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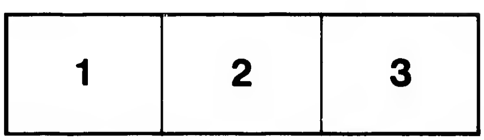
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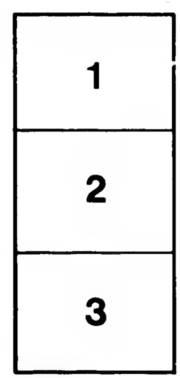
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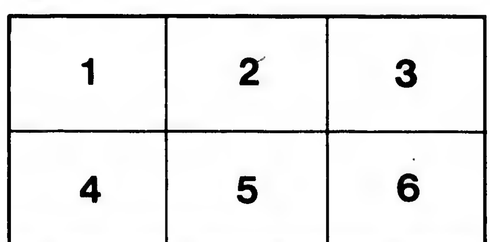
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GEOGRAPHIC MONOGRAPH

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NIAGARA FALLS AND THEIR HISTORY

BY

PROF. G. K. GILBERT,

U. S. GEOLOGICAL SURVEY.

NOTE.—Separate Copies of this Paper can be purchased from the American Book Company, New York City, at twenty cents per Copy.

NIAGARA FALLS AND THEIR HISTORY.

By G. K. Gilbert.

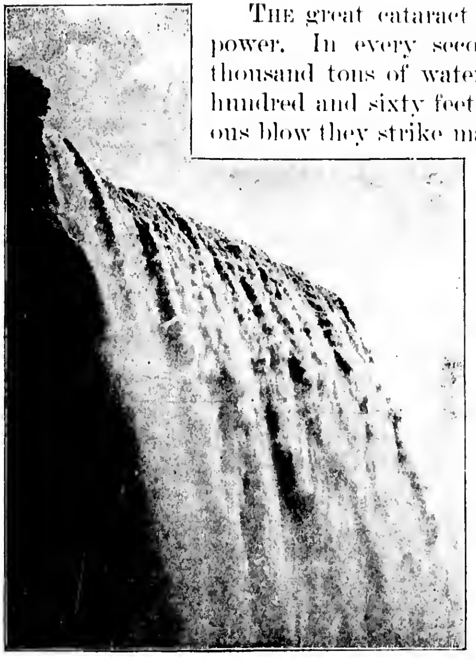

Fig. 1.—American Fall from below.

The great cataract is the embodiment of power. In every second, unceasingly, seven thousand tons of water leap from a cliff one hundred and sixty feet high, and the continuous blow they strike makes the earth tremble. It is a spectacle of great beauty. The clear, green, pouring stream, forced with growing speed against the air, parts into rhythmic jets which burst and spread till all the green is lost in a white cloud of spray, on which the rainbow floats. Its charms are the theme of many a gifted bard and artist, but the fascination of its ever-varied yet continuous motion, and the awe that waxes rather than wanes with familiarity, are not to be felt at second-hand; and so the world, in long procession, goes to see. Among the multitude there are some whose appreciation of its power has a utilitarian phase, so that they think most of the myriad wheels of industry its energy may some day turn; and there are a few who recognize it as a great natural engine, and in its activity and its surroundings see an impressive object lesson of geographic progress. Its aesthetic and utilitarian aspects need no expounder, but its geographic significance is too little appreciated. This paper endeavors to tell in simple language some of the lore of the professional geographer and geologist, in order that the layman may gain pleasure not only from the beauty and grandeur of the scene, but through understanding its meaning as a part in the great drama of nature.

Nature is full of change. The bud we saw yesterday is a flower to-day: the leaf that was broad and green in summer, in autumn is shriveled and brown; the bush we knew in childhood is now a broad, spreading tree. Such changes are easily seen, because they fall within the span of a man's life, and so the principle of perpetual progress in the organic world is familiar to all. Progress in the inorganic world is so slow that it is less easily seen, and there is a widespread impression that the hills are everlasting and unchanging. This impression is false. Not only hills, but mountains, plains, and valleys, are perpetually acted on by heat and cold, sunshine and rain, wind and stream, and are gradually changed. Not only do they now undergo change, but by such agents each feature was originally formed, and by such agents it will eventually be transformed into a feature of different type. Thus every element of the landscape has an origin and a history. To relate these is to explain it. This monograph may be regarded as an explanatory account of Niagara Falls and the associated natural features.

THE DRAINAGE SYSTEM.

The drainage system of the St. Lawrence is of exceptional character. In most regions the freshly fallen rain gathers into rills; these, as they run, join one with another, making brooks; brooks are united into rivers; and rivers flow to the sea. In all its journey from the hillside to the sea, the water moves forward without halt. This uninterrupted journey is rendered possible by a wonderful adjustment of slopes. The channel of the rill slopes toward the brook, the bed of the brook slopes toward the river, and the river bed slopes toward the sea. Impelled by gravity to flow downhill, the water moves continually forward from the beginning to the end of its journey. In the drainage district of the St. Lawrence there is no such continuity of slope. The district is composed mainly of a group of great basin-like hollows, in each of which the surface slopes toward some central point, and not toward the mouth of the river. Each basin is filled with water to the level of the lowest point of its rim, and each of the lakes thus formed is a storage reservoir receiving a group of streams from the surrounding country, and pouring an even discharge over its rim to one of its neighbors. Lakes Superior and Michigan discharge to Lake Huron; Huron overflows to Erie; and Erie, having thus received all the outflow of the upper and greater lakes, sends its surplus through the Niagara to Ontario. The Niagara River is thus, from one point of view, a strait connecting two inland seas; from another point of view, it is a part of the St. Lawrence River,—the part connecting two great expansions. Viewed either way, it departs so widely from the ordinary or normal river that its name is almost misleading.

In a normal drainage system the slope is not everywhere equally steep: it is gentler in the bed of the main stream than in the beds of tributaries, and it varies from point to point so that the current, especially at low water, shows an alternation of rapid and quiet reaches. The streams of the Laurentian system not only exhibit these alternations, but have many cataracts where the water cascades down a rocky stairway or leaps from the brink of a cliff.

A normal river receives most of its water directly from rain or melting snow, and varies with the season, swelling to a flood in time of storm or at the spring snow melting, and dwindling to relative insignificance in time of drought. The water of Niagara comes only remotely from storm and thaw. The floods of the tributaries are stored by the lakes, to whose broad surfaces they add but a thin layer. The volume of Niagara depends only on the height of Lake Erie at Buffalo, and from season to season this height varies but little. On rare occasions a westerly gale will crowd the lake water toward its eastern end, and the river will grow large. On still rarer occasions a winter storm will so pile up or jam the lake ice at the entrance to the river as to make a dam, and for a day or two the river will lose most of its water.

A normal river, with its continuous current, rolls forward the pebbles loosened by its tributaries till they reach its mouth.

The rains that make its floods dislodge particles of soil, and wash them into the tributaries in such multitude that they discolor the water. The pebbles of its bed and the mud with which it is discolored are the river's load, which it transports from the face of the land to the bed of the sea. The tributaries of Niagara carry their loads only to the lakes, where the loads sink, and leave the water pure. Thus Niagara is ever clear. Sometimes, when storm waves lash the shores of Erie, a little sand is washed to the head of the river, and carried downstream; sometimes a little mud is washed into the river by the small creeks that reach its banks. Thus Niagara is not absolutely devoid of load, but its burden is so minute that it is hard to detect.

THE TWO PLAINS.

From Lake Erie to Lake Ontario the Niagara runs northward. The longer axes of the lakes trend nearly east and west, and the lakes lap past each other for a distance of forty miles, including between their parallel shores a strip of land about twenty-five miles wide. This strip, where the river crosses it, consists of two plains, sharply separated by a cliff or escarpment. The relations of the plains to the escarpment and to the lakes are shown by the map (Fig. 2)

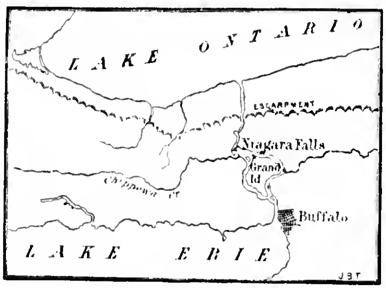

Fig. 2.—Niagara River and Vicinity.

and the bird's-eye view (Fig. 4). The upper and broader plain has a gently undulating surface, which does not differ greatly in height from the surface of Lake Erie. Along the shore of that lake it rises in a low ridge, and there is also a gentle rise toward the escarpment. Its middle part is drained by two sluggish creeks,—the Tonawanda, flowing to the river from the east; and the Chippewa, from the west. The lower and narrower plain follows the shore of Lake Ontario, and rises gently thence to the foot of the escarpment. Its upper part is of rolling contour, like the upper plain; its lower is remarkably smooth and even, having once been the bed of a lake. The escarpment is a steep slope about two hundred feet high. Near the top it is generally a rocky cliff, giving a sharply defined boundary to the upper plain; at the bottom it merges insensibly with the lower plain.

