N. R. Graves, Photo.

THE ROCHESTER CANYON

View looking south, upstream, toward Driving Park Avenue bridge

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THE ROCHESTER CANYON AND THE GENESEE RIVER BASE-LEVELS

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Introduction

In the course of the Genesee River lie three ravines: the Portage Gorge, the Mount Morris "High Banks," and the Rochester Canyon. These narrow, steep-walled sections of the river valley are the youngest portions of the valley, being the sections where the river has been recently forced, by glacial interference, into new paths. In these ravine sections the river has been flowing only some tens of thousands of years, or since the latest ice sheet disappeared; while the broad, open stretches of the valley represent millions of years previous to the Glacial Period.

The canyon of the Genesee at Rochester is superior in both scenic beauty and scientific interest. Somewhat smaller than the gorge at Niagara, and with much less volume of the river flow, it excels in the beauty of its wooded banks and in the variety of the rock strata. The section of strata on the Genesee is classic in American Geology. The general history and the stages in the canyon erosion are identical for the two sister streams, Niagara and Genesee; but the latter gains in scientific interest by the three falls to offset the grandeur of the single Niagara. The height of Niagara is 160 feet; the three Rochester falls total 228 feet. Lying through and adjacent to the city, with miles of smooth navigable river opening to Lake Ontario, between high walls covered with primeval forest, it affords unusual opportunity for recreative use to multitudes of people.

Of course the canyon has been excavated by the river, aided by the destructive action of the atmosphere on the walls. The river did not discover the ravine, the river made it. Rivers are the valley-makers.

A person who is not informed on the local geology would probably say that the Genesee River has simply carved its channel in its fall toward Lake Ontario. But this erosion or intrenching of the stream has not been a steady or continuous process, or without interference. After the student learns that the gravel ridge which carries the "Ridge Road" is the deserted beach of a long-lived glacial lake (Lake Iroquois), he might suppose that the river at first excavated the ravine down to the level of the Lake Iroquois, and that after Iroquois disappeared the lower part of the ravine, beneath the level of the Ridge Road, was excavated. This explanation would be incomplete, because a glacial lake lay over Irondequoit Bay and the northern part of the city previous to Lake Iroquois. And Lake Ontario was not the immediate successor of Iroquois. Between the time of Iroquois and Ontario, some thousands of years, an arm of the ocean occupied the St. Lawrence Valley and the Ontario Basin. During that time the Genesee River poured into Gilbert Gulf, an arm of the Champlain sea (figure 4). The site of Charlotte was then only 91 feet above the sea (see the diagram, figure 8).

Furthermore, the succession of water levels is not the whole complication, for the reason that during the life of the several water bodies this part of the continent was rising, with tilting uplift, thereby introducing peculiar complexity in the water levels.

The reader who wishes to know a real romance of science, the drama of the later Genesee history, may read the following pages. It will not be easy reading, for it requires the scientific or constructive imagination in order to picture the changing conditions and to carry in mind the complex relations of the geologic factors.

Pre-Glacial Genesee River; Irondequoit Valley

For many millions of years before the Glacial Period the predecessor of the Genesee River, which we may call the ancient Genesee, flowed through the valley of Irondequoit (plate 2). That broad and deep valley, now much filled with glacial and lake deposits, was excavated from the solid rock strata by the river erosion, aided by storm-wash, frost and chemical decay. The ancient river passed north and joined a great river or trunk-stream in the bottom of the Ontario valley. At that time there was no Lake Ontario, and probably [illegible] lakes in eastern America. The Ontario Valley, like the Irondequoit, was carved out of rock strata by the combined work of river and atmospheric agencies. Since the bottom of Lake Ontario, as well as the rock bottom of the Irondequoit Valley, is far below sea-level it is evident that this part of the continent was very much higher above the sea than it is today. Judging by the drowned valleys about the ocean shores the continent must have been, in one of its ups-and-downs, 1000 or 2000 feet higher during some phase of Pre-Glacial time.

Before the ice age the ancient Genesee flowed northward past Avon, as today, but then turned eastward, along the outcrop of the weak Salina shales, somewhere in the district of Rush or the course of the lower Honeoye Creek. In some unknown course the river swung northward, into the valley we call Irondequoit. This indirect course had been produced by the adjustment of the old drainage to the structure, or varying resistance, of the underlying rock strata. It should be stated that the Genesee River was not created as a unit, the entire length at once, but is the product of union by stream capture of several streams, during a vast length of time.

The latest ice sheet, the Labradorian (Quebecan) glacier, swept a mass of rock-rubbish, "glacial drift," into the east-and-west section of the old valley, somewhere between Rush and Fishers. When the ice sheet melted away and the glacial lakes which faced the ice front were drained down, and the river flow was resumed, the latter found the old channel obstructed by the drift blockade. The river, naturally, took the lowest path it could find, winding among the drift hills north of Avon, and crossing the Pinnacle moraine, established its present course (plate 2).

Post-Glacial Land Uplift

Figures 5–7.

The rise and fall of great areas of the earth's surface, very slowly as judged by human experience, is the fundamental and simple fact of geology. The rocks beneath the City of Rochester, a sequence of limestones, shales and sandstone, were laid as sediments in shallow oceanic waters many millions of years ago. Since the Rochester strata were deposited this region has been involved in great oscillations of level. These uplifts and downthrows (diastrophic movements) have continued through millions of years down to the present time; and the very recent rise of the land has caused remarkable changes of level in the standing waters, which were the baselevels of drainage; thus limiting the flow and work of the Genesee River at Rochester and Charlotte.

One proof of recent change in land level, which the reader will readily appreciate, is recorded in the Iroquois beaches. The Ridge Road lies on the gravel embankments or bars built by the waves of the great glacial Lake Iroquois; or, in a few places, on erosion shelves cut by the waves in the land surface. The south shore of the lake has been mapped throughout its whole extent, from

