342 feet.

An old channel about three miles in width, having a flat bottom, was occupied by the Sheyenne River when that stream discharged into Lake Sargent. A deeper part of the channel a mile to a mile and a half west of Englevale is known as the Big Slough. When the glacial Sheyenne River flowed here the ice of the great Ice-Sheet had not melted off from the region about Lisbon, and the Dovre Moraine west of Lisbon was being formed.

VERONA.—(LaMoure County.) 75.6 miles. Altitude, 1,385 feet.

Between the channel of the glacial Sheyenne River and Verona the Waconia, or Sixth, Moraine is crossed.

LaMoure.—87.0 miles. Altitude, 1,308 feet. Population, 457.

The city lies in the broad valley of the James River. Terraces occur along the west side of the valley. Fine undulating prairie west of the valley.

BERLIN.—97.0 miles. Altitude, 1,469 feet.

That trees can be successfully grown on these prairies is proven by a fine grove of cultivated trees at Berlin. Good farm buildings bespeak the thrift of the farmers in this section. In the distance along the western horizon rises the blue outline of the great plateau, the Coteau du Missouri.

EDGELEY.—108.5 miles. Altitude, 1,567 feet. Population, 306.

The Coteau highland rises eight to ten miles west. East of Edgeley the hills of the Antelope, or Third Moraine are crossed. Drift hills also occur along the foot of the plateau west.

MONANGO.—(Dickey County.) C., M. & St. P. Railway. 122.6 miles. Altitude, 1,501 feet.

Low round hills and hollows of the Antelope Moraine crossed near Monango. Crossing Bismarck Branch of Soo Railway.

Ellendale.—135.0 miles. Altitude, 1,446 feet. Population, 750.

Low rolling hills of the Antelope Moraine six miles west. In the distance fifteen to twenty miles west the highland of the Coteau du Missouri rises suddenly to an elevation of more than 2,000 feet. All about Ellendale, and east and south is a fine farming section.

CHAPTER THE TWENTY-THIRD.

GEOLOGY FROM A CAR WINDOW—THE SOO LINE.

FAIRMOUNT.—(Richland County.) Distance from St. Paul, 201.3 miles. (Distance east of Portal, 359.0 miles.) Altitude, 983 feet. Population, 284.

The Soo Line enters North Dakota at Fairmount, in the southeast corner of the State, and passes in a northwesterly direction, crossing the International Boundary at Portal. Fairmount is located a mile and a half west of the Bois des Sioux River, on the level axis-plain of Lake Agassiz.

OSWALD.—Distance from Fairmount, 5.8 miles. (Distance east of Portal, 353.2 miles.) Altitude, 987 feet.

Level prairie from Fairmount westward, but now begins to be slightly undulating, and soon broken into short, choppy sand billows, the wind blown sands of the Sheyenne Delta.

HANKINSON.—14.5 miles. (344.5 miles.) Altitude, 1,068 feet. Population, 713.

Rising conspicuously from the prairie south of Hankinson stands a large dune 150 feet high, covered scatteringly with trees, known as Lightning's Nest. A tract of dunes from ten to thirty feet high and mostly covered with grass extends to the northwest. Lightning's Nest has been built up from the sands of the Herman Shore-Line, where it crosses the Sheyenne Delta. The Norcross Beach passes close east of Hankinson as a well defined sand ridge. The hills of the Dovre Moraine are a prominent range south and west.

MANTADOR.—22.0 miles. (337.0 miles.) Altitude, 1,027 feet.

The railroad crosses the tract of dunes which extends from Lightning's Nest. Beyond the dune tract fine level prairie. Wild Rice River is crossed north of the dune tract.

WYNDMERE.—31.9 miles. (327.1 miles.) Altitude, 1,060 feet.

Fine level prairie about Wyndmere and south. North the surface is broken into swells and hollows of wind-blown sand. Farther north still the knolls become sharper in outline and the road-bed cuts through them, showing the white delta and beach sand of which they are composed. For forty-five miles from Hankinson to Anselm the Soo Road passes over the delta plain of the glacial Sheyenne River. The sand of this delta is piled by the wind into knolls often fifty feet high, and this gives the landscape its peculiar appearance. Nothing but wind-blown sand could form hills such as these. Where the surface does not become grass-covered, the sand drifts precisely as does dry snow, the hills slowly traveling across the plain as the sand is continually carried up over the crests of the hills and falls down the other side.

SANDOUN.—(Ransom County.) 44.2 miles. (314.8 miles.) Altitude, 1,074 feet.