These surface features are definitely related not only to the peculiarities of the river, but to the rocky framework of the country. The rocks are flat layers or strata resting one upon another, and of nearly uniform thickness for great distances. Nearly but not quite level, they slope gently toward the south; the descent, or dip, amounting on the average to thirty-five feet per mile. Their arrangement is illustrated by Fig. 3, which gives a north-and-south profile, with such a section of the formations

FIG. 3.—Profile and Section from Lake to Lake.
Vertical scale greater than horizontal. Base line represents sea level.

as might be seen if a very deep trench were dug from lake to lake. The heavy line at the left, and the belt below divided into blocks, represent limestones, rocks notably hard and strong, while the intervening spaces are occupied chiefly by shales, which are relatively soft and weak. Originally all the formations extended farther to the north, but they have been worn away; and, since the soft rocks were removed more easily than the hard, the edges of the hard are left somewhat prominent. This association of hard rocks with uplands and cliffs is not rare, but is rather the rule in hilly and mountainous districts. In the last preceding monograph of this series, Mr. Willis describes the plateaus and ridges of the Appalachian district, showing how frost and storm slowly but persistently ate out the soft rocks, and the rock waste was washed into streams, till valleys and lowland plains were made.

The higher of the two limestones presented in the diagram is called the Corniferous limestone. It makes a low ridge along the north shore of Lake Erie, and dips beneath the lake. The Salina shales occupy the middle part of the upper plain, and dip beneath the Corniferous. The second limestone, called the Niagara limestone, constitutes the northern part of the upper plain, and the escarpment everywhere marks its northern limit. Its full thickness is about a hundred and forty feet, but in some places it has been greatly reduced by the wasting of its upper surface. Below it is a great series of mud rocks or shales, a thousand feet thick, interrupted near the top by a few thin beds of limestone and sandstone. These shales occupy the lower part of the escarpment and the whole of the lower plain. Their softness and the hardness of the Niagara limestone guided the erosive agents in making the escarpment and the lower plain.

Over all this rocky foundation lies a mantle of loose material, —clay, sand, gravel, and bowlders,—collectively called the *drift*. Its ordinary thickness is thirty or forty feet; but there are places, especially on top of the escarpment, where it is nearly absent, and elsewhere it fills hollows or is built into hills with a thickness of several hundred feet. It was spread over the country after the broader features of the topography had been shaped, and the agency by which it was deposited was moving ice, as will be explained a little later.

THE RIVER AND THE GORGE.

From Lake Erie the Niagara River runs over a low sag in the ridge of Corniferous limestone. Where the current crosses this rocky barrier, it is rapid and disturbed. Thence for fifteen miles it flows above shales, but rarely touches them, the banks and bed consisting chiefly of drift. The channel is broad, and the water glides along with unruffled surface. Then, a little below the mouth of Chippewa Creek, the Niagara limestone appears in the bed, and the whole habit of the stream is quickly changed. For a thousand yards it is a broad, roaring rapid, tumbling over one ledge after another with tumultuous haste; and then it pours over a precipice to the bottom of a narrow, deep, steep-walled gorge. For seven miles it courses, with alternation of deep, boiling pools and narrow, violent rapids, through this gorge, whose steep walls of rock then turn abruptly

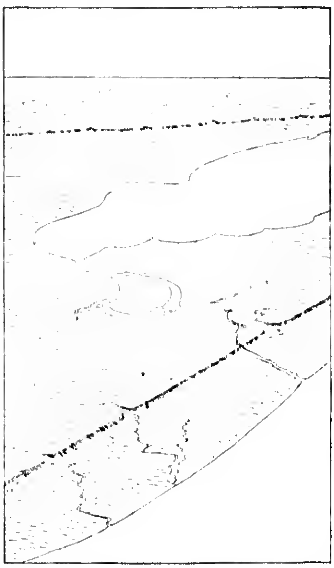

FIG. 4.—Bird's-eye View of the Niagara River from Lake Ontario. Beyond the Ontario shore are the Lower Plain, Escarpment, Upper Plain, and Lake Erie.

to the right and left, and merge with the face of the escarpment. Thence to Lake Ontario the width is moderate, and the current is strong and deep between steep banks of red shale capped with drift.

Thus for two thirds of its journey across the upper plain the river travels on top of the plain, and then for the remaining third it runs from two hundred to three hundred feet below the plain in a narrow trench. This contrast is the geographic fact on which scientific interest in Niagara has centered, and its importance is not readily overestimated.

The walls of the trench are vertical cliffs in their upper part, and are there seen to be composed of the same limestone that underlies the plain. The limestone cliffs are of moderate height,

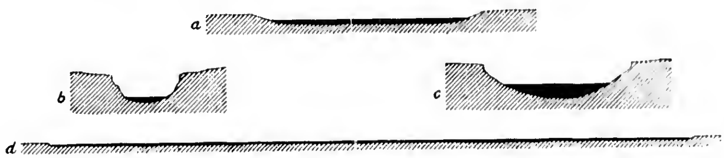

FIG. 5.—Cross Sections of Niagara River.

a, two miles below the escarpment; *b*, in the narrowest part of the gorge; *c*, in a broad part of the gorge; *d*, two miles above the falls. Scale, about 2,000 feet = 1 inch.

and from their base there usually starts a talus or apron of fragments, which descends to the river's edge. The general appearance of the gorge is fairly illustrated by the view in Fig. 7. Here and there the talus is scant or altogether absent, so that the strata can be seen; and wherever they can be seen, examination shows the two sides to have the same beds, in the same order, and at the same heights. First come gray shales about fifty feet thick; then a blue-gray limestone full of fossil shells, and ten or fifteen feet thick. This is the Clinton limestone of geologists; and it is so firm, as compared with the beds immediately above and below it, that rain and frost have affected it less, and it projects beyond its neighbors. There are several places where the edge of the bed is a cliff, though the adjacent shales are covered by fallen fragments (Fig. 6). Next below are green-gray shales, with thin limestone beds, and a soft, gray sandstone, the whole occupying a vertical space of about thirty feet; and then the color changes to a bright red, which characterizes the lower beds. These are chiefly shales, but there are soft sandstones among them; and there is one hard sandstone bed, of a pale gray color, which stands out prominently like the Clinton limestone, and for the same reason. It is twenty feet or more in thickness, lies one hundred and twenty feet below the Clinton limestone, and is called the quartzose sandstone (see Figs. 10 and 21). The observer who sees these various rocks, hard and soft, gray and red, matched bed for bed on the opposite sides of the

FIG. 6.—Cliff and Talus of American Bank above the Whirlpool.
The Niagara limestone appears in the upper cliff; the Clinton, in the lower. The quartzose sandstone is not seen, being below the water.

gorge, and who studies them at the angles of the walls, so as to realize that each is a great level plate, which, if continued through the air, would bridge the chasm to its companion in the opposite wall, never doubts that the rock beds were originally continuous, and that the gorge is of later origin. As to the way in which the gorge was made, there has been some difference of opinion. One or two writers have thought it was a crack of the earth violently rent apart, and one or two others have thought it was washed out by ocean tides; but the prevailing opinion is that it was made by the river that flows through it, and this opinion is so well grounded that it is hardly worth while to consider its rivals in this place. The agency of the river is shown by the modern recession of the cataract, by banks, terraces, gravels, and shells, marking earlier positions of the river bed, and by a cliff over which part of the river once poured as a cataract. It is qualified by a buried channel belonging to an earlier and different system of drainage. As these evidences are intimately connected with the history of the cataract and river, they will be set forth somewhat fully.

THE RECESSION OF THE CATARACT.