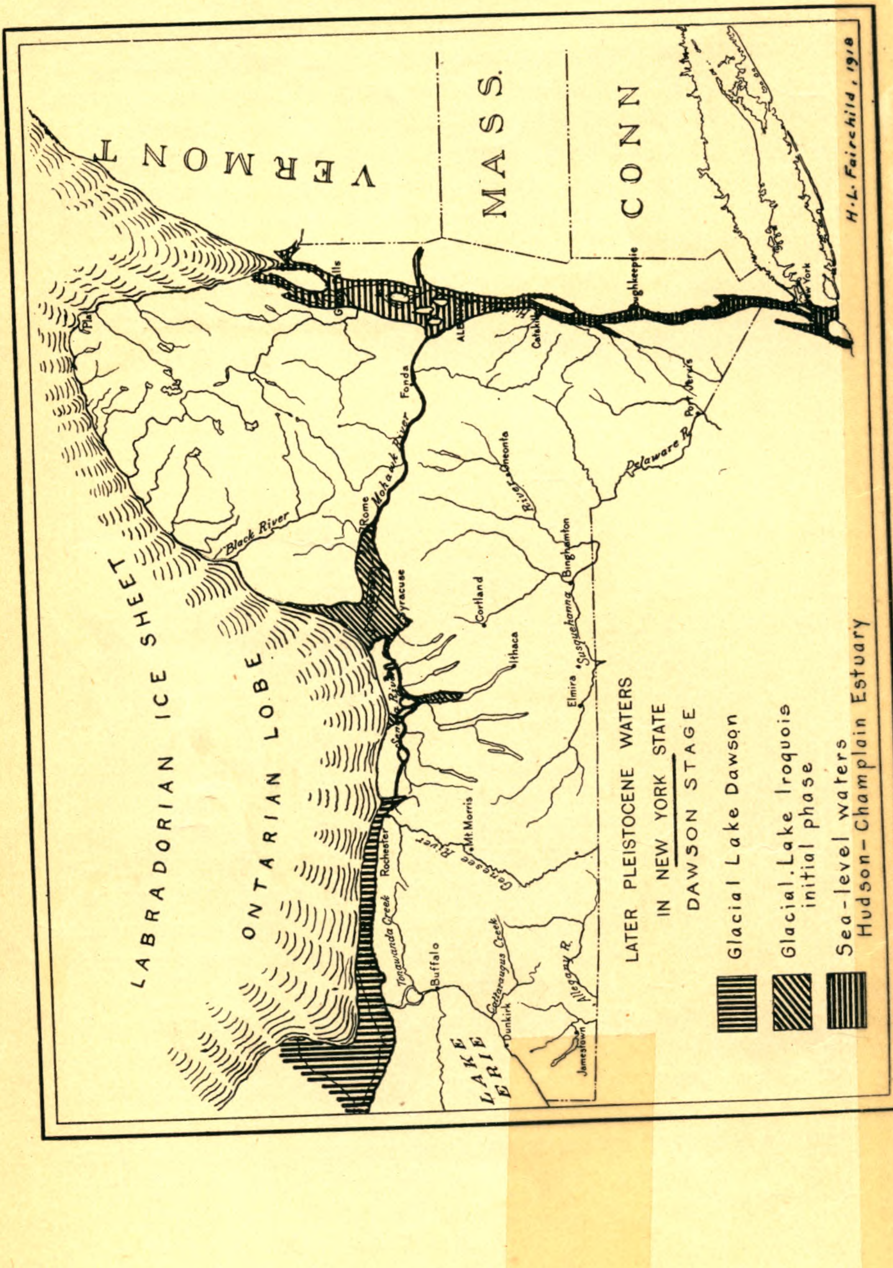


FIGURE 1. *Dawson Stage of the Glacial Waters*

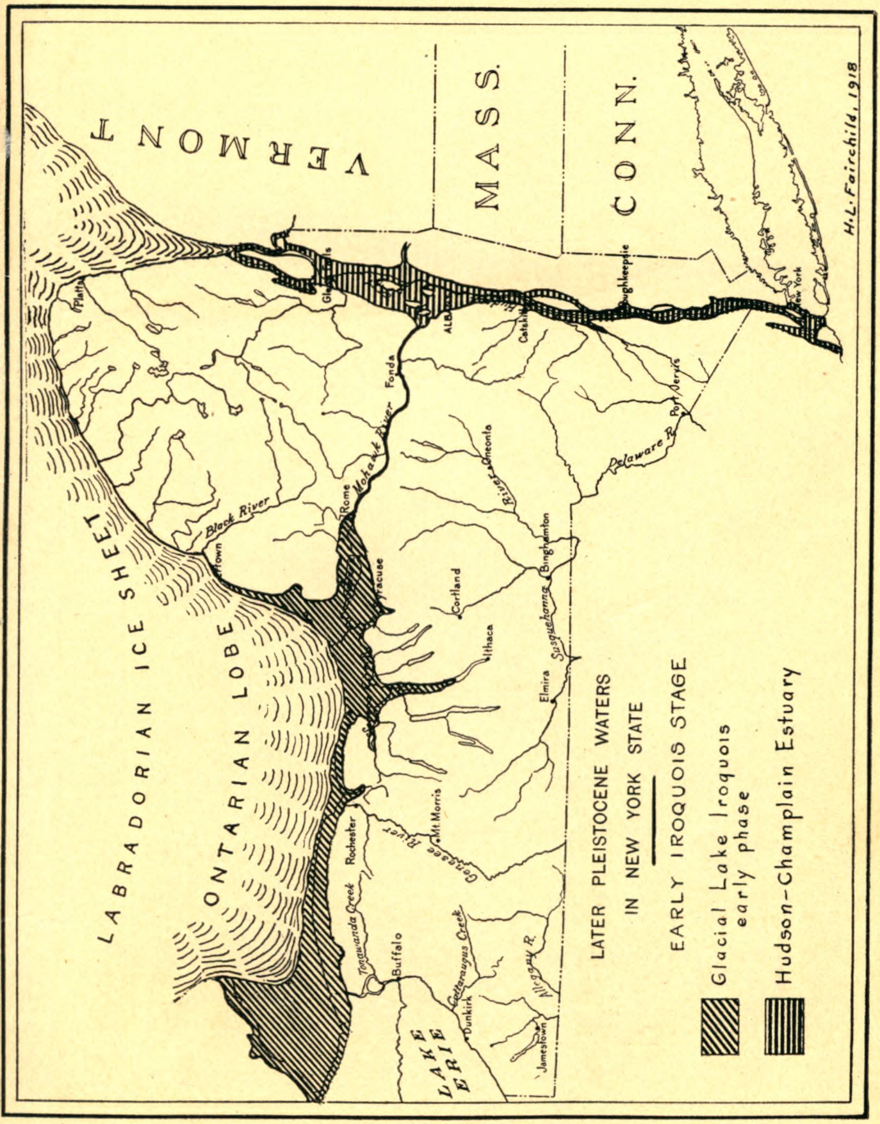


FIGURE 2. *Early Iroquois Stage*

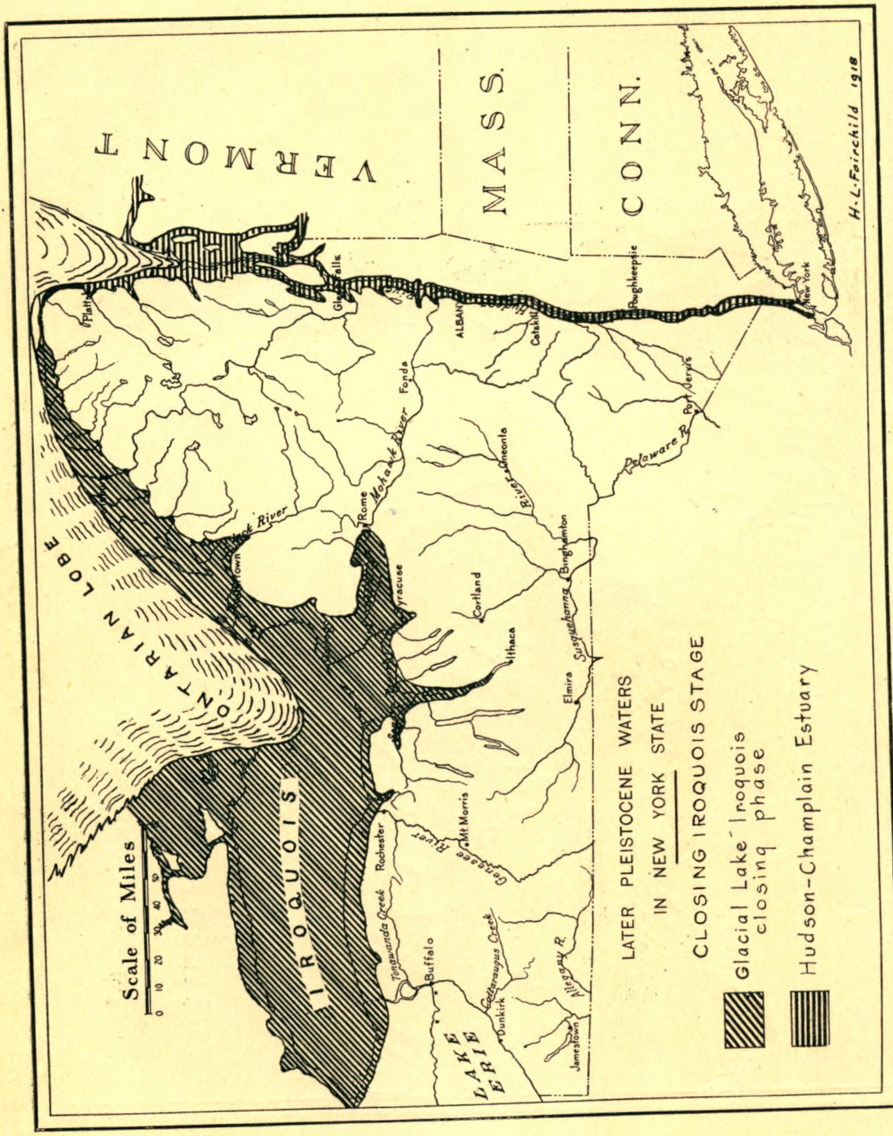


FIGURE 3. *Closing Iroquois Stage*

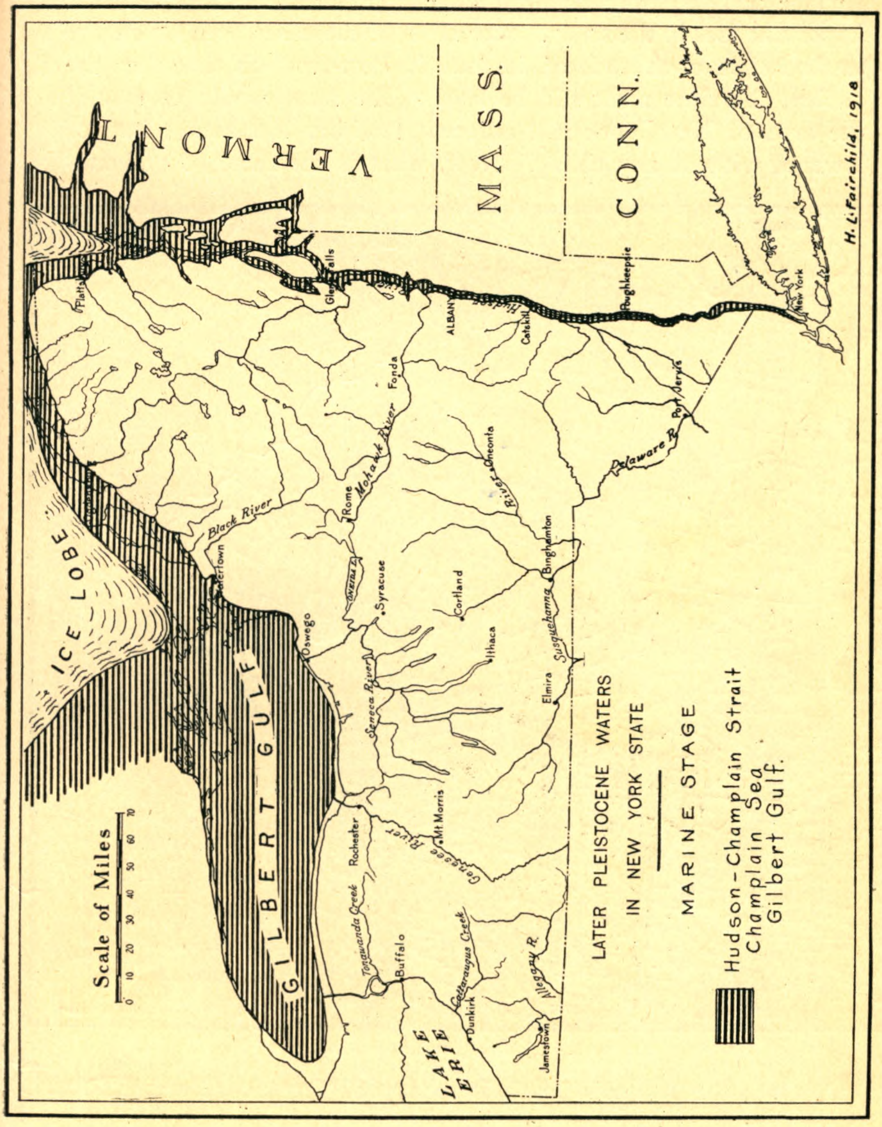


FIGURE 4. *Gilbert Gulf, Sea-Level Waters*

Hamilton, Ontario, to its final outlet on the north border of the State. When the lake arrived at the time of its extinction its surface and its shoreline must have been level. This is the first important fact in the study. Moreover, if there has been no change in the height or attitude of the land in Post-Iroquois time then the ancient shoreline must still be level. The same would be true if the area of New York and adjacent territory has been raised or lowered without any tilting. Now, what is the fact? At Hamil-