Billowy dunes rise ten to fifty feet or more, the hollows between being often filled with water. Hills mostly thinly covered with grass.

VENLO.—53.8 miles. (305.2 miles.) Altitude, 1,062 feet.

The Sheyenne River, which runs at the west side of the Sheyenne Delta, is crossed between this and the next station. The Herman Beach, the highest shore-line of Lake Agassiz, is a little south of the River, but is so much broken up that it is not easily recognized. The Big Bend of the Sheyenne, ten miles south, marks the place where the great glacial river discharged into Lake Agassiz at the time the large delta was built.

ANSELM.—57.6 miles. (301.4 miles.) Altitude, 1,085 feet.

Cuts in the valley side made in grading the railroad show the stratified sands and gravel of the delta. High dunes rise in the distance east. Anselm is just off from the delta plain, and the different aspect of the landscape is at once apparent. The prairie becomes gently rolling with occasional high round knobs, morainic hills. There are no hills of this character, no morainic "knobs," on the area covered by Lake Agassiz, which is what is known as the "Red River Valley."

ENDERLIN.—66.1 miles. (292.9 miles.) Altitude, 1,082 feet. Population, 636.

Enderlin is situated in the valley of the Maple River, here a deep glacial valley such as the Sheyenne. Fine prairie north to Lucca and Fingal.

FINGAL.—(Barnes County.) 79.2 miles. (279.8 miles.) Altitude, 1,277 feet. Population, 376.

The rapid rise in elevation here is due to the railroad passing upon the Manitoba Escarpment, the highland which formed the western side of the pre-glacial Red River Valley.

CUBA.—84.8 miles. (274.2 miles.) Altitude, 1,352 feet.

The hills of the southern loop of the Fergus Falls Moraine appear in the east and north.

LANONA.—90.9 miles. (268.1 miles.) Altitude, 1,387 feet.

Knobs and irregularly-shaped hills of the Fergus Falls Moraine.

Valley City.—95.8 miles. (263.2 miles.) Altitude, 1,227 feet. Population, 2,446.

Valley City is located in the broad and deep valley of the Sheyenne. The station is two miles north of the city. The hills which form the sides of the valley rise 150 to 200 feet. Much of the material which was eroded by the great glacial stream which cut this large valley makes up the delta plateau which has just been crossed. (See p. 219.)

ROGERS.—109.5 miles. (249.5 miles.) Altitude, 1,422 feet.

The railroad ascends by a narrow, crooked, deep, and boulder-strewn coulee nine miles to the beautiful level prairie about Rogers. A rise of nearly 200 feet has been made in this distance. Blue shale is exposed in many cuts.

LEAL.—115.4 miles. (243.6 miles.) Altitude, 1,465 feet.

Morainic hills of the Waconia, or Sixth, Moraine.

WIMBLEDON.—123.6 miles. (235.4 miles.) Altitude, 1,468 feet. Population, 226.

Fine level tract of prairie lying between the Waconia Moraine, which is seen in the distance to the east, and the Elysian, or Fifth, Moraine, the low swells of which are seen here. Shallow lakes occupy many hollows.

COURTNEY. — (Stutsman County), 129.8 miles. (229.2 miles.) Altitude, 1,523 feet. Population, 346.

Broad tract of prairie again, between the Elysian and Kiester, or Fourth, Moraines. Many boulders strew the prairies, and shallow lakes without outlets show that as yet drainage systems have not become established.

KENSAL.—139.4 miles. (219.6 miles.) Altitude, 1,541 feet.

Kensal is situated among the hills of the well-marked Elysian Moraine. From here the railroad descends to the Valley of the James River. The course of the river for more than twenty miles lies amid the hills of the Kiester Moraine, the hills and the river seeming to be in a struggle for the mastery! South of the railroad bridge the river broadens out to form Arrowood Lake, the valley being blocked by the drift, which nearly fills it. North of the bridge the river is a broad, sluggish, pooling, lake-like stream. Fine examples of morainic hills are here displayed. Some high knobs of this moraine are nearly 200 feet high. Upon rising from the Valley of the James the great Missouri Plateau, the Coteau du Missouri, appears in the distance west about twenty miles.

BORDULAC.—(Foster County), 152.4 miles. (206.6 miles.) Altitude, 1,530 feet.

Low morainic hills of the Kiester Moraine in distance east. Lakes George and Bordulac are broad shallow glacial pans, their waters hemmed in by low morainic hills.