Modern Recession.—The cataract is divided unequally by Goat Island. The part on the southwestern or Canadian side is the broader and deeper, and is called the Horseshoe Fall; the

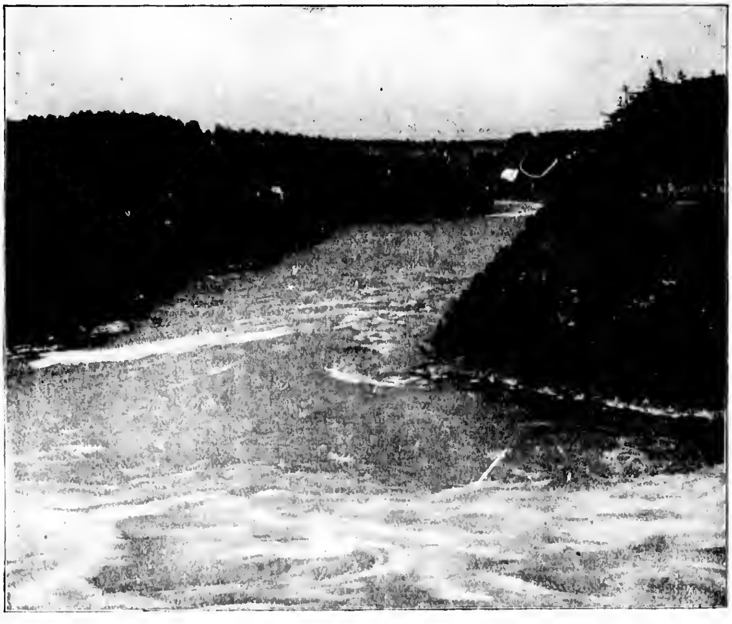

Fig. 7.—The Gorge below the Whirlpool, with Part of the Whirlpool in the Foreground.

other is the American Fall. As shown by the map (Fig. 15), the Horseshoe Fall is at the end of the gorge; the American, at its side. The cliff over which the water pours is from one hundred and forty to one hundred and seventy feet high, measured from the water of the river below. It is composed of the Niagara limestone at top, from sixty to eighty feet thick; and the shales, etc., beneath, as already described. At the edge of each fall, where one can look for a distance under the sheet of descending water, the limestone projects like a cornice beyond the wall of

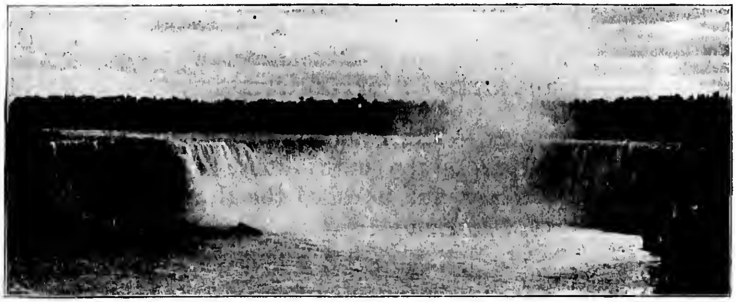

FIG. 8.—The Horseshoe Fall, from the Canadian Bank.

shale; so that there is a strip of the upper rock which is not directly supported by the lower, but is sustained by its own strength. From time to time portions of this cornice have been seen to break away and fall into the pool of water below, and other fallings have made themselves known by the earth tremors

FIG. 9.—The American Fall, from the Canadian Bank.

they produced. Usually the falling masses have been large; so that their subtraction has produced conspicuous changes in the contour of the cataract, and their dimensions have been estimated in scores of feet. Nearly all have broken from the cliff under, or at the edge of, the Horseshoe Fall. As these catastrophes depend on the projection of the limestone without support, we are warranted in supposing that it is gradually deprived of support by the removal of the softer rocks beneath; and, although it is impossible to see what takes place amid the fearful rage of waters, we may properly infer that that very violence makes the cataract an engine of destruction by which the shales are battered and worn away. Under the middle of the Horseshoe, where the pouring sheet is at least twenty feet thick, its force is so great as to move most, or perhaps even the largest, of the fallen blocks of limestone, and by rolling them about make them serve as weapons of attack.

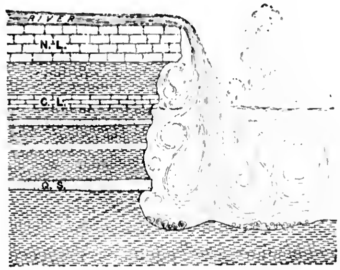

FIG. 10.—Profile and Section at Middle of Horseshoe Fall, showing Arrangement of Rocks and Probable Depth of Pool under Fall.

N.L., Niagara limestone; C.L., Clinton limestone; Q.S., quartzose sandstone. Scale, 300 feet = 1 inch.

In 1827 Capt. Basil Hall, of the British Navy, made a careful drawing of the Horseshoe Fall by the aid of a *camera lucida.* The use of that instrument gives to his drawing a quality of accuracy which constitutes it a valuable record. Sixty-eight years afterward, in 1895, a photograph was made from the same spot, and our illustrations (Figs. 11 and 12) bring the two pictures together for comparison. The bushes of his foreground have grown into tall trees which restrict the view, but the region of greatest change is not concealed. A vertical line has been drawn through the same point (Third Sister Island) in each picture to aid the eye in making the comparison. The conspicuous changes are the broadening of the gorge by the falling-away of its nearer wall, and the enlargement of the Horseshoe curve both by retreat to the right and by retreat in the direction away from the spectator. In 1842 Professor James Hall, State geologist of New York, made a careful instrumental survey of the cataract for the purpose of recording its outline, so that subsequent recession might be accurately measured by means of future surveys. His work has been repeated at various times since, the last survey being by Mr. A. S. Kibbe, assistant State engineer, in 1890. The outlines, as determined by these surveys, are reproduced in the chart on page 216 (Fig. 13), which shows that the greatest change has occurred in the middle of the Horseshoe curve, where the thickness of the descending stream is

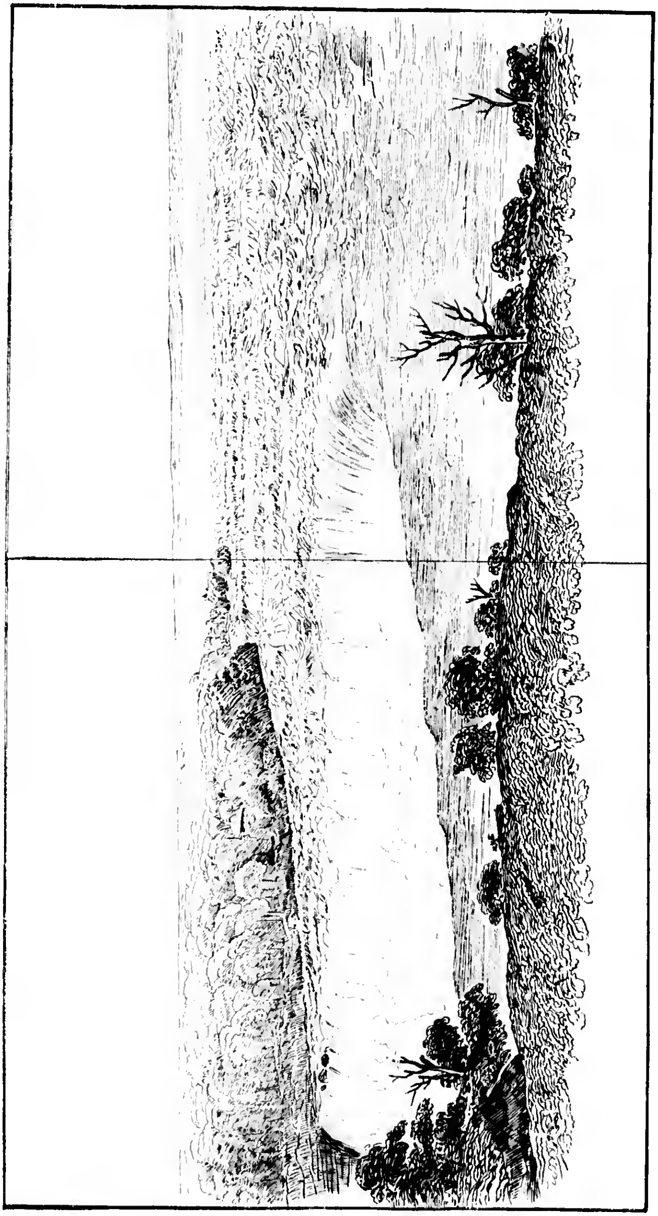

FIG. 11.—The Horseshoe Fall from Forsyth's Hotel, 1827. (Compare with Fig 12.)