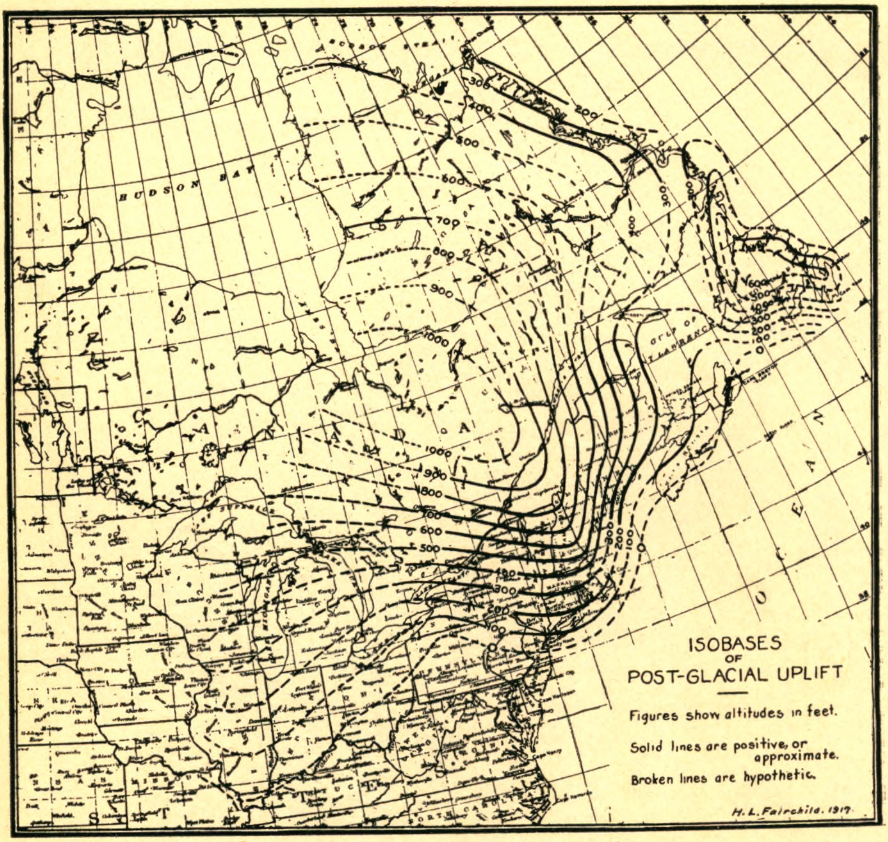


FIGURE 5. *Uplift of Northeastern America*

ton, Ont., the Iroquois beach is today 362 feet above ocean. At Rochester it is 435 feet; at Watertown 671 feet; and at Covey outlet 1030 feet (see tabulation, figure 7). There has been a

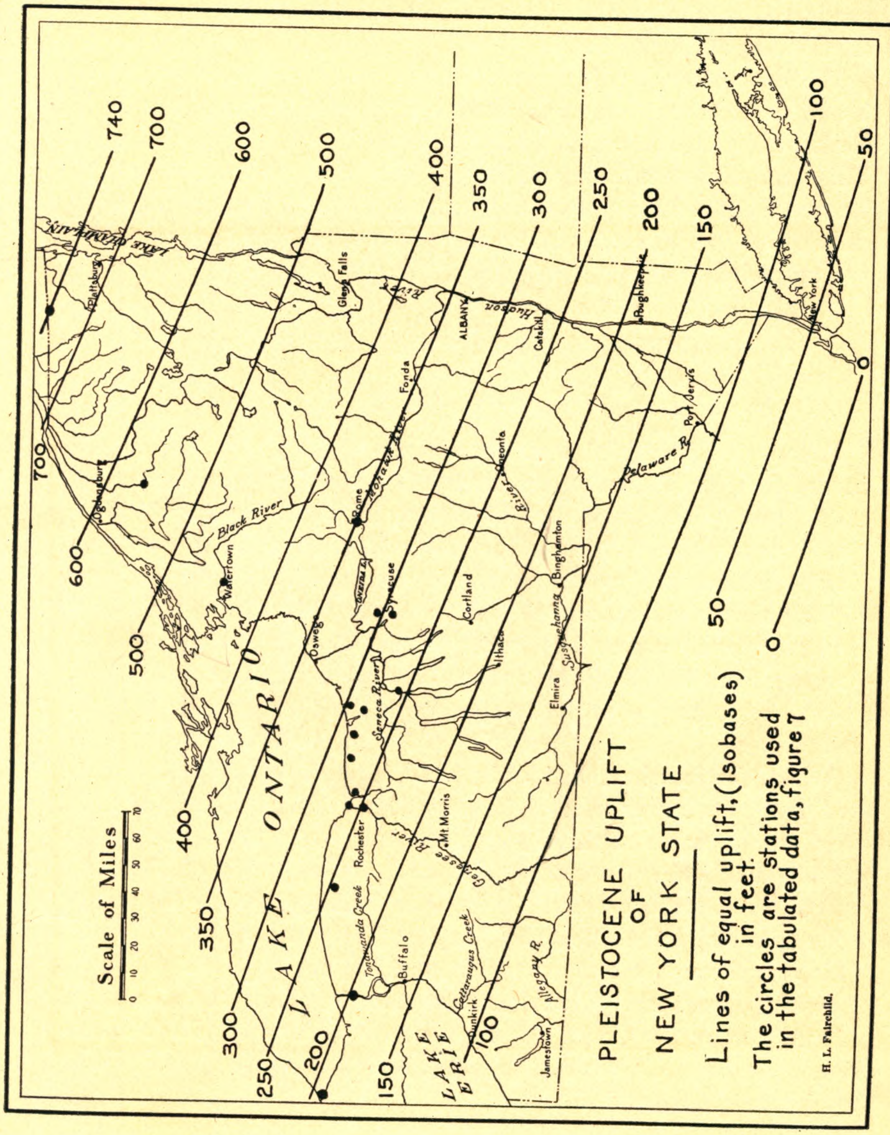


FIGURE 6. *Tilting Uplift of New York*

tilting, or differential uplift, between Hamilton and Covey of 668 feet. And we have sufficient evidence that the tilting has been produced by rise at the northeast end of the basin, and not by any sinking at the west end.

We have clear proof, therefore, that this part of the continent has risen, accompanied with northward up-tilting, in recent time. Perhaps the uplift has not entirely ceased; at least for Canada. This fact of recent tilting uplift of New York State is most important in the study of the local water levels, and should be clearly understood by the reader. The maps and tabulation (figures 5–7), are requisite.

Lake Dawson History; Fairport Channel

Plates 2, 3.

A series of glacial lakes, at successively lower levels, had existed in the Genesee Valley as the front of the waning glacier receded northward. These lakes had outlets at different times to the Susquehanna; to the Mississippi by different routes; and to the Mohawk-Hudson, giving the most complex and dramatic drainage history of any valley, probably, in all the world. The story of the Genesee glacial waters has been partially told in former writings (see numbers 14, 23 of the attached list of writings) and does not belong here, as the present paper begins with the Lake Dawson episode.

When the ice sheet had melted off from the site of Rochester and from the larger part of the Irondequoit Valley, but while the ice front lay north of the city and across Penfield town, east of the Irondequoit Valley, a glacial lake occupied as much of the west end of the Ontario basin as the ice sheet had deserted. This water-body is called Lake Dawson (23, page 58). It had its outflow in Fairport, through the capacious channel leading east, past Palmyra, Newark, Lyons and Clyde; and poured its flood into the Lake Montezuma in the Cayuga depression, and eventually to the primitive Lake Iroquois wkhich then lay over the district from Rome to Syracuse (plates 2, 3).

The floor of the Fairport channel, on the divide, is today 460 feet (see plate 2). If we allow about 15 feet for the depth of water in the great river, and 5 feet for the difference of land uplift between Fairport and Rochester, we have 480 feet for the altitude of the Dawson shore about the city. This shore is found to lie at the junction of East Main Street and Culver Road, forming the east-facing slope at the University Athletic Grounds; and it curves around through the north part of the older city on the 480 contour of the topographic map, or about 45 feet higher than the Iroquois plane. The Dawson features, as well as the Iroquois, are shown in plates 2, 3. The shore features are weak and inconspicuous, because the lake had a relatively short life, and also for the reason that the surface level was probably falling as the Fairport river deepened its channel, first in drift and then in the Salina shales.

During Dawson time Lake Erie and Niagara River had come into existence (23), and the waters of the Great Lakes area, as much as the ice had uncovered, along with the copious flood from the melting of a thousand miles of ice front, passed eastward through Lake Dawson toward the sea, in the Hudson Valley. The valley at Fairport and on to Lyons carried an immense river, a predecessor of the St. Lawrence.

The mouth of the Genesee River during Dawson time was probably at about the location or level of Lorimer and Scrantom Streets. The part of the Genesee ravine south of this locality, and above the upper falls, was in progress of cutting. Beneath the level of what is now 480 feet no river channel then existed; the horizontal strata being uncut and continuous.

The maps, figures 5, 6, and the tabulated data, figure 7, show that the total amount of land uplift at Rochester has been 250 feet, since the ice melted off. Substracting this from 480 the present uplifted altitude of the Dawson shore gives us 230 feet as the actual height above sea of the Lake Dawson water surface.