Carrington.—161.1 miles. (197.9 miles.) Altitude, 1,579 feet. Population, 1,150.

The Soo Railway passes through a fine tract of farming country in Foster and Wells Counties, along the upper James and Sheyenne Rivers. The highland of the Missouri Plateau rises thirty miles west. In the distance to the east the high knobs of the Kiester Moraine can be seen, fifteen miles away. Hawk's Nest, an outlying fragment of the great plateau, stands fifteen miles southwest. It is a high drift-covered pinnacle of the old landscape before the Ice Age.

LEMERT.—168.8 miles. (190.2 miles.) Altitude, 1,594 feet.

Small ranges of low morainic hills cross the broad prairies. Many large granite boulders are strewn along the track between Lemert and Cathay. It is noticeable that many of these have one side planed off smooth and flat. When examined closely many of these flat surfaces are found to be marked with parallel lines, or striations. This shows that they have been carried long distances, and planed off in the process of being shoved over hard surfaces.

CATHAY.—(Wells County), 176.2 miles. (182.8 miles.) Altitude, 1,584 feet.

Beautifully undulating and rolling crest of the moraine which was noticed west of Carrington now plainly in view west.

EMRICK.—181.6 miles. (177.2 miles.) Altitude, 1,597 feet.

Morainic ridges west, probably belonging to the Antelope, or Third, Moraine.

Fessenden.—188.6 miles. (170.4 miles.) Altitude, 1,610 feet. Altitude James River, low water, 1,591 feet. Population, 637.

Low morainic ridges south and west, well defined. Occasional hummocky knobs, such as are characteristic of terminal moraines. The moraine which was crossed at the James River, and which filled its valley, is still seen in the east and north from about Fessenden.

MANFRED.—195.0 miles. (164.0 miles.) Altitude, 1,605 feet.

A prominent cluster of hills west, a morainic heap, the crests of the ridges giving the moraine a rugged appearance. A small "glacial lake" hemmed in by the hills lies close north.

HARVEY.—205.0 miles. (154.0 miles.) Altitude, 1,596 feet. Sheyenne River, low water, 1,527 feet. Population, 590.

Low water of the Sheyenne is sixty-nine feet below the prairie surface, while that of the James, less than ten miles south, is only nineteen feet. The Sheyenne is thus shown to have been the great avenue of escape for the waters of the melting ice-sheet, from this portion of the State. Moraine with high rugged hills west. Moraine also east in distance. Fine tract of prairie intervening between.

ANAMOOSE.—(McHenry County), 221.5 miles. (137.5 miles.) Altitude, 1,620 feet. Population, 430.

Approaching Anamoose high and rugged moraines lie on both sides of the railroad. A lake hemmed in by the hills south. High knobs mark the surrounding hills. West of Anamoose, east of the railroad, is a large valley having distinct terraces on its sides, and a broad, flat bottom, with no stream upon it, and many boulders scattered upon the terraces. Such a deep and well-defined valley, having no stream on its bottom, and having well marked terraces, shows by its form that it is the channel of a glacial stream, a stream which ceased when the waters from the melting ice-sheet had disappeared, and the terraces mark the flood-plain of the stream during its earlier stages, before its channel had been cut down to the present bottom.

Still further west the railroad runs upon the bottom of a broad level channel, having extensive hay meadows and shallow lakes along its course. A dry lake southwest from Balfour lies in this channel, which is the old southern outlet of Lake Souris, at an earlier stage than that when its waters escaped to the Sheyenne by the Big Coulee outlet.

BALFOUR.—236.1 miles. (122.9 miles.) Altitude, 1,613 feet.

A few rods west of the station the track crosses the famous "Balfour Ridge," a beach of gravel and sand, which extends from two to three miles south of Balfour, north by northwest for about fifteen miles, to the Mouse River, at Pendroy. Where the railroad crosses it a section showing the sand and gravel in layers is exposed. The ridge rises six to eight feet above the prairie at its southern end, and becomes gradually higher toward the north. It is about thirty feet high at its northern end. The smooth and uniform surface and sloping sides, about equal in height, make it appear much like a railroad grading, and it has been surveyed and set apart for use as a public highway. The level crest of the ridge can be seen from the east window for some distance west of Balfour. Southwest of Balfour about twenty miles rises the blue and hazy head of Dog Den Butte. This is a large outlying hill of the Missouri Plateau. Its crest is crossed by several morainic ridges, and small lakes are on its top. The low and level prairie east of Dog Den is known as the "alkali flats." Many shallow alkaline lakes with shores of white sand lie along the tract.