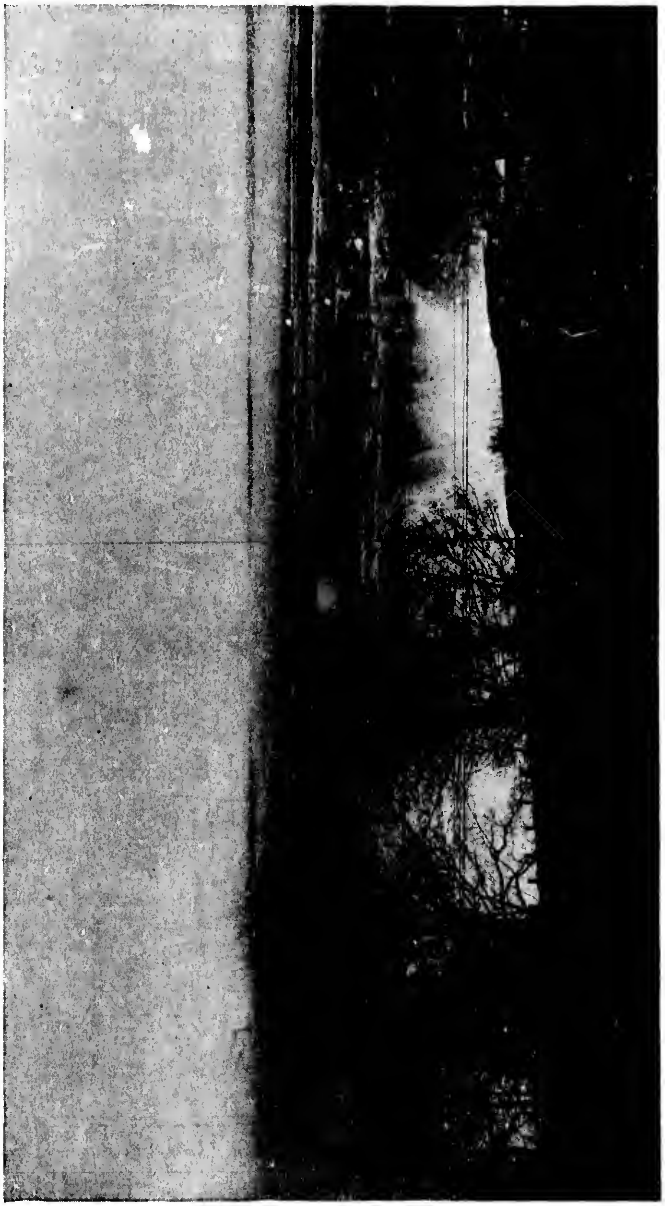

FIG. 12.—The Horseshoe Fall from the Site of Forsyth's Hotel, 1895. (Compare with Fig. 11.)

greatest. In that region about two hundred and twenty feet of the limestone bed have been carried away, and the length of the gorge has been increased by that amount. From these data it has been computed that the cataract is making the gorge longer at the rate of between four and five feet a year, and the general fact determined by the observation of falling masses and the comparison of pictures thus receives a definite expression in the ordinary terms of time and distance.

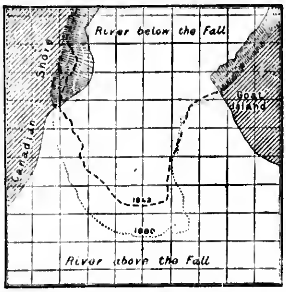

Fig. 13.—Outlines of the Crest of the Horseshoe Fall.

The vertical and horizontal lines are 200 feet apart.

The agent which has wrought such important changes during the brief period to which careful observation has been limited is manifestly able to hollow out the entire gorge if only granted enough time, and the theory which ascribes the making of the gorge to the work of the falling water is thus strongly supported.

Mode of Recession.—Before passing to other facts bearing on this point, it is well to call attention to certain peculiarities of the process whereby it differs from the normal process of cataract erosion. Pure water has little power to erode solid rock. It can pick up loose particles or roll them along; but firm, coherent rock cannot be broken by so soft a tool. Rock is, indeed, worn away by rivers, and the erosion accomplished in this way is enormous; but the water does it indirectly by carrying along rock fragments which rub and pound the solid rock of the river bottom. The rock fragments are of the same material, generally speaking, as the solid rock, and they wear it away just as diamond dust wears the solid gem. As already pointed out, the Niagara is peculiar in that its current carries no rock fragments. The geographic work performed by the cataract is practically dependent on the tools furnished by the blocks of fallen limestone. It is therefore of prime importance to the work of the cataract that it shall be able to roll the limestone fragments about, and thus grind them against the river bed. A study of the different parts of the cataract, comparing one with another, shows that the water has this power only where its body is great; namely, in the middle part of the Horseshoe curve. Under each edge of that fall and under the American Fall great blocks of limestone lie as they have fallen, manifestly too large to be moved by the moderate streams that beat against them. Some of these are shown in the general view of the Horseshoe Fall (Fig. 8), and more clearly in the view of the American Fall (Fig. 9). The block at the extreme right of the American Fal' s also pictured in Fig. 14. The resistance opposed by these blocks makes the rate of erosion of the American Fall comparatively slow. In fact, it is so slow that attempts to measure it have thus far been unsuccessful, because the changes which have taken place in its outline between the dates of surveys have been little greater than the inaccuracies of the surveys. Where the heaviest body of water pours down, the blocks are not merely moved, but are made to dig a deep hollow in the shale. The precise depth cannot be measured, because the motion of the water is there too violent for sounding; but a little farther down the river, where the cataract performed its work only a few centuries ago, the plummet shows a depth of nearly two hundred feet, and it is probable that the hollow directly under the Horseshoe is not shallower than that. The general fact appears to be that in the center of the main stream the water digs deeply, and the brink of the fall recedes rapidly. After the gorge has been lengthened by this process, it is somewhat widened by the falling in of its sides; and this falling in is in a measure aided by the thinner water streams near the banks, which clear away the smaller limestone fragments, though leaving the larger. After the cataract has altogether passed, the cliff is further modified by frost. The wall of shale, being wet by spray or rain, is exposed to the cold air of winter, and the water it contains is frozen. The expansion of freezing breaks the rock, either crumbling it or causing flakes to fall

FIG. 14.—The "Rock of Ages," a Fallen Block of Niagara Limestone at the Southern Edge of the American Fall.

away. In this way the shale is eaten back, and the limestone above is made to fall, until enough fallen fragments have been accumulated to protect the remainder of the shale from frost, after which time the process of change becomes exceedingly slow.

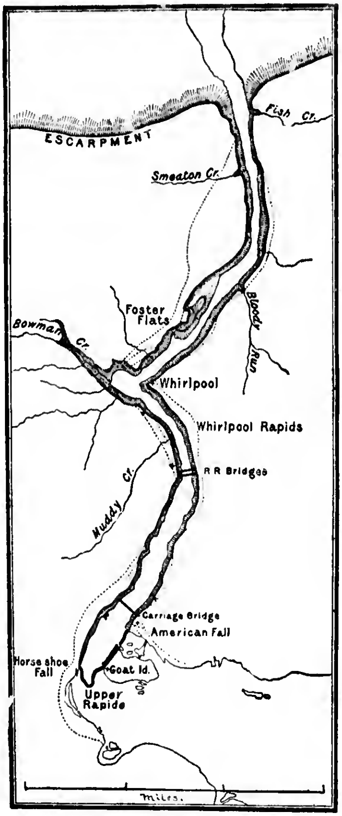

FIG. 15.—The Niagara Gorge, showing Physical Features.

Old river banks are shown by dotted lines; shell localities, by crosses.

Thus two different modes of cataract recession are illustrated by the two falls of Niagara. They resemble each other in the most essential particular,—that the soft shale beneath is worn away, and the hard limestone above falls for lack of support,—but they differ widely in other respects. In the recession of the Horseshoe Fall, the blocks of limestone are pestles or grinding tools by which the shale is beaten or scoured away. In the recession of the American Fall, the limestone blocks have no active share, but are rather obstructive. The falling water, striking them, is splashed against the cliff, and this splashing is the only force continually applied to the shale. In the spring, ice cakes are drifted from Lake Erie into the entrance of the river, and float to the falls. Borne with the water, they, too, must be dashed against the cliff of shale, and, though softer than the shale, they probably help to dislodge it. The recession in one case is far more rapid than in the other, the difference being explained primarily by the difference in the volume of the water.