The extinction of Lake Dawson occurred when the ice sheet, lying across Penfield, receded a few miles and permitted Lake Iroquois to penetrate westward and around into the Irondequoit Valley. Then the Dawson waters fell to and blended into Lake Iroquois. The surface of Iroquois was then about 110 feet above sea. The fall in water level, and the further drop of the Genesee River, was from 230 feet down to 110 or 120 feet. This relation of the water levels is shown in figures 8, 9.

Lake Iroquois History

Plates 2, 3; Figures 2, 3.

In contrast with Lake Dawson the Lake Iroquois was long-lived, and produced remarkable shore phenomena; long stretches of heavy gravel ridges and conspicuous erosion cliffs. It was the latest glacial lake in eastern America, at least of any note; was one of the largest in area and longest in life, and affords us the fullest knowledge. During most of the life of that ice-impounded lake the outlet was at Rome, N. Y., with outflow down the Mohawk Valley to the ocean in the Hudson Valley. The great sandplain extending from Schenectady to Albany, and southward, is the delta built at sea level by the river, called Iromohawk. This relation and outflow persisted as long as the latest ice sheet lay over the St. Lawrence Valley. As the glacier diminished, and its south front receded northward, the waters of Iroquois extended northeastward, penetrating between the waning ice margin and the northwest slope of the Adirondacks, and eventually found a second outlet at Covey Pass, on the international boundary at the north edge of the State (figure 3).

When the ice front backed away a little distance, about three miles from the State line; on the steep north face of Covey Hill, the waters of Lake Iroquois were drained down to ocean level. Then the sea-level waters, Gilbert Gulf (figure 4), took possession of the Ontario Basin. But this was some thousands of years before Lake Ontario came into existence.

As a lake level is determined and controlled by the height of its outlet, the rise at Rome of 180 feet during Iroquois time (figure 7), produced corresponding rise of the entire lake surface. It is an important fact that all the Iroquois shores south of the Rome isobase (figure 6) were shaped by rising waters. The large gravel ridges of wave construction, with high and steep lakeward faces, and with no subordinate flutings or deserted bars below 20 or 25 feet, indicate construction in rising waters. The huge ridge at Hamilton, Ont., is the best example (10).

The Iroquois water plane at Rome is today 460 feet, being determined by several gravel bars southwest of the village. The total uplift there is 350 feet, which leaves 110 feet as the intial height of that plane. There are reasons for thinking that the earliest outlet

PLEISTOCENE GEOLOGY OF THE ROCHESTER DISTRICT

This map includes the Rochester and Macedon quadrangles. Plate 3 joins it on the east. The oval hills are drumlins. The lines across the map indicate, in feet, the total amount of Postglacial land uplift.

of the primitive lake (figure 2) had a lower plane than the floor of the present channel at Rome (26 page 38). If that is true then the primitive lake was lower than 110 feet. We see no way at present of measuring the amount of rise at Rome previous to the time when the Iroquois waters reached the Irondequoit Valley and Rochester. The height might have been somewhat under or over the 110 feet. For the present purpose we assume the height as 110 feet. Whatever error there may be in this figure is of no large consequence in the succeeding history, as it has no effect on any later data.

Changes of Land Level; Tabulation of Data

Figure 7.

In a former publication (29) the relation of the several uplifted water planes in New York was discussed, and a tabulation was used that included some Canadian stations. In the table here given, figure 7, more New York stations are used, and some of the numerals are slightly changed. A brief description of the manner in which the figures of the table are derived will be helpful to the reader.

At Covey outlet, the second and latest discharge of Lake Iroquois, the upraised marine plane is 740 feet. The shore features produced by the sea-level waters have been traced from the vicinity of New York City up the Hudson and Champlain valleys to Covey Hill, and about that salient. Splendid series of heavy gravel bars at about 735 feet lie southeast of Covey pass, on the Champlain side of the highland; and similar beaches at accordant altitude on the St. Lawrence side of the salient. The marine shore has been traced in the St. Lawrence Valley, southwest from Covey Hill, until it passes beneath the waters of Lake Ontario east of Oswego (20).

The Iroquois level at Covey Hill is 1030 feet. The vertical interval of 290 feet between the Iroquois and the marine planes determines the height of Lake Iroquois above the sea at the time of its extinction. It is believed, moreover, that so little tilting of the land occurred during the short episode of the down-draining of Iroquois that we may regard the 290 feet as correctly represent-

		Hamilton, Ont.	Lewiston.	East Gaines.	Rochester.	Charlotte.	West Webster.	Ontario.	Sodus.	Rose.	Wolcott.	Montezuma.	Syracuse.	Woodard.	Rome.	Watertown.	Russell.	Covey.
A	Total land uplift, by isobases. (See maps, figures 5, 6.)	185	195	245	250	260	255	270	280	280	295	260	290	305	350	450	560	740
B	Present altitude of the summit (closing) Iroquois = A plus F plus G	**362**	**385**	**430**	**435**	445	**443**	**448**	**456**	**455**	**464**	**415**	**440**	**452**	**460**	**671**	**815**	**1,030**
C	Altitude of Iroquois at time of extinction. = 290 feet	290	290	290	290	290	290	290	290	290	290	290	290	290	290	**290**	**290**	**290**
D	Land uplift since extinction of Iroquois. Present height of the marine plane. = B minus C	72	95	140	145	155	153	158	166	165	174	125	150	162	170	**381**	**525**	**740**
E	Land uplift during Iroquois time, Glacial uplift. = A minus D	113	100	105	105	105	102	112	114	115	121	135	140	143	180	69	35	0
F	Rise of Iroquois level by flooding, south of Rome isobase, due to excess of rise at Rome. = 180 ft. minus E = B—(A + G) Splitting of beaches north of Rome.	67	80	75	75	75	78	68	66	65	59	45	40	37	0	**62**	**35**	0
G	Initial altitude of Iroquois. South of Rome isobase. = C minus 180 ft.; = B—(A + F) = B—(180ft. + D)	110	110	110	110	110	110	110	110	110	110	110	110	110	110	?	?	**290**
H	Present unlifted altitude of the initial Iroquois plane. South of Rome, = G plus A; = B minus F	295	305	355	360	370	365	380	390	390	405	370	400	415	**460**	**733**	**850**	**1,030**

FIGURE 7. *Tabulation of uplift data*

Altitude figures refer to ocean level. The figures in black face show actual measurements made in the field ing the interval between the two planes everywhere in the St. Lawrence and Ontario Valleys. Field measurements at many places confirm this theory.

This interval of 290 feet is the master key to the amount of glacial and post-glacial uplift, when used in combination with the isobases of total uplift, shown in figures 6 and 7. The lines of these maps give the total uplift during all of Pleistocene time, as the rise of the land did not begin, it is thought, until the latest ice sheet had melted off. If we know either the Iroquois or the marine altitude at any point we may obtain the other by subtracting or adding 290 feet. And knowing the figure for the total uplift of the station, found by scaling the maps, we can calculate two elements, first, the amount of uplift during Glacial (Iroquois) time, and second, the amount of rise during Post-Glacial (Post-Iroquois) time, or since the sea-level waters took possession of the Ontario basin. The latter figure is, of course, the uplift of the marine plane.

In the study of the levels of the glacial lakes another element is critical. It will be seen by the table that Rome, the point of outlet and control of Iroquois, was lifted 180 feet during Iroquois time, while Rochester and Charlotte were raised only 105 feet. But as the height of the lake outlet determined the level of the lake it is apparent that the greater rise of the land at Rome produced a rise of the water-level, or a flooding, at all points south of the Rome isobase. At Rochester and at Charlotte this flooding was about 75 feet. In the diagrams, figures 8 and 9, the amount of flooding is not conveniently separated from the rise of land; but the two taken together, land rise 105 feet and flooding 75 feet, make the total rise of the Iroquois water level, 180 feet.

This tabulation is deserving of careful study. It indicates that the land uplift was by a wave movement, progressive from south to north, or following behind the waning ice sheet, due to relief of pressure. It shows, also, that the rise in Iroquois time was proportionately greater on the south side of the basin, and decreases to zero at Covey outlet; while, on the other hand, the rise since Iroquois time, the uplift of the marine plane, increases toward the northeast to 740 feet at Covey pass. The table also gives the initial altitude of the Iroquois plane. The figure south of the Rome iso-