VOLTAIRE.—251.3 miles. (107.7 miles.) Altitude, 1,587 feet.

Westward from Balfour the old outlet channel of Lake Souris is a mile or more in width, seen west of the railroad. Extensive hay-meadows lie upon its bottom. From Voltaire the railroad descends to the Mouse River "bottoms" by the steep, sharp valley of Spring Creek. This coulee is a notch or channel cut in the bottom of the old outlet channel since the waters of Lake Souris disappeared.

VELVA.—256.3 miles. (102.7 miles.) Altitude, 1,525 feet.

West of Velva deep coulees with steep sides border the valley of the Mouse. The highland along the valley on the west was the shore of Lake Souris.

Minot.—(Ward County), 277.4 miles. (81.6 miles.) Altitude, 1,557 feet. Population, 1,277.

The valley of the Mouse is a great trough eroded by a great glacial river, its bottom being one to two miles across, and the hills forming the sides of the valley rising 150 to 200 feet above the flat bottom. The sides of the valley are beautifully serrated by little coulees, as though a giant hand had drawn a coarse comb across the hillsides and made the little furrows, or coulees. (See p. 206.)

BURLINGTON.—285.2 miles. (73.8 miles.) Altitude, 1,590 feet.

Here is the point of meeting of the Des Lacs and Mouse Rivers, both of which flow in large glacial valleys. The Soo Road follows the course of the Des Lacs Valley, traversing the bottom of the valley more than forty miles. The valley was eroded by the glacial flood waters deeply into the shales which underlie the drift. Coal mines are opened by tunneling from the hillsides along the valley. The Burlington mines are extensively operated. (See Fig. 71, p. 167.)

FOXHOLM.—295.2 miles. (63.8 miles.) Altitude, 1,657 feet.

Fine examples of terraces, marking the flood plain of the river at an earlier time before its valley had been eroded to the present bottom. One such terrace plateau lies on the east side of the railroad west of Burlington, rising twelve to fifteen feet above the railroad grade. It is almost perfectly flat on top, and strewn with many boulders. West of Foxholm another fragment of the older flood plain occurs, about ten feet high. Approaching Carpio, the terrace is well developed on west side of valley.

CARPIO.—306.6 miles. (55.4 miles.) Altitude, 1,696 feet.

Layers of brown sandstone outcrop in the sides of the high banks west. Black layers indicate lignite coal in thin seams. Nearing Donnybrook are seen fine examples of "alluvial fans," soil carried down to the valley bottom by streams flowing in the steep coulees and spreading out upon the flat plain.

DONNYBROOK.—312.7 miles. (46.3 miles.) Altitude, 1,760 feet.

The town stands upon one of the alluvial fans just mentioned. On the west side of the valley, where two coulees enter, a butte has been formed, its sides steep, its top flat. Sandstone and clay are exposed in horizontal layers on the south and east sides. On the east side of the valley opposite Donnybrook a line may be traced along the side of the valley about half way to the top of the hillside, by the difference in the vegetation above and below the line. This marks the depth of the drift which overlies the sandstones and shales which are the "bed rock." The Des Lacs River is a very small stream, little more than a meadow ditch which a small boy could jump across. Its course is very crooked, showing that it flows very slowly. Such is the modern representative of the great glacial stream which carved the deep broad valley on the flat bottom of which this tiny rivulet now meanders. The bottom of the Des Lacs valley in the upper half of its course is covered by a series of lakes. These are there simply because there is not enough fall to the bottom of the valley to cause the water to run. The first of these lakes is a pretty sheet extending from one side of the valley to the other and about two miles long, lying about eight miles west of Donnybrook.

KENMARE.—327.4 miles. (31.6 miles.) Altitude, 1,799 feet. Altitude, low water, Des Lacs Lake, 1,783 feet. Altitude, top of hill adjoining, 1,950 feet. Population, 300.