OLD RIVER BANKS AND GRAVELS.—As just explained, the retreating cataract lengthens the gorge most rapidly in the middle of the stream, where the water is deepest. As the gorge is extended, the current turns toward its head from both margins, and portions of the river bed on either side are thus gradually abandoned by the water. After these strips of river bed have become dry land, they retain certain features by which they can be recognized. Usually the whole of the drift is washed away as far as the water extended, so that the rock is bare, or nearly bare; and the edge of the undisturbed drift at the margin of this strip of bared rock has a steep slope, which so closely resembles the modern banks of the river above the cataract that the imagination readily restores the former outline of the water (see Fig. 16).

FIG. 16.—Old River Bank and River Bed, One Mile North of American Fall.

Sometimes the river, after running for a while at one level, has been drawn down to a lower level, and the change has caused a second bank to be produced, the space between the first and second banks standing as a bench of land, or terrace. At some points there are two or three such terraces. Along the greater part of the gorge these old banks can be found on both sides, and there are few spots where they do not survive on one side or the other. The farthest point to which they can be traced downstream is about half a mile from the end of the gorge, and they thus serve to show that all the remainder of the gorge has been wrought during the life of the river; for it is evident that the river could not run on the upland while the gorge was in existence.

In a few cases, where the top of the limestone lies rather low, the old river beds are not excavated down to the rock, but their terraces are partly carved in drift. In yet other places the old river not only carried away material, but made additions, leaving a deposit of gravel and sand that had been rolled along by the current. In this gravelly deposit, shells have been found at a number of places, and they are all of such kinds as live in the quieter parts of the river at the present time.

On the chart on page 218 (Fig. 15) the most important of the old river banks are shown, and also a number of spots at which shells have been found in the river gravels.

Foster Flats.—About two miles and a half south of the escarpment the gorge assumes a peculiar phase not elsewhere seen. It is unusually wide at the top; but the river is quite narrow, and runs close under the cliff on the eastern or American side. On the Canadian side an irregular lowland lies between the cliff and the river, but this is encroached on by a quadrangular projection of the cliff. The lowland is Foster Flats; and

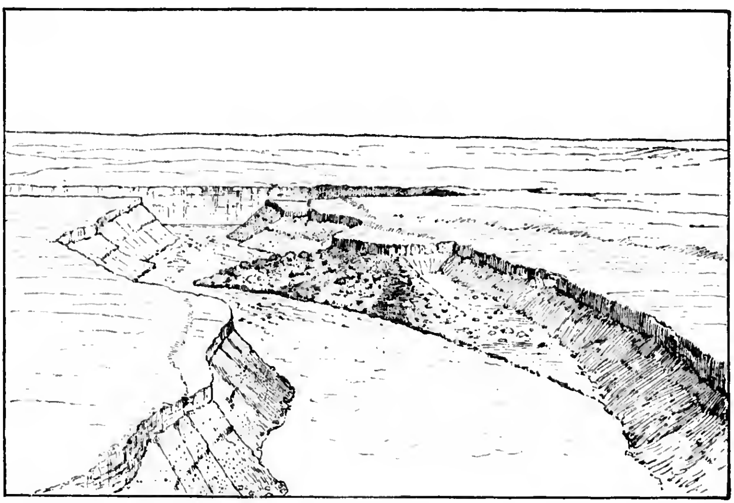

Fig. 17.—Bird's-eye View of Foster Flats, looking Southwest (Forests omitted).

the cliff projection, Wintergreen Flat. These and other features of the locality are portrayed in the bird's-eye view (Fig. 17), and also in the map (Fig. 18). The map represents the slopes of the land by means of contour lines, or lines of equal height, drawn at vertical intervals of twenty feet.

Wintergreen Flat is a platform of limestone a little below the general level of the plain, and separated from the plain by a steep bluff. This bluff is one of the old river banks, very similar to the one pictured in Fig. 16, and the platform is part of the river's bed. Following the direction of flow—parallel to the bank—to the point *A* (Fig. 18), the observer finds himself on the brink of a cliff over which the water evidently descended in a cataract; and before him, extending from the foot of the cliff to the point *B*, is a descending valley with the form of a river bed. From Wintergreen Flat only its general shape can be made out, as it is clothed with forest; but when one gets down to it, he finds it a northward-sloping plain, bounded by steep sides, and strewn here and there with great fallen blocks of limestone which the river current could not remove. The left bank of this channel has the ordinary profile of the wall of the gorge,—a cliff of the Niagara limestone at top and a talus slope below, covered by blocks of the same rock. The right wall is lower, rising at most but fifty feet above the channel, and gradually disappearing northward. It is merely the side of a low ridge which separates the abandoned channel from the river bed at the east. Its surface is exceedingly rugged, being covered by huge blocks of limestone, so that the ridge seemingly consists of a heap of them; but there is doubtless a nucleus of undisturbed shale, with a remnant of the Clinton ledge. Eastward from Wintergreen Flat there is a continuous descent from the limestone cliff to the river; but this is less steep than the ordinary talus slope of the gorge, and it is cumbered, like the ridge, by

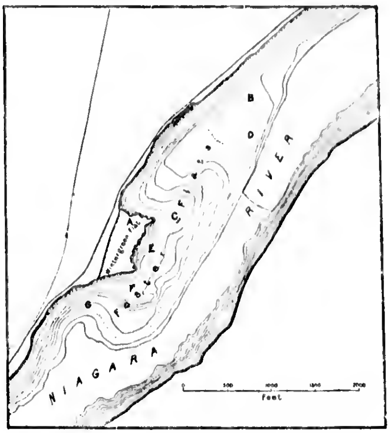

FIG. 18.—Map of Foster Flats.

blocks of limestone. There is an obscure terrace at about the level of the Clinton limestone, and there are other irregular terraces on the southward prolongation of the slope.

The history which appears to afford the best explanation of these features is as follows: When the cataract, in its recession from the escarpment, had reached the point *B*, it was a broad waterfall. Just above it, occupying the position *C—D*, was a narrow island, dividing the river as Goat Island now divides it. On reaching the island, the cataract was separated into two parts corresponding to the present Horseshoe and American falls, only at that epoch the greater body of water passed on the American side of the island, so that the American Fall retreated upstream the more rapidly. When the Canadian Fall reached the head of the island, the American had just passed it, and part of the sheet of water on Wintergreen Flat was drained eastward into the gorge opened by the American Fall. The Canadian Fall, through the loss of this water, became less active, and soon fell out of the race, leaving the cliff at *A* to record its defeat. For a time there was a cataract at *E* falling over the west wall of the gorge just as the modern American cataract falls over the east wall. The island was not broad enough to survive as a monument. After the cataracts had passed, its pedestal of shale was crumbled by the frost, and the unsupported limestone fell in ruins. As the main fall retreated still farther, the western portion of the water sheet was withdrawn from Wintergreen Flat, occupying a position at *F*, and at the same time the stream near the Canadian shore acquired greater volume, so as to recede rapidly toward *G* and thus broaden the channel. Probably at about the same time the whole amount of water in the river was increased in a manner to be considered later.

When the reader next visits Niagara, he will find himself fully repaid for his pains if he will go to this spot, and examine these features for himself. It is peculiarly impressive to stand on the silent brink of the old waterfall and look down the dry channel, and it is no less impressive to enter that channel and wander among the blocks of rock which record the limit of the torrent's power to transport. It is evident that here the cataract did not hollow out a deep pool, as under the Horseshoe Fall of to-day, but was rather comparable in its mode of action to the American Fall, though perhaps somewhat more vigorous. The slope eastward from Wintergreen Flat probably corresponds closely with what one would find under the American Fall if the river were stopped and the pool drained.

Thus Foster and Wintergreen flats repeat the story told by the old river banks and the shell-bearing gravels. There was a time when there was no gorge, but when the river ran over the top of the plain nearly to its edge; and since that time the gorge has been gradually dug out by the power of the plunging water.