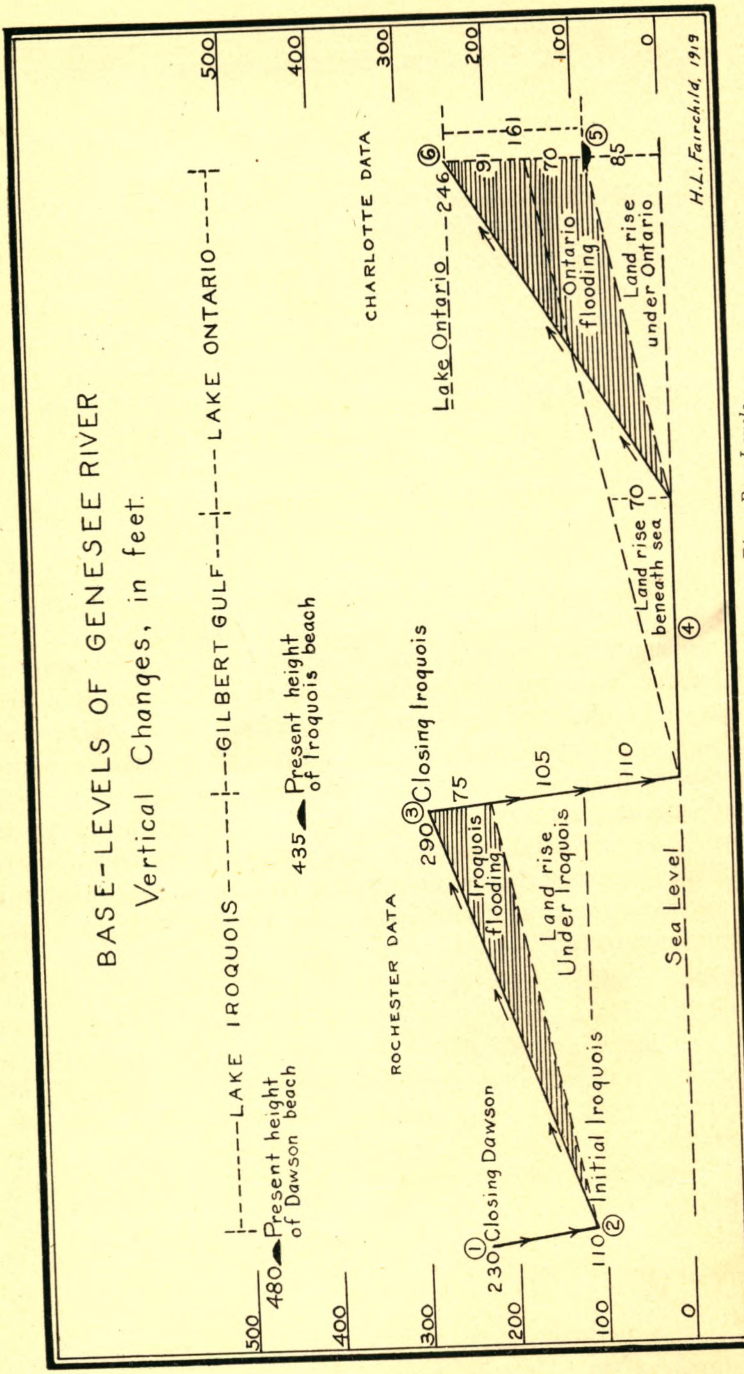


FIGURE 8. *Vertical Changes in the Genesee River Base-Levels*

base, 110 feet, is the intial height of the Iroquois plane at Rome, or in other words, it is the original altitude of the plane which is now raised up to 460 feet. But the actual water-level of the primitive Iroquois might have been somewhat lower, depending on some conditions at Rome and Little Falls. It must be understood that all figures in the tabulation refer to levels of the water planes, not of lake or river bottoms.

While the uplift at Rome, being more rapid than southward, produced rise of the water surface or flooding on the area south of the Rome isobase, the wave uplift of the land north of the Rome outlet raised the land out of the Iroquois water, and produced the vertical succession of beaches or gravel bars so conspicuous between Richland and Adams Center, and occurring as far as Malone. The vertical range of the bars, or "splitting" of the beaches increases from zero at Rome to 62 feet at Watertown, and from that district declines to zero at Chateaugay and Covey pass. The explanation for this fact is discussed in paper No. 29.

Vertical Changes in the Water Levels

Diagram, Figure 8.

The plotting in this diagram aims to show the up-and-down movements of the standing waters which served as the control, or base-levels, of the Genesee River in the Rochester district. The causes of these changes of level, land tilting and shifting of outlets, are not indicated. Merely the effects on the surface level of the river, at its mouth, are shown. The changes in horizontal position of the mouth of the river are not given, but this is suggested in the next diagram. The horizontal element in the diagram represents the time factor.

All altitude figures in this writing refer to ocean level. In the diagrams, figures 8, 9, the order of occurrence or succession of levels is indicated by the numerals in circles. Arrow points in figure 8 show the direction of movement. As already stated, the figures in this diagram, and in all the diagrams and table, are altitudes of water surface, not the floor or bottom of the channel. The depth of the river, or height above tide of the floor of the channel, can only be estimated.

The critical element in the study is the control of the water levels exercised by the outlets, on the northeast. For Iroquois this is known quite definitely; and precisely for Lake Dawson. For the initial Ontario we are not sure with precision. The control today, 246 above sea, is between Alexandria Bay and Brockville. But what we require is the point on the axial line of the St. Lawrence Valley which was first lifted out of the ocean-level waters (Gilbert Gulf), and which initiated Lake Ontario. We have learned from the tabulation, figure 7, that the land uplift was a wave movement, following the removal of the ice sheet, and hence somewhat earlier at the southwest than at the northeast; but greater in amount toward the northeast. From these facts it appears that the locality which first rose above the Gilbert Gulf waters, and became the sill or waste-wier for the outflow of the primitive Lake Ontario could not have been the place of present outflow, but was somewhat to the southwest. The controlling point was probably in the district of Alexandria Bay, or possibly yet farther this way. For the purpose of this study the primitive control of initial Ontario is taken on the isobase of Alexandria Bay, and the depth below the surface of Lake Ontario of the drowned mouth of the Genesee River depends on that point of original control, as will appear later in these pages.

The changes in the river level during Dawson and Iroquois times are quite clear. During Dawson time the altitude was about 230 feet (480 feet minus total land uplift of 250 feet). From this level the waters fell to the primitive Iroquois, to about 110 feet. Then the Iroquois level slowly rose, with the rise of the Rome outlet, to 290 feet. The rise of the land at Rochester was 105 feet during Iroquois time, and the flooding, due to excess of uplift at Rome, was 75 feet. This sequence of events in the history is proven by the position and character of the Iroquois beaches and deltas, as will be described later. An important fact to be noted is that the fall of the water level from 230 feet (Dawson) to 110 feet (primitive Iroquois) was relatively sudden, at least giving no chance for efficient wave work; but that the rise of Iroquois up to its extinction, 290 feet, was very slow, probably covering several thousand years, and permitting effective geologic work. The fall of Iroquois was, like that of Dawson, too prompt and continuous to allow the production of conspicuous shore features; but some deltas were built at intermediate levels in the courses of heavy streams from the Adirondacks.

The primitive Iroquois features must lie down the land slope, northward, from the "Ridge Road" beach, and the study of these early levels is transferred to Charlotte.

As already described, Lake Iroquois was extinguished by the melting away of the edge of the Labradorian ice sheet from the steep north face of Covey Hill, just north of the international boundary; and the water level in the Ontario basin became the ocean level. That ancient shore of the first sea-level waters is out one or two miles under the waters of the present Lake Ontario. Referring to the tabulation, figure 7, it will be seen that Charlotte has been lifted 155 feet since the close of Iroquois or beginning of Gilbert Gulf. As the present lake has been flooded, by the rise of its outlet, to 246 above tide it follows that the earliest marine beach is 91 feet beneath the waters of Ontario. This fact will be used later.

We must now study the Post-Iroquois history at Charlotte in connection with the land movement at the place of the earliest outlet of Lake Ontario. As stated above; this point is taken near the head of the St. Lawrence River, on the isobase of Alexandria Bay. The maps of isobases, figures 5 and 6, show that the total rise of that place has been about 500 feet. The uplift of glacial time is calculated as about 50 feet. This leaves 450 feet as the amount of rise at that point in Post-Iroquois time; or since sea-level waters were established in the Ontario basin. As the point (always water surface) has been raised 246 feet above the sea it follows that it was 204 feet beneath the sea at close of Iroquois time, or under Gilbert Gulf waters. Of course Lake Ontario was not initiated until that point was raised out of the sea. The relation of that event to the movement at Charlotte is the next problem.

While Alexandria Bay was rising 450 feet Charlotte rose 155 feet. We must now determine how much Charlotte rose while Alexandria Bay was rising in sea-level waters, or 204. By simple proportion we find this to be 70 feet (450; 155; 204, 70). By similar calculation we find that Charlotte has risen 85 feet during the life of Lake Ontario. Further we find that the excess of rise at Alexandria Bay has caused 161 feet of flooding at Charlotte (246 minus 85).