Kenmare stands upon the hillside overlooking the second lake. The lake covers the entire width of the valley bottom so that the shores come down abruptly to the water's edge. A hay-meadow lies upon the valley bottom between the second and third lakes, the latter being a long ribbon of water half a mile to a mile in width, and extending along the valley bottom thirty miles to the International Boundary. Along the sides of the valley at Kenmare are the machinery and tracks, and the openings to the very extensive coal mines for which Kenmare and the State of North Dakota are noted. Sandstone rock suitable for building purposes is obtained from the hillsides, evidences of which are seen in the substantial buildings constructed from this stone in the city of Kenmare. West of Kenmare the railroad leaves the Des Lacs valley, laboriously climbing up the side of the valley and emerging upon the beautiful level prairie. At once the lake has disappeared from sight, for the eye scans the prairie only to look directly across the valley, which lies entirely below the general prairie level, a deep flat bottomed trough cut in the great plain. If any further proof were needed that this is a valley of glacial erosion this would serve the purpose, for the country along the stream course would be cut into hills if the valley had been cut by the ordinary development of a drainage system.

Bowbells.—339.6 miles. (19.4 miles.) Altitude, 1,958 feet. Population, 398.

A splendid prairie, unbroken by any coulee or mark of drainage. The horizon line in the east is a straight line unbroken by any hill or elevation. In the west, twenty miles away, rises the highland of the great Coteau du Missouri. The horizon line in the west is rendered undulating and wavy by the knobs and ridges of the Altamont, or First, Moraine, which lies along the plateau top.

Flaxton.—349.3 miles. (9.7 miles.) Altitude, 1,956 feet.

Between Bowbells and Flaxton the railroad crosses a low belt of morainic hills, which give to the prairie a gently rolling aspect. A long slough, a lake during very wet seasons, a fine hay-meadow usually, has been a lake, the waves of which have beaten upon the shores forming a wave-cut terrace along its border. It is a relic of the flood waters from the melting ice-sheet.

Portal.—359.0 miles. Altitude, 1,954 feet.

Portal, as its name indicates, is the "gate city," standing upon the International Boundary between North Dakota and Assiniboia. A range of sandy morainic hills is crossed by the railroad just as it passes into Canada. Extending far south is a fine tract of prairie. The "Hills," the great Missouri Plateau, rise majestically against the sky twenty miles distant in the west.

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BISMARCK EXTENSION

HANKINSON.—(Richland County), 14.5 miles from Fairmount.

LIDGERWOOD.—26.6 miles. Altitude, 1,090 feet. Population, 585.

About four miles west of Hankinson is the Herman Shore-Line of Lake Agassiz. Three miles southwest the hills of the Dovre Moraine are 100 to 150 feet high. This moraine lies south of the railroad about two miles and parallel with it for nearly twenty-five miles. The Herman Beach is about six miles north of Lidgerwood. On the broad flat prairie between the moraine on the south and the Herman Shore north are many broad shallow lakes.

RANSOM.—(Sargent County), 38.0 miles. Altitude, 1,128 feet.

Cross the Wild Rice River. The Dovre Moraine is here crossed by the railroad, a belt of rolling hills about a mile wide. Many granite boulders occur scattered upon the prairie east and west of the moraine. On the western side of the moraine was the eastern shore of Lake Sargent. (See p. 117.)

Forman.—49.7 miles. Altitude, 1,247 feet. Population, 257.

At Forman the depth of the water of Lake Sargent was about fifty feet. At Perry, six miles east, it was about 100 feet, and along the eastern side of the lake near the Dovre Moraine, about 150 feet. Many boulders are scattered upon these prairies.

NICHOLSON.—61.3 miles. Altitude, 1,305 feet.

Nicholson is near the western shore of Lake Sargent. To the north is a hill two to three miles long, north and south, covered with a smooth veneering of drift, a pre-glacial hill. Westward from Nicholson the railroad crosses a belt of morainic hills about six miles in width, a compound moraine representing the Waconia, Elysian, and Kiester Moraines.

OAKES.—(Dickey County), 72.6 miles. Altitude, 1,320 feet. Population, 668.

West of the compound moraine mentioned the northern end of the plain of the bottom of Lake Dakota is crossed, here about six miles in width. The James River flows south across this old lake bottom. (P. 116.)

MERRICOURT.—106.3 miles. Altitude, 1,644 feet.

Near the crossing of the C., M. & St. P. Railway, ten miles east, a low range of hills, the Antelope Moraine, is crossed. The landscape rises quite rapidly here toward the top of the great Plateau, the Coteau du Missouri. Low. long, undulating and rolling swells, the hills of the

Gary Moraine, occur westward toward Kulm. The train toils heavily up the steep grade. The broad rolling hills rise twenty-five to forty feet above the hollows, and the crests stand 400 feet above the plain to the east.

KULM.—(La Moure County), 118.8 miles. Altitude, 1,966 feet. Population, 463.