Beginning of Recession.—When the geographer notes that some natural process is producing changes in the features of the land, he naturally looks backward, if he can, to see what were the earlier features which preceded the changes in progress, and looks forward to see what will be the eventual condition if changes of the same sort are continued. The tracing of the history of change in either direction is apt to be difficult, because it is not easy to tell what allowances to make for changes of circumstance or condition. In tracing the early history of Niagara such difficulties as these arise, but there is one difficulty which is not altogether unfortunate, because it leads to the discovery that the Niagara history is definitely related to one of the most interesting events of the geographic development of the continent.

Having learned from the cataract that it is engaged in the work of gorge making, and having learned from the old river beds along the margins of the gorge and from the old cataract cliff at Foster Flats that this work of gorge making has been carried on through the whole length of the gorge, we are carried back in imagination to an epoch when the river traveled on the upper plain all the way from Lake Erie to the escarpment, and there descended. The general history is clearly traced back to that point, but there it seems to stop abruptly. We may compare the river to an artisan sawing the plateau in two. The work goes on merrily and the saw cut is still short. As geologists reckon time, it is not long since the task was begun. But Nature's artisans cannot stand idle; while they live, they must work. So, before this task was begun, either the stream had some other task or else there was no Niagara River. It seems impossible to suggest any other task, and all geographers are agreed that there was none. The river's first work was the digging of the gorge, and the date of its beginning was the date of the river's beginning.

The nature of this beginning, the series of events which led up to it, or, in other words, the cause of the river, was long sought in vain; and an interesting chapter might be written on the fruitless search. The needed light was an understanding of the origin of the drift; and it was not till a young Swiss geologist, Louis Agassiz, brought from the Alps the idea of a drift-bearing ice field that the discovery of Niagara's pedigree became possible.

DEVELOPMENT OF THE LAURENTIAN LAKES.

THE ICE SHEET.—The history of the great Canadian glacier is a large subject, to which some future monograph of this series will doubtless be devoted. Any account of it which can be given here must needs be inadequate, yet a full understanding of Niagara cannot be reached without some knowledge of the glacier. In the latest of the geologic periods the climate of North America underwent a series of remarkable changes, becoming alternately colder and warmer. While the general temperature was low, there was a large area in Canada over which the fall of snow in winter was so deep that the heat of summer did not fully melt it; so that each year a certain amount was left over, and in the course of centuries the accumulation acquired a depth of thousands of feet. By pressure, and by melting and freezing, the snow was packed, and welded into ice. When the climate again became warmer, this ice was gradually melted away; but while present it performed an important geographic work. Ice in large masses is plastic; and when the ice sheet had become thick, it did not lie inert and motionless, but spread itself outward like a mass of pitch, its edges slowly pushing away from the central tract in all directions. This motion carried the ice border into regions of warmer climate, where it was melted; and for a long period there was a slow but continuous movement from the central region of accumulation to the marginal region of waste by melting. The principal region of accumulation was north and northeast of the Great Lakes, and the flowing ice passed over the lake region, invading all our Northern States. Where the ice pressed on the ground, it enveloped bowlders, pebbles, and whatever lay loose on the surface; and as it moved forward, these were carried with it, being dragged over the solid rock, and scraping it. Thus the country was not merely swept, but scratched and plowed, with the result that its surface was worn down. The amount of wear was not everywhere the same, but varied from place to place, and many basins were hollowed out. When the general climate became gradually warmer, the waste of ice near its margin exceeded the supply, and the extent of the sheet was diminished. When the ice was gone, the stones and earth it had picked up and ground up remained on the land, but in new positions. They were spread and heaped irregularly over the surface, constituting the mantle of *drift* to which reference has already been made. Thus by the double process of hollowing and heaping, the face of the land was remodeled; so that when the rain once more fell on it, and was gathered in streams, the old water ways were lost, and new ones had to be found.

This remodeling gave to the Laurentian system of water ways its abnormal character, supplying it with abundant lakes and waterfalls. Not only were the Great Lakes created, but a multitude of minor lakes, lakelets, ponds, and marshes. If the reader will study some good map of the United States or of North America, he will see that this lake district includes New England also, and by tracing its extent in other directions he can get a fair idea of the magnitude of the ice sheet.

The lakes have had a marked influence on the history and industries of mankind. Still water makes an easy roadway, and the chain of Great Lakes not only guided exploration and early settlement, but has determined the chief routes of commerce ever since. The most easterly of the ice-made basins, instead of holding lakes, receive arms of the sea, giving to New York and New England some of the best harbors in the world. Each cataract is a water power, and the lakes and ponds upstream are natural storage reservoirs, holding back floods, and doling the water out in time of drought. So Chicago and New York City are the centers of trade, and New England is a land of humming spindles and lathes, because of an invasion long ago by Canadian ice.

The district of the Niagara lay far within the extreme limit of the ice, and the drift there lying on the rocks is part of the great ice-spread mantle. Wherever that drift is freshly removed, whether by the natural excavation of streams or the artificial excavation of quarrymen and builders, the rock beneath is found to be polished, and covered by parallel scratches, the result of rubbing by the ice and its gritty load. These scratches show that in this particular district the ice moved in a direction about

30° west of south. They can be seen on the western brink of the gorge four hundred yards below the railroad suspension bridge, in the beds of several creeks near the Whirlpool, and at various quarries above the escarpment. The best opportunity to study them is at a group of quarries near the brink of the escarpment, about two miles west of the river.

Ice-dammed Lakes.—During the period of final melting of the ice sheet, when its southern margin was gradually retreating across the region of the Great Lakes, a number of temporary lakes of peculiar character were formed. In the accompanying sketch map of the Great Lake region (Fig. 19) the broken line marks the position of the southern rim of the St. Lawrence basin. It is the watershed between the district draining to the St. Lawrence and the contiguous districts draining to the Mississippi, Ohio, Susquehanna, and Hudson. When the ice sheet was greatest, its southern margin lay south of this watershed. The rain which fell on the

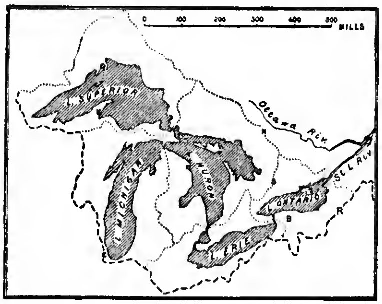

Fig. 19.—The Great Lakes and their Drainage Districts.

The watersheds bounding the drainage districts are represented by dotted and broken lines.

ice, uniting with the water made by melting ice, ran from the ice field on to the land, and flowed away with the rivers of the land. Afterward, when the extent of the ice had been somewhat reduced, its margin lay partly beyond and partly within the basin of the lakes; but the water from it could not flow down the St. Lawrence, because that valley was still occupied by the ice. It therefore gathered between the ice front and the watershed in a series of lakes, each of which found outlet southward across some low point in the watershed. To see this clearly may require some effort of the imagination. The reader should bear in mind that the watershed is not a simple ridge, but a rolling upland of varying height, with here and there a low pass. The St. Lawrence basin is not simple and regular in form, but is made up of many smaller basins separated by minor uplands or watersheds. Some of these watersheds are shown on the map. When the ice occupied part of minor basins, it acted as a dam, holding the water back, and making it fill the basin until it could flow in some other direction. As the position of the ice front changed, these lakes were changed, being made to unite or separate, and often to abandon one channel or outlet when another was opened at a lower level. Sometimes there were chains of lakes along the ice margin, one lake draining to another across a minor watershed, and the lowest discharging across the main watershed.

Wherever water ran from a lake, it modified the surface. The loose drift was easily moved by the current, and each stream quickly hollowed out for itself a channel,—a trough-like passage with flattish bottom and steep sides. When the lakes afterward disappeared, the channels lost their streams, but their forms remained. They are still to be seen in a hundred passes among the hills of the Northern States. The larger and longer-lived of the lakes carved by their waves a still more conspicuous record. In ways explained by Professor Shaler in the fifth monograph of this series, the waves set in motion by storms cut out strands and cliffs from the drift and built up barrier beaches, so that after the lake waters had departed there were terraces and ridges on the hillsides to show where the shores had been. Many of the old channels have been found, some of the old shore lines have been traced out and marked on maps, and by such investigation the history of geographic changes in the Great Lake region is gradually being learned.