The uncertainty in these figures for Charlotte rests in the doubt

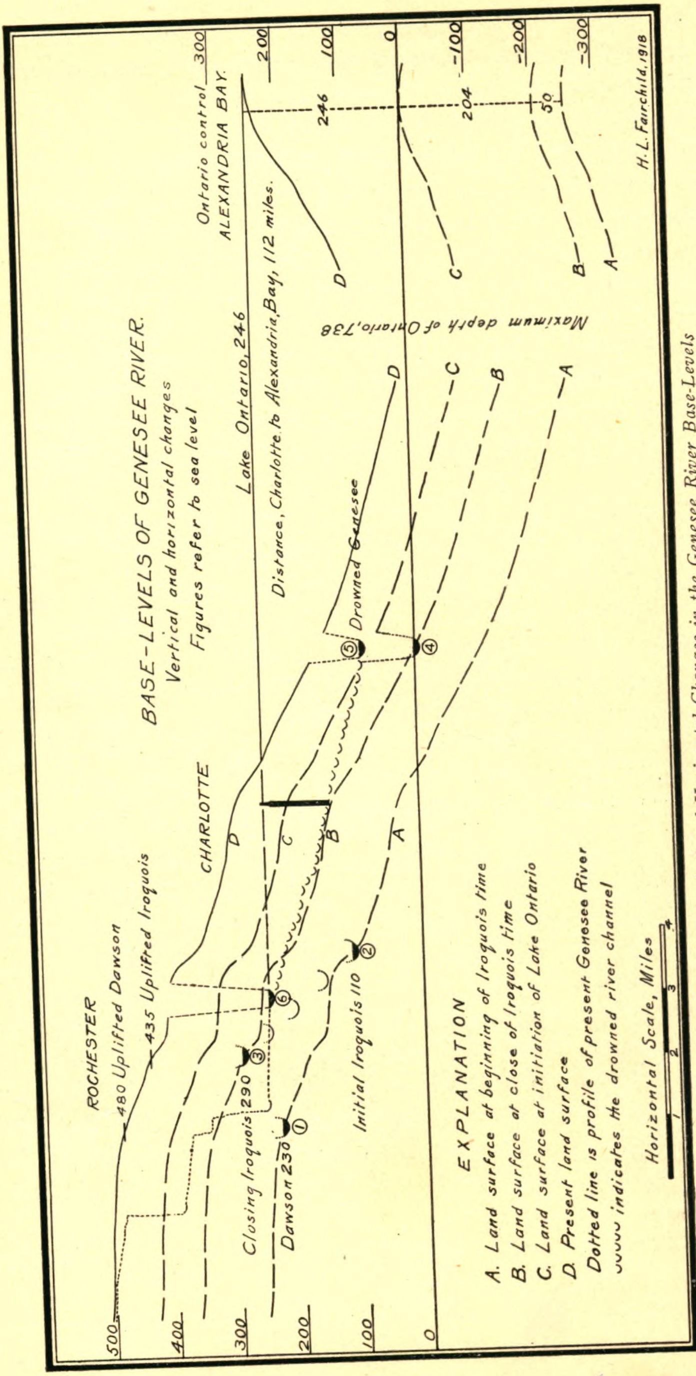


FIGURE 9. Vertical and Horizontal Changes in the Genesee River Base-Levels

as to the precise point at the head of the St. Lawrence Valley which first emerged from the ocean-level waters. For anyone who might like to follow this problem in more detail the following tabulation is inserted of the elements at Alexandria Bay and three other stations.

Station.	Total land uplift.	Uplift in Glacial time.	Rise beneath Sea.	Rise above Sea.	Post-Iroquois uplift.	Charlotte.		
						Rise under Sea.	Rise under Ontario.	Flooding of Ontario. Submergence of the Genesee.
Cape Vincent	450	70	134	246	380	55	100	146
Clayton	480	65	169	246	415	63	92	154
Alexandria Bay	500	50	204	246	450	70	85	161
Brockville ..	540	40	254	246	500	79	76	170

The interesting question now arises, where is the floor or bottom of the Genesee River, at Charlotte, as it existed during Gilbert Gulf time. The discussion of this interesting and practical engineering problems must be deferred until the next diagram in described.

Vertical and Horizontal Changes in Water Levels

Diagram, Figure 9.

The diagram should be compared with figure 8 and with the tabulated data, figure 7. This diagram is much exaggerated in the vertical as compared with the horizontal scale. It is intended to illustrate roughly how the mouth or debouchure of the Genesee River was shifted horizontally, up and down the land slope, as the water levels fell or rose.

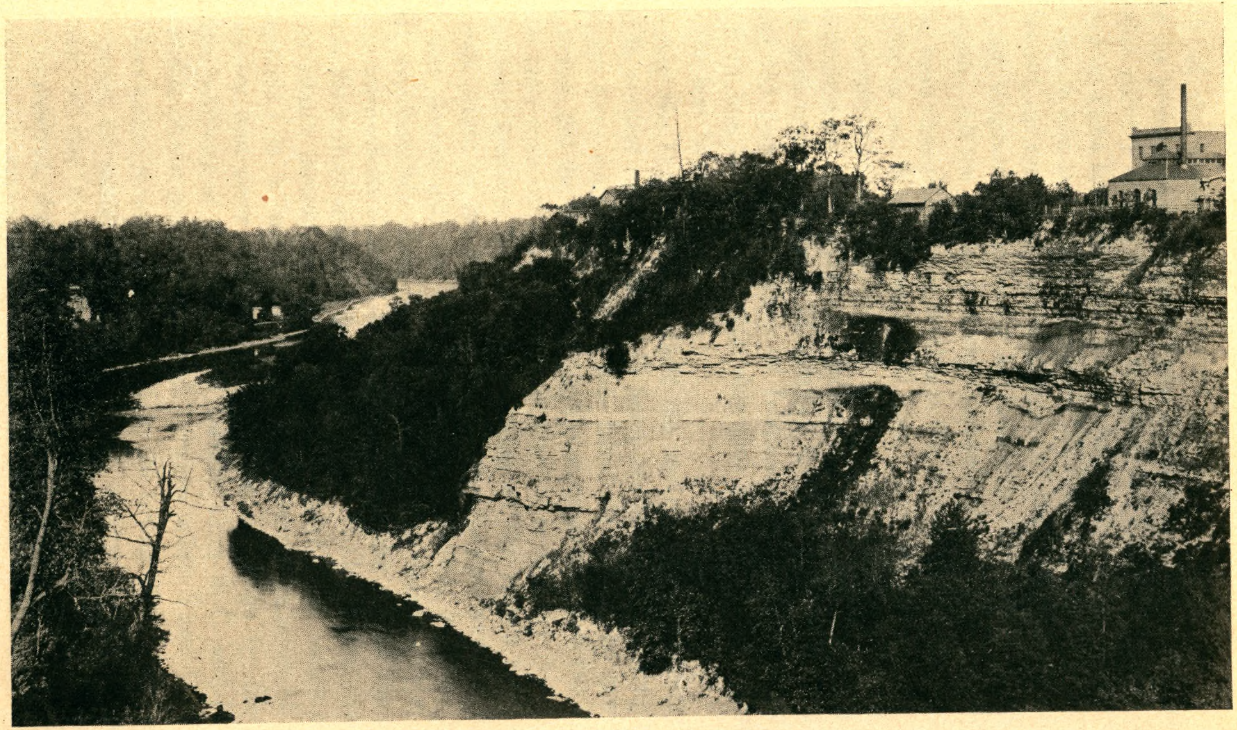
The apparent discrepancy between the amount of uplift at Rome and Alexandria Bay is explained by the fact that Rome lies much farther south, and the progressive land uplift lifted Rome earlier and in greater amount during Iroquois time. But on the other hand, Alexandria Bay was raised much more than Rome during Post-Glacial time.

When Lake Dawson was drained down 120 feet, vertical, the mouth of the Genesee was shifted northward, down the slope; along its present path between Lake Avenue and St. Paul Street, or from point 1 of the diagram to point 2. Subsequently, as the surface of Lake Iroquois rose, by the rise of the Rome outlet, the river mouth was slowly lifted through 180 feet, vertical, and shifted southward, up the slope, to the position of the Ridge Road; point 3 of the diagram. The water surface was then 290 feet above the ocean. All the figures in these diagrams refer to water surface.

The next change in water level was the relatively sudden drop of Iroquois to sea level, through 290 feet. During this episode the river mouth was rapidly shifted northward, down the slope, to some point north of Charlotte. The water surface, sea level, and the beach then had the position of number 4, on line B. But the land rise of 155 feet since the close of Iroquois has lifted the point on line B to line D, and the initial shoreline of Gilbert Gulf is now only 91 feet beneath Ontario.

During the life of Gilbert Gulf the river mouth was certainly fixed in vertical relation, its height being sea level. But during that time, we have found, Charlotte was lifted 70 feet. The question now arises, did the river mouth migrate northward, down the slope, as the land rose out of the sea-level waters, or did the river hold its sea-level position by the down-cutting of the river's bed? As the rock strata in the lower section of the canyon, and for some 800 feet downward, are chiefly weak red shales, and the land uplift was certainly slow, it seems quite certain that the river was able to intrench its channel, keeping pace with the rise of the land. This is the history indicated in the diagram. No horizontal shifting of the river's mouth during the life of Gilbert Gulf, needs to be recognized. It is impracticable to represent the relation of land movement and river channel further than is shown by the successive positions of the rising land surface, lines B. C. and D, and the profile of the present river bed, between points 6 and 5.

When Lake Ontario was initiated, by the lifting of the Alexandria Bay point of initial outflow above the marine plane, the north portion of the river canyon (now buried and drowned) had been intrenched, during Gilbert Gulf time, about 70 feet. Then the receiving waters began to rise, and of course the river level in accordance. That rise has been 246 feet, producing the present



ROCK STRATA, ROCHESTER CANYON
View looking north from Driving Park Avenue bridge

N. R. Graves, Photo.

relation of the lake, the river and the canyon. But while the lake rose 246 feet the land at Charlotte rose 85 feet, leaving 161 feet for the Ontario flooding. It will be seen, therefore, that the plane of the river surface, as it existed at the close of Gilbert Gulf time, is as much beneath the present level of Ontario as the height of the lake minus the rise of land since the lake was initiated. This is 246—85=161 feet. This depth of 161 feet is for the plane of the ancient river surface, not for the bed of the river. The rock bottom at the mouth of the drowned channel may be 10 to 20 feet lower, or 170 to 180 feet. The location of the mouth of the drowned channel is out in the lake about 2 miles from the present shore; but the channel is filled and obliterated by the drifting sand and silt in the lake.

It is not claimed that these figures are precise. They are certainly suggestive and quite certainly approximate. The exploration of the buried channel at Charlotte, described in the next chapter, confirms the accuracy of the calculations.

The reader may think that the history is complex and difficult to grasp. But it is as simple as will explain the known facts. It is possible that the actual sequence of events is even more complicated, as there might have been facors which are not yet recognized.

Channel Features at Charlotte

Diagram, Figure 10.

Fortunately for this study we have important and interesting data concerning the buried river channel at Charlotte, which confirm the conclusion derived from the geologic study. The engineering work on the new bascule bridge at Charlotte has determined the depth of the river silt and the position of the rock floor of the buried river channel at that point.