Kulm is on the high prairie of the Missouri Plateau, a gently rolling, broad expanse of prairie. Northwest from Kulm the landscape is marked by broadly rolling swells. Extensive hay-meadows in the low, broad sloughs. Many small granite boulders lie upon the surface. Farther west, in southeastern Logan County, the landscape is more rough, hills steep, long hay-meadows in old glacial drainage channels. Railroad often cuts through the hills, showing gravel and drift clay. Boulders strewn upon surface. West of this belt of hills the surface is more smooth. Wave cliffs and terraces on the sides of sloughs show where have been lakes during the time of the melting of the ice-sheet. Frequent alkali lakes among the hills west.

LEHR.—(McIntosh County), 139.3 miles. Altitude, 2,017 feet.

The Altamont Moraine is crossed, with hills high and steep. Railroad winds among the hills, with frequent cuts. Hills 150 to 200 feet high, with steep boulder-strewn sides. Railroad follows old drainage channel, with steep grade westward, rising onto the immense ridge or belt of the Altamont Moraine.

WISHEK.—149.8 miles. Altitude, 2,010 feet.

Between Lehr and Wishek is one of the most majestic developments of a terminal moraine crossed by any line of railway in the State. The height of the moraine is from 2,000 to 2,075 feet above sea level and rises 200 feet above the nearly level prairie on either side. The belt where crossed by the railroad east of Wishek is about eight miles in width, and is one of the most striking morainic regions in the State. The deep, well-marked valleys having no streams of importance in them indicate the action of glacial flood waters at the time these and later ranges of morainic hills were being formed along the edge of the Great Ice-Sheet. Many deep hollows containing lakes, having clearly cut terraces on their shores showing the higher stage of the water at a former time, broad hay-meadows, which were once lake bottoms, and long channels marked by high terrace flood-plains, tell of the great amount of water which once was here. The hills are very high and steep, and strewn with boulders. The landscape is one almost inaccessible to travel through overland, except on horseback. And then the traveler is very likely to lose his way, the high knob which was taken as a guide treacherously allowing another to be mistaken for it! A broad valley, an old drainage channel from the Altamont Moraine to the Missouri River, lies west of Wishek, along which the railroad runs. This valley is broad and deep, having flat bottom and well-defined terraces along its sides. A branch of the railroad south to Ashley follows this channel.

Napoleon.—(Logan County), 171.0 miles. Altitude, 1,951 feet.

From Wishek the railroad runs nearly northwest to Napoleon, following the bottoms of glacial channels, broad and flat bottoms with small streams, or none at all. The sides of the valleys are steep, owing to the Fox Hills Sandstone, which forms the surface layer of rock, thinly overlaid with drift. Two large drainage channels meet at Berry Lake west of Napoleon. A terrace of gravel and sand fills the lower part of these valleys to a height of about twenty-five feet above the water of the lake. Traces of this terrace are seen along the valley running west.

Campbell.—(Emmons County), 180.9 miles. Altitude, 1,896 feet.

Terraces well shown along valley, which is followed by the railroad. A cut shows brown shaly sandstone in thin strata.

Braddock.—187.9 miles. Altitude, 1,860 feet.

From Campbell west the railroad follows the deep, broad valley, marked terraces occurring along its sides. The valley is more than 100 feet below the general level west of Campbell. Morainic hills occur north, but these are largely concealed from view by the high valley walls.

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Ashley.—(McIntosh County), 167.8 miles. Altitude, 1,998 feet.

Ashley is eighteen miles southeast of Wishek. The railroad follows large glacial drainage channels through most of the distance. Many conspicuous channels of this character occur in this neighborhood. No part of the State offers a more interesting field for the study of glacial drainage than this region, in McIntosh and Logan Counties. High bouldery terraces and chains of lakes along these old lines of drainage give the landscape a unique appearance. The Altamont Moraine, which was crossed east of Wishek, extends nearly parallel with the line of the railroad as far south as Ashley, when it extends eastward to about the edge of the great Missouri Plateau in southwestern Dickey County. The hills of this range rise from 100 to 150 feet in height between Wishek and Ashley, and in the southwestern township of Dickey County the higher knobs are nearly 200 feet high, their high crests standing conspicuously against the sky, as seen from the east, 500 to 600 feet above the plain to the east. Ashley stands upon a nearly level plain about six miles square, having a deep, fine, silt-like soil, as though it had been the bottom of a lake for a long time. A larger plain of similar character, though not as nearly level, extends over a large region west of the high morainic range.