At one stage of that history there was a long lake occupying the western part of the Ontario basin, much of the Erie, part of the Huron, and probably part of the Michigan. Its outflow crossed the main watershed at Chicago (*C*, Fig. 19), and its eastern extremity was near Batavia (*B*) in western New York. The ice mass filled the greater part of the Ontario basin, and kept the water from escaping eastward. When it melted from that region, the water shifted its outlet from Chicago to a low pass at Rome (*R*), where it discharged to the Mohawk valley. This change lowered the lake surface several hundred feet, and, by uncovering watersheds that had before been submerged, separated the Huron, Erie, and Ontario basins, and three lakes took the place of the single long lake. In the Huron basin was a lake half walled by ice; in the Erie basin, Lake Erie; and in the Ontario basin, Lake Iroquois, an ice-dammed lake with its outlet at Rome.

The draining away of so large a body of water occupied some time, so that the lake level was gradually lowered. When it reached the pass between the Erie and Ontario basins at Buffalo, and Lakes Erie and Iroquois were thereby parted, the Erie level could fall no lower, but the Iroquois continued downward. As soon as there was a difference of level, a stream began to flow from Lake Erie, and that stream was the infant Niagara, newly born. It was a short stream, because the edge of the Iroquois water was close to Buffalo; but it grew longer day by day, as fast as the Iroquois edge receded. It had no channel until it made one, but its growing end, in following the retreating lake, selected at each instant the direction of steepest slope; and as the slopes had been formed by the glacier, it may be said that the glacier predetermined the course of the river.

During some centuries or millenniums of its early life the river was shorter than now, because the Iroquois Lake flooded more land than the Ontario, and kept the river nearer the escarpment; but in course of time the ice dam disappeared, the lake outlet was removed from Rome to the Thousand Islands, part of the lake bottom was laid bare by the retiring water, and the river stretched itself over the broadened plain. It grew, in fact, to be a few miles longer than now, and there were other changes in length; but the entire story is too long and intricate for these pages.

THE CANTING OF BASINS.—The geographers who have mapped the glacial lakes by tracing their shore lines have also measured the heights of these lines at many points. From these measurements they have found that the lines are not level. The surface of each ice-dammed lake was, of course, level, and its waves, beating on the shores, carved beaches and strands all at the same level. But these abandoned strands, preserved as terraces on the basin slopes, are not level now; and it is therefore inferred that the earth itself, the rocky foundation on which the terraces rest, has changed its form. The idea of earth movements, the slow rising of some districts and the sinking of others, is not new; but, until these old shore lines were studied, it was not known that such changes had recently affected the Lake region.

The departure of the old shore lines from horizontality is of a systematic character. They all rise toward the north and east, and fall toward the south and west. The amount of this tilting or inclination is not the same everywhere, nor is it everywhere in precisely the same direction; but the general fact plainly appears, that the northeastern portion of the Great Lake district has been raised or the southwestern portion has been lowered, or both, several hundred feet since the epoch of these ice-dammed lakes, i.e., since the time when the Canadian ice sheet was slowly melting away. The effect of this change was to tip or cant each lake basin, and the effect of the canting was similar to the effect of canting a hand basin containing water. In the hand basin the water rises on the side toward which the basin is tipped, and falls away on the opposite side. In the lake basin there was a constant supply of water from rain and streams, so that it was always filled up to the level of the lowest point of its rim, and the surplus of water flowed away at that point; so, when it was canted, the changes in the extent of the lake were partly controlled by the outflow. If the outlet was on the northeastern side of the basin, the southwesterly canting would make the water rise along its southwestern shore, the submerged area being thereby enlarged. If the outlet was toward the southwest, then the canting would draw the water away from the northeastern slopes, and diminish the submerged area. If the lowest point of the rim was originally on the northeast side, the canting might lift this part of the rim so high that some point on the southwest side would become lowest, and the point of outlet might thus be changed from north or east to south or west. The evidence of the old shores and channels shows that all these possible changes have actually occurred in the lake basins, and that some of them were related in an important way to the history of the Niagara River.

The gradual canting affected the size of Lake Erie, Lake Ontario, and the temporary Lake Iroquois, making each grow toward the southwest. When Lake Erie was born, its length could not have been more than half as great as now, and its area was much smaller. The original Lake Huron may have had about the same size as the present lake, but its form and position were different. Less land was covered at the south and west, more land at the north and east, and the outlet was at North Bay (N, Fig. 19). By the tipping of the basin the lake was made gradually to expand toward the west and south till at last the water reached the pass at the head of the St. Clair River. Soon afterward the water ceased flowing through the North Bay outlet. The water then gradually withdrew from the northeastern region till finally the shores assumed their present position.

At an earlier stage, while the North Bay district was blocked by the ice sheet, it is probable that the basin had an outlet near Lake Simcoe (*S*), but the evidence of this is less complete. If the Huron water crossed the basin's rim at that point, it followed the Trent valley to Lake Iroquois or Lake Ontario; when it crossed the rim at North Bay, it followed the Ottawa valley to the St. Lawrence; and in each case it reached the ocean without passing through Lake Erie and the Niagara River. Thus there was a time when the Niagara River received no water from the Huron, Michigan, or Superior basins, but from the Erie basin alone. It was then a comparatively small stream, for the Erie basin is only one eighth of the whole district now tributary to the river; and the cataract more nearly resembled the American Fall than the Horseshoe.

THE WHIRLPOOL.

The Whirlpool is a peculiar point in the course of the river. Not only does the channel there make an abrupt turn to the right, but with equal abruptness it is enlarged and again contracted. The pool is a deep oval basin, communicating through narrow gateways with the gorge above and the gorge below. The torrent, rushing with the speed of an ocean greyhound from the steep, shallow passage known as the Whirlpool Rapids, enters the pool and courses over its surface till its headway is checked. The initial impulse prevents it from turning at once toward the channel of exit, and the current circles to the left instead of the right, following the curved margin of the pool, and finally descending under the entering stream so as to rise beyond it at the outlet. Thus the water describes a complete loop, a peculiarity of current quite as remarkable and rare as the feats of railway engineering which bear that name. In the chart of the Whirlpool (Fig. 20) the surface currents are indicated by arrows; and some idea of the appearance of the currents may be obtained from the view in Fig. 7, where the swift incoming current crosses the foreground from right to left, and the exit current occupies the middle of the picture. In the smoother tract between these two visible currents the water rises after passing under the nearer. These currents can be watched from any of the surrounding cliffs, and there is a fascination about them akin to that of the cataract itself and the Whirlpool Rapids.

The gorge above, the gorge below, and two sides of the Whirlpool are walled by rock; but the remaining side, that opposite to the incoming stream, shows no rock in its wall (Figs. 20 and 21). On the north side, the edge of the Niagara limestone can be traced to *A* (Fig. 20) with all its usual characters, but there it disappears beneath the drift. The Clinton limestone disappears in a similar way just below it, and the quartzose sandstone, which there skirts the margin of the water, is a little more quickly covered, being last seen at *B*. On the south bank the Niagara limestone can be traced farther. Its edge is visible almost continuously to *E*, and is laid bare in the bed of a small creek at *F*. The Clinton bed is similarly traceable, with slight interruption, to *D*; and the quartzose sandstone passes under the drift at *C*. Where each rock ledge is last seen it points toward the northwest, and betrays no tendency to curve around and join its fellow in the opposite wall. In the intervening space the side of the gorge seems to be composed entirely of drift. Sand and clay, pebbles and bowlders, make up the slope; and a beach of bowlders margins the water from *B* to *C*. It is inferred from this arrangement of rock and drift that there was a deep hollow in the plain before the drift was spread by the ice, the drift being deposited in it and over it until it was filled and covered. The parallel directions of the rock ledges suggest that the hollow was part of a stream channel running northwestward; and this interpretation is borne out not only by certain topographic features two or three miles away, but by a study of the bed and banks of Bowman Creek (Fig. 15). That stream, which rises two miles away, has carved a ravine where it approaches the Whirlpool. The northeast bank of the ravine (Fig. 20) seems to be composed entirely of drift; but the opposite bank, though chiefly of drift, lays bare the rock at a number of places, revealing a sloping wall descending toward the northeast. The bed of the stream in general shows nothing but drift; but there is one place where the creek swerves a little to the southward, and

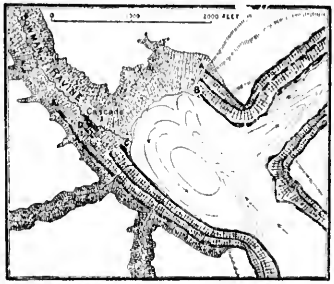

FIG. 20.—The Whirlpool.
Rock is indicated by crosshatching; drift, by dots. Arrows indicate the direction of current.

for a few rods presses against the rock slope; and it has there made a small cut into the rock, cascading at one point over a sandy ledge that is harder than the associated shale.