Through the courtesy of the County Engineer, Mr. J. Y. McClintock, and the help of Mr. Fred C. Line, Assistant to the County Engineer, who had immediate oversight of the caisson work, a diagram is here included, figure 10, showing a cross-section of the valley at the site of the bridge, and the facts, as far as the exploration now reveals, of the old river channel as it was cut during Gilbert Gulf time.

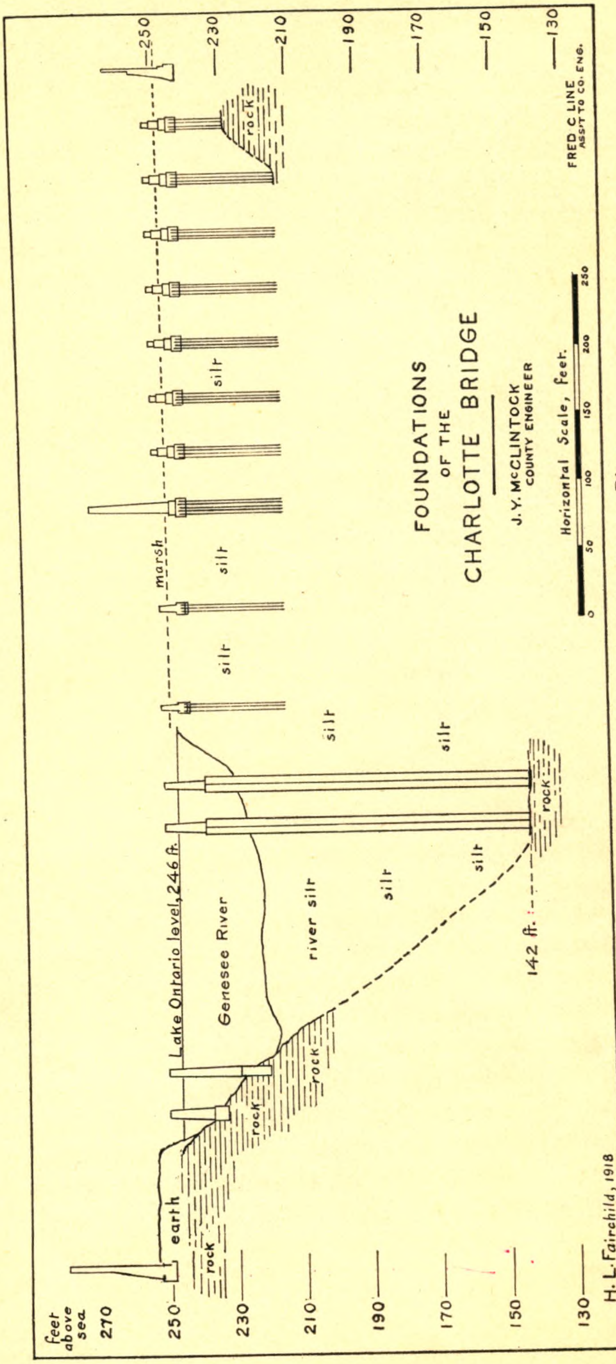


FIGURE 10. *Drowned Channel of the Genesee River*

The west piers of the bridge stand on the rock which makes the west bank of the river. The four east piers, 180 feet distant from the west piers, stand on rock at depth below the average river surface (246 feet) of 103.14 to 105.67 feet. The four caissons for these concrete piers explored the rock surface over a rectangle 38 feet north-and-south by 41 feet east-and-west. The variation from horizontality of the four surfaces uncovered by the caissons was two and one-half feet; and the differences do not indicate any definite direction of slope. The area covered by the exploration is probably too large to represent merely a shelf on the west side of a deeper channel, especially as the red shales are too weak to support wide terraces. It appears more than probable that we have here found the ancient channel bottom. This is now 142 feet above tide, and averages 104 feet below Ontario lake surface.

On the diagrams, figures 9, 11, the position of the east piers is shown. It will be seen that the piers stand on the theoretic line of the graded river channel. These diagrams were made before the data from the Charlotte bridge were used.

The Canyon History

Plates 4, 14. Figures 11, 12.

In the production of the canyon features two factors are concerned; the varying character and resistance to erosion of the rock strata, and the changing levels of the standing waters. The latter factor has already been considered, but the rocks must be briefly described.

The accompanying diagram, figure 11, gives the succession of strata, from the red shales at the bottom of the canyon up to the limestone that is the top stratum through the city, conspicuous at the upper falls and from Court Street bridge. These rocks are all of oceanic origin, having been accumulated as clay, sand or lime sediments in the shallow waters of an inland sea. We may liken the waters to the Hudson Bay or the St. Lawrence Gulf of the present time. In age the rocks are very old, dating from the ancient Silurian Period, as attested by the abundant fossils of salt-water origin found in most of the beds.

The important features of the canyon are of three classes:

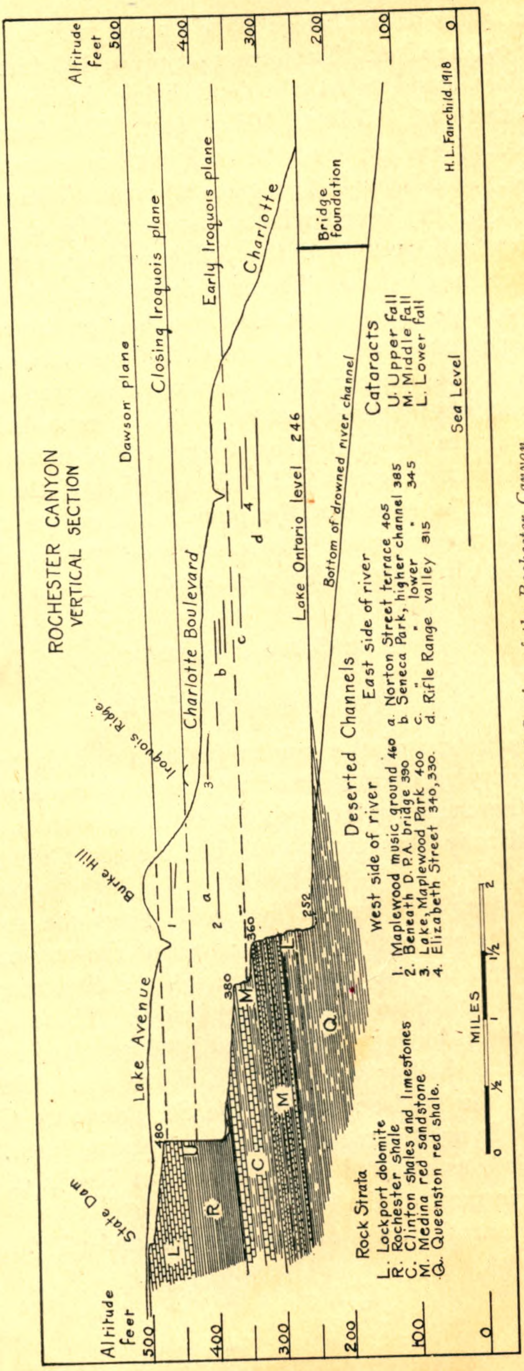


FIGURE 11. *Vertical Section of the Rochester Canyon*

(1) the cataracts; (2) the curvatures or meanders; and (3) the deserted channels or scourways on the sides of the ravine.

Cataracts

Cataracts and cascades are produced by unequal resistance of the rocks to the stream erosion. Vertical falls occur where strong or resistant beds cap or overlie weak beds. The upper fall is a good illustration of the vertical cataract, where we find the lower beds of the relatively hard Lockport (Niagara) dolomite capping the thin-bedded and weaker Rochester shales. The middle fall was due to the lower Clinton limestone overlying the weak Clinton lower shale (Maplewood green shale). The lower fall is not vertical, but a steep cascade, due to the thick and very hard beds of the Medina sandstone. The characters of the three falls are shown in the photographs, plates 4–14, and their relation to the water levels in the diagram, figure 11. It appears that the upper fall was no more than initiated in Dawson time; but was cutting during all of Iroquois time, and of course, during all later time. The middle fall was no more than started, if cut at all, in Iroquois time, as that plane was soon flooded by the rise in Iroquois waters. The lower fall is wholly post-Iroquois.

It must not be supposed that the several falls originated at the points where they now stand. In the development of the cataracts there has been migration, backward, up stream. They began as rapids or low cascades and were developed to their present height and form by the up-stream recession. It is not possible, nor very important, to locate the point of origin of the different falls. The southward dip of the strata, suggests that the point and plane of initiation of each cataract was somewhat higher than the present position, proportionate to the distance northward.

If the whole length of the canyon, from City to lake, had always been equally exposed to the air and river work the lower and northward part would have originated first and have deepened more rapidly, because the rocks toward Lake Ontario are only the very weak red shales. But in fact the northern, lower and deeper part of the canyon is youngest, dating from the close of Iroquois time. It was cut during Gilbert Gulf time. The upper part of the ravine, through the business portion of the city, is the oldest, beginning dur-the Dawson time.

The altitudes and heights of the falls are given approximately in the following table. Compare with figure 11.

GENESEE RIVER IN THE ROCHESTER CANYON

	Altitude at crest of falls.		Height of falls.	
	Topog. Map.	Roch. R. & L. Co's Survey.	Authority?	Roch. R. & L. Co's Survey.
Upper fall	480	—	92	—
Middle fall	380	370	28	31
Lower fall	360	341	96	89

Drop of the Genesee River in the three falls....................	216 feet
Drop of the Genesee River between the three falls	12 feet
Total drop, to foot of lower fall	228 feet
Drop of river beyond lower fall	6 feet
Total drop of river	234 feet
Elevation of Lake Ontario	246 feet
Altitude of crest of upper fall	480 feet

Deserted Channels and Meanders

Figure 12.