AN INDEX.

SUBJECT TITLES IN HEAVY-FACED TYPE.

APPENDIX.

Explanation: In the Spring of 1900, at the time when the swelling tide of immigration into the then newer northwest of North Dakota was attracting wide attention, three articles appeared in the Mayville *Tribune*, from the author's pen, written at the request of the editor to give a brief statement of the geological situation of the Mouse River Valley with reference to the bearing of this upon the agricultural resources of that region. In one of these articles a study of the rainfall, from the United States Weather Bureau statistics, was presented. All the geological matter which was given in these articles was later embodied in the text of the present volume, but not the statistics of rainfall.

Many requests for copies of this tabulated record of rainfall have been received, and, as the original article is not now available, it has been deemed advisable to insert this table and the accompanying discussion in the present edition of *The Story of the Prairies* as an appendix.

The articles were originally written with local reference to the northwestern portion of the State, and the local character of the description has not been changed. Those who may be interested in the question of rainfall in other regions adjacent, either in North Dakota, Montana, or the Canadian Northwest, will be able to make comparisons from the figures given, by reference to the official records of rainfall in the particular localities in which they may be interested.

The only changes made in the original tables are in bringing the data down to include the year 1902.

THE RAINFALL IN NORTH DAKOTA.

The question of rainfall is an important one in any agricultural district. To all appearances North Dakota has unlimited resources in fertility of soil if only climatic conditions are such as to make the natural fertility of the soil available in crop production. Records of the amount of rainfall have not been made at all points which would be desirable in determining an estimate of the comparative rainfall in this portion of our State and that of the eastern portion. However, we have compiled such data as are available for the months of April, May, and June, which months are deemed to be the most important ones, and from these some idea may be formed of the amount of rainfall in this northwestern portion of the State as compared with the Red River Valley.

In the accompanying table the figures indicate the amount of rainfall in inches and hundredths of an inch, and are compiled from the annual reports of the director of the Weather Service at Bismarck. The stations, which are named in the table, have been selected with the idea of showing the comparative rainfall in the Mouse River Valley; the great Plateau region to the west; the medium upland east of the basin of Lake Souris (Mouse River Valley), and the Red River Valley. By comparing the figures in the two tables the rainfall for any locality given in Table A for the months of April, May, and June may be compared with the average for that month for the entire State (Table B). And by reference to the columns of figures in Table A marked "Total for three months" and the horizontal line of figures in Table B showing the average rainfall for a particular locality, comparison may be made with that for the whole State. The average annual precipitation (rain and snow) for each year for the whole State is also given in Table B. The column in Table A, "Total for the three months for eight years," is given for the ready comparison of one locality with another of the total rainfall for the months of April, May, and June over a period of eight years. The figures in the column marked "Average for three months for each year" in Table A, which represent particular localities, may be compared with the figures in Table B showing "Average rainfall for three months" for the whole State.

If any person has labored under the impression that these lands in the northwestern part of the State are subject to drought and hence not adapted to profitable farming, a study of the climatic records will tend to dispel that idea.

TABLE A

Showing April, May, and June rainfall from 1895 to 1902 inclusive, at eleven North Dakota Stations, expressed in inches and hundredths of inches.
Where blank spaces occur no records are available.
Compiled from the Annual Reports of the Director of the Weather Service at Bismarck, N. D.

STATIONS.	1895				1896				1897				1898			
	April	*May*	*June*	*Total for 3 months*	*April*	*May*	*June*	*Total for 3 months*	*April*	*May*	*June*	*Total for 3 months*	*April*	*May*	*June*	*Total for 3 months*
Portal	1.52	2.81	3.67	8.00	2.40	4.16	4.24	10.80	1.34	.34	2.03	3.71	.82	.82	3.40	5.04
McKinney	1.60	3.56	4.25	9.31	1.86	4.65	6.82	13.33	1.65	.32	10.40	12.37	.87	.01	3.37	4.25
Williston	2.52	3.02	3.67	9.21	2.86	5.79	3.45	12.10	1.17	.72	2.71	4.60	1.08	1.21	4.56	6.85
Berthold Agency	1.15	2.76	4.19	8.10	4.04	7.71	7.08	18.83	.70	1.77	1.06	3.53	.33	2.04	2.24	4.61
Bottineau	.80	3.63	3.74	8.17	*2.73	4.05	5.94	12.72	------	------	------	------	55	.05	3.11	3.71
Willow City	1.31	3.37	3.45	8.13	3.60	5.71	3.18	12.49	0.00	.58	.70	1.28	* .35	.25	3.68	4.28
Churchs Ferry	1.46	1.95	2.90	6.31	5.98	4.06	4.68	14.72	1.20	.55	2.97	4.72	1.26	2.21	4.20	7.67
Devils Lake	------	------	------	------	------	------	------	------	1.10	.80	4.43	6.33	.19	1.39	3.50	5.08
Larimore	1.19	2.24	6.17	9.60	*5.30	3.22	4.95	13.47	.81	.35	3.09	4.25	.53	2.96	3.62	7.11
Grafton	3.22	.90	4.70	8.82	4.75	6.72	3.31	14.78	.40	.20	.20	.80	1.10	1.05	4.45	6.60
Fargo	1.36	1.62	4.81	7.79	3.64	4.70	2.41	10.75	.89	.74	7.10	8.73	.88	4.15	2.25	7.28