With the aid of this information, it is easy to understand the peculiar features of the Whirlpool. The Niagara River did not seek this old channel and thus find an easy way northward, but ran upon it accidentally at one point. Its course on the plain was determined for it by the slopes of the drift, and the arrangement of these slopes happened to guide the water across the buried channel at the Whirlpool. In making the gorge from the Whirlpool to the escarpment, and also in making the upper part of the gorge, the river found hard rock to be removed; and it worked as a quarryman, digging down below in the softer rocks with such tools as it had to use, and thus undermining the limestone cap. At the Whirlpool there was no need to quarry, because there was no limestone cap; and, to carry out the homely figure, the river merely dug in a gravel pit, shoveling the loose drift quickly away. This work of excavation did not cease when a channel of the usual width had been opened, because the angle in the course of the river set the current strongly against the bank of drift, and caused it to clear out a basin in the old channel. Had the drift been wholly, as it is partly, of sand, still more of it would have been carried out; but it included large bowlders, and these were sorted out and accumulated until they made a sloping wall or sheathing, which covers all that part of the sand below the level of the pool, and resists further encroachment by the water. So the peculiar form of the river at this place was caused by the old channel with its filling of loose sand and gravel. The looped current evidently depends on the peculiar shape of the channel. The water enters the pool with such impetus that it is carried past the outlet, and the return current follows the bottom of the pool because that route is the easiest.

TIME.

Just under the escarpment where it is divided by the river stand two villages,—the American village of Lewiston, the Canadian village of Queenston. Lewiston is built partly on an old beach of Lake Iroquois, and near its steamboat wharf is a gravel pit where one can see the pebbles that were worn round by rolling up and down the old strand. That part of the escarpment which overlooks Lewiston is somewhat terraced, or divided into steps, and was called "The Three Mountains" a century ago, when loads that had been brought by boat to the landing (Lewiston) were toilsomely carried up the steep ascent on their way to other boats plying on the upper Niagara.

The escarpment above Queenston is called Queenston Heights; and from its crest rises Brock's monument, a slender shaft commemorative of a battle between British and American soldiers. Within this shaft is a spiral staircase, and from a little chamber near the top one can look through portholes far away in all directions. Eastward and westward runs the escarpment, and the eye follows it for many miles. Southward stretches the upper plain, diversified by low, rolling hills, and divided in the foreground by the gorge. In the still air a cloud of spray hovers over the cataract, and a cloud of smoke at the horizon tells of Buffalo. Northward lies blue Ontario, and straight to its shore flows the deep-channeled, majestic Niagara, dividing the smooth green lowland into parts even more closely kin than the brother nations by which they are tilled. Beyond the water, and forty miles away, gleams Scarboro Cliff, where the lake waves are undermining a hill of drift; and twenty or thirty miles farther the imagination may supply—what the earth's roundness conceals from the eye—a higher upland that bounds the Ontario basin.

The Brock monument, the Niagara gorge, and the Ontario basin are three products of human or of natural work, so related to time that their magnitudes help the mind in grasping the time factor in Niagara history. The monument, measured in diameter by feet and in height by scores of feet, stands for the epoch of the white man in America. The gorge, measured in width by hundreds of yards and in length by miles, stands for the epoch since the ice age. The basin, measured in width by scores of miles and in length by hundreds of miles, stands for a period before the ice, when the uplands and lowlands of the region were carved from a still greater upland. The monument is half a century old; the gorge was begun some tens or hundreds, or possibly thousands, of centuries ago; and the hollowing of the basin consumed a time so far beyond our comprehension that we can only say it is related to the gorge epoch in some such way as the gorge epoch is related to the monument's half century.

The glacier made changes in the Ontario basin, but they were small in comparison with its original size, and the basin is chiefly the work of other agents. Before the glacial age it was a river valley, and we may obtain some idea of its origin by thinking of the Niagara gorge as the beginning of a river valley, and trying to imagine its mode of growing broader. It has already been explained (p. 218) that the gorge walls fall back a little after the cataract has hewn them out, but seem to come to rest as soon as all the shale is covered by talus. So nearly do they approach rest that their profile is as steep near the mouth of the gorge as it is one mile below the cataract; but, in fact, they are not unchanging. Water trickling over the limestone cliff dissolves a minute quantity of the rock. This makes it porous, and lichens take root. Lichens and other plants add something to the water that increases its solvent power. The fragments of the talus are eaten faster because they expose more surface. Each winter the frost disturbs some of the stones of the talus, so that they slowly move down the slope; and wherever the shale is laid bare, frost and rain attack it again. Thus, with almost infinite slowness,—so slowly that the entire age of the gorge is too short a unit for its measurement,—the walls of the gorge are retreating from the river. At the same time every creek that falls into the gorge is making a narrow side gorge. The strongest of them has worked back only a few hundred feet (Fig. 15); but in time they will trench the plain in many directions, and each trench will open two walls to the attack of the elements. Space forbids that we trace the process further; but enough has been said to show that valleys are made far more slowly than gorges, and that the ancient shaping of the land into valley and upland was a far greater task than the comparatively modern digging of the gorge.

The middle term of our time scale, the age of the gorge, has excited great interest, because the visible work of the river and the visible dimensions of the gorge seem to afford a means of measuring in years one of the periods of which geologic time is composed. To measure the age of the river is to determine the antiquity of the close of the ice age. The principal data for the measurement are as follows: (1) The gorge now grows longer at the rate of four or five feet a year, and its total length is six or seven miles. (2) At the Whirlpool the rate of gorge making was relatively very fast, because only loose material had to be removed. Whether the old channel ended at the Whirlpool, or extended for some distance southward on the line of the river, is a matter of doubt. (3) Part of the time the volume of the river was so much less that the rate of recession was more like that of the American Fall than that of the Horseshoe. Some suggestions as to the comparative extent of slow work and fast work are to be obtained from the profile of the bottom of the gorge. While the volume of the river was large, we may suppose that it dug deeply, just as it now digs under the Horseshoe Fall (see p. 216); while the volume was small, we may suppose that a deep pool

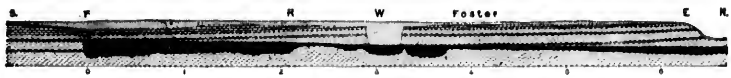

FIG. 21.—Longitudinal Section of the Niagara Gorge, with Diagram of the Western Wall.

The base line is at sea level. It is divided into miles. Water, black; drift, dotted; Niagara limestone in block pattern; shales, broken lines; F, falls; R, railway bridges; W, whirlpool; Foster, Foster Flats; E, escarpment.

was not made. Fig. 21 exhibits the approximate depth of the water channel through the length of the gorge; and by examining it the reader will see that the depth is great near the mouth of the gorge, again from the head of Foster Flats to the Whirlpool, and then from the bridges to the Horseshoe Fall. It is small, indicating slow recession, in the neighborhood of Foster Flats, and also between the Whirlpool and the railroad bridges. The problem is complicated by other factors, but they are probably less important than those stated.

Before the modern rate of recession had been determined, there were many estimates of the age of the river; but their basis of fact was so slender that they were hardly more than guesses. The first estimate with a better foundation was made by Dr. Julius Pohlman, who took account of the measured rate of recession and the influence of the old channel at the Whirlpool; he thought the river not older than 3,500 years. Dr. J. W. Spencer, adding to these factors the variations in the river's volume, computes the river's age as 32,000 years. Mr. Warren Upham, having the same facts before him, thinks 7,000 years a more reasonable estimate. And Mr. F. B. Taylor, while regarding the data as altogether insufficient for the solution of the problem, is of opinion that Mr. Upham's estimate should be multiplied by a number consisting of tens rather than units. Thus estimates founded on substantially the same facts range from thousands of years to hundreds of thousands of years. For myself, I am disposed to agree with Mr. Taylor, that no estimate yet made has great value, and the best result obtainable may perhaps be only a rough approximation.

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