The erosional work of the river in the process of cutting the canyon is partially shown in the remnants of the abandoned channels or scourways that are now found along the sides of the canyon. These occur from the Dawson level down to near the Ontario level. They are not indicated clearly by the contours of the Rochester Sheet, but the more important ones are mapped in figure 12.

The largest, most evident and most interesting of the old river channels are those in Maplewood and Seneca Parks. These parks are located as they are because of the river work. The smooth, rolling tracts of ground now utilized for the pleasure of the people were shaped by the river during its erosion of the canyon. These are shallow troughs or flutings, or terraces and benches, carved in the rock strata, and with a down-slope always to the north.

The highest old river bed and bank correlates with the lowering Lake Dawson. It is seen on both sides of the canyon at Driving Park Avenue. On the east side it is the level stretch in the little park south of the avenue. On the west side it is all the ground of

UPPER FALL, GENESEE RIVER, ROCHESTER, N. Y.

N. R. Graves, Photo.

LOWER FALL, GENESEE RIVER, ROCHESTER, N. Y.

upper Maplewood Park. The slope of the rose garden and that used for seating in front of the Band Stand is the west bank of the old river. (Plate 9.) The altitude of these floors of the river channel is about or somewhat over 460 feet. We may call this the Upper Maplewood channel. When it carried the river it extended across from the west to the east bank, and there was no cutting below. This was the lowest point that the river had reached to that time.

Some 70 feet beneath the Upper Maplewood channel are conspicuous be ches in the canyon walls on which stand the abutments of the arch of the Driving Park Avenue bridge. The west terrace (see Plate 10) is the more prominent, and carries the concrete pavilion or shelter that stands just north of the bridge. This terrace is floored by the Clinton lower limestone (Reynales limestone of Chadwick). Its altitude is 390 feet at the south and 388 feet at the shelter. The corresponding shelf on the east side of the canyon is not conspicuous.

Passing north from the Upper Maplewood Park the successive work of the old river is seen in hollows and banks, declining northward and ending at the brink of the deep canyon. Along the Maplewood Drive a good, broad scourway lies at the junction of the Seneca Parkway, with altitude about 440 feet. The channel with clearest character on the west side is the one in Lower Maplewood Park, at the Ball Ground, Refectory and lake. The altitude here is 400 feet.

Since figure 12 was engraved Professor Chadwick has recognized another channel remnant in the lower Maplewood Park. This is a shelf, 110 feet wide and over 500 feet long, on the west wall of the canyon some 35 feet beneath the Refectory channel, noted above. This cutting is in Medina sandstone, with altitude about 365–370 feet. Making allowances for distance and grade it seems probable that the floor of which this shelf is a remnant correlates with the lower (Lake) channel in Lower Seneca Park, to be described below.

Going north on the east side of the canyon a broad scourway is found at the junction of Norton Street with the Seneca Park Drive. The latter parkway follows the terrace to the junction of the Brewer's Dock Road. The altitude is 405 feet. The locality was a part of old Carthage village.

FIGURE 12. *Deserted Channels of the Genesee River*

One half mile south of the main portion of Seneca Park a small channel occurs which the Park Drive crosses by a filling. The sharp cut behind a rock knoll is conspicuous; with altitude 385 feet.

Lower Seneca Park occupies two elegant old channels. To Professor Chadwick is due the credit of being the first observer to explore these deserted channels with recognition of their genesis and to appreciate their significance in the canyon history.

The lower and larger scourway is the one which carries the deer park, the music ground, pavilion and the artificial lake. This channel begins in a definite depression at the top of the east wall of the deep canyon, and leads northeast, curving to northward and widening. The banks are very evident, the west bank passing through the deer park and forming the slope on which are placed the benches for the concerts. (See plate 11.) The lake has been made by constructing a dam across the lower, northern, end of the channel. The features here deserve careful study.

The rolling plain in which the channel is cut has altitude about 350 feet. The floor of the channel is about 345 feet at the head and 337 feet for the lake surface. The theoretic level of the primitive Iroquois is 360 feet. As the erosional features are about the depth below the lake surface to which the vigorous river, provided with abrading materials, would erode its channel bed, it suggests that we have here the lake and river bottom of initial Iroquois. The bank by the Band Stand is rock, the soft, red Queenston shale. The width between the definite banks is over 500 feet; sufficient to carry the river. Gravel deposits are spread over the plain. As both ends of the channel are cut off by the east wall of the deep canyon it is apparent that the latter is later in time.

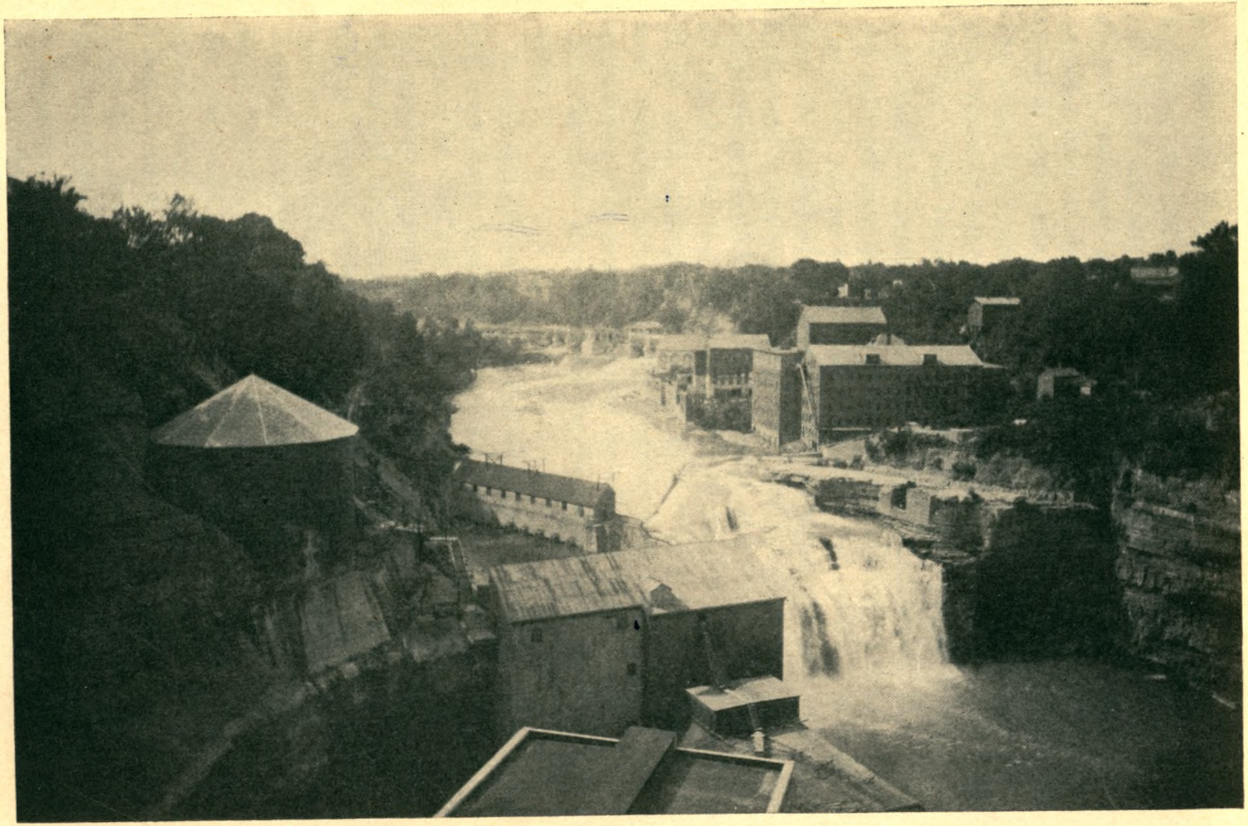
The lake channel is certainly stream work, and if not related to the early and lower level of Lake Iroquois then it must be attributed to the falling Iroquois. If the latter, it is difficult to understand why the river in its downcutting should desert this capacious channel and make the ravine on the west, in the same kind of rock. A better explanation appears in the view; that the plain and channel was primarily cut in early Iroquois time, following the down-draining of Dawson; that as Iroquois rose and the waters here deepened, the channel was buried in delta gravels; then when the lake finally fell away the river currents swept out the gravel and produced the present forms, while the main flow was on the west, beginning the ravine.

A higher and less capacious channel is utilized by the New York Central Railroad, and by the electric line into the Park. The terminal loop of the latter (incorrectly shown in the topographic map) is in the middle of the channel, at altitude about 380 feet. The tennis courts and animal enclosures are on higher eroded spaces along the west side of the railroad channel, at elevation about 385–390 feet. The Refectory stands on the west bank of this channel.

It should be clearly realized that when these Seneca Park channels were forming they were the lowest channel cut by the river, and that there was no canyon below the 337 feet floor. The detritus from the erosion of the channel and the upper part of the canyon, southward to beyond the upper falls, was contributing to the broad silt plains at Charlotte and Summerville, now lifted to 340–360 feet in altitude. As the Iroquois level rose the Seneca Park channels of the early cutting were buried in the delta deposits; but these were swept out later, when the Iroquois waters were drained down to sea level. The present form of these lower channels must be partially due to the river work during the falling away of the Iroquois waters.

In this brief description it has been assumed that the old channels were cut in succession from the highest to the lowest, but this may not be wholly true. The scourways have the form that would be expected of rapid flow for a brief period. The channels through Maplewood and Seneca Parks and lying beneath the level of the closing Iroquois (Ridge Road), fall within the range of three lake episodes, the falling Dawson, the rising Iroquois, and the falling Iroquois. During Iroquois time the river probably had time to intrench itself, so that during the rise from lower to higher levels the river was probably confined to its rock-walled canyon. It appears that