STATIONS.	1899				1900				1901				1902				Total for the 3 months for 8 years	Average for 3 mos. for each year
	April	*May*	*June*	*Total for 3 months*	*April*	*May*	*June*	*Total for 3 months*	*April*	*May*	*June*	*Total for 3 months*	*April*	*May*	*June*	*Total for 3 months*		
Portal	.40	1.26	4.55	6.21	T	1.52	.50	2.02	1.10	.40	6.12	7.62	2.52	2.83	6.14	11.49	54.89	6.86
McKinney	.61	2.50	5.18	8.29	.05	.81	.43	1.29	.21	T	5.90	6.11	T	.78	1.50	2.28	57.23	7.15
Williston	.60	2.39	3.72	6.71	.57	1.46	.65	2.68	.46	.71	8.84	10.01	.53	2.69	3.92	7.14	59.30	7.41
Berthold Agency	1.20	7.79	8.08	17.07	.96	.38	* .57	1.91	.47	T	4.02	4.49	------	------	------	------	†58.54	8.34
Bottineau	1.15	2.96	4.63	8.74	.20	.70	* .47	1.37	.17	.17	7.08	7.42	.10	4.10	*3.06	7.26	†49.39	7.05
Willow City	* .88	2.60	6.38	9.86	T	.94	.51	1.45	.16	0.00	8.12	8.28	.20	2.04	4.69	6.93	52.70	6.59
Churchs Ferry	3.29	3.00	3.74	10.03	.32	.66	.53	1.51	.08	0.00	7.45	7.53	.49	3.87	3.45	7.81	60.30	7.54
Devils Lake	1.56	2.84	2.21	6.61	1.10	.22	2.06	3.38	.24	.10	8.27	8.61	.24	3.03	3.99	7.26	‡37.27	6.21
Larimore	1.03	2.22	1.82	5.07	1.24	.16	.90	2.30	2.89	.17	5.93	8.99	.98	4.45	2.88	8.31	59.10	7.39
Grafton	2.14	1.76	2.44	6.34	.43	1.03	1.46	2.92	.45	T	7.45	7.90	1.25	*4.31	2.40	7.96	56.12	7.01
Fargo	1.39	4.22	3 44	9.05	1.82	.81	2.11	4.74	1.76	.98	5.91	8.65	2.30	4.25	3.07	9.62	66.61	8.32

* The record for this month was not given, and the average for the two nearest points are given. † Total for seven years. ‡ Total for six years.

TABLE B

Showing the average rainfall for the State for the months of April, May, and June for several years; also showing average annual precipitation for the same time.

	Average for many years	*Average for* **1892**	*Average for* **1893**	*Average for* **1894**	*Average for* **1895**	*Average for* **1896**	*Average for* **1897**	*Average for* **1898**	*Average for* **1899**	*Average for* **1900**	*Average for* **1901**	*Average for* **1902**
April	1.60	2.65	1.73	3.06	2.23	4.37	1.01	1.38	1.36	0.75	0.91	1.05
May	2.36	2.21	1.64	1.54	2.48	4.89	0.71	1.98	3.49	0.69	0 27	3 45
June	3.51	3.35	5.54	3.44	4.67	3.80	3.75	3.19	3.81	1.39	6.09	3.48
Average rainfall for three months	7.47	8.21	8.91	8 04	9.18	13.06	5.47	6.55	8.66	2.83	7.27	7.98
Total average precipitation for the State	17.23	18.14	17.98	15.64	19.09	23.57	15.88	15.17	17.67	18.96	18.48	17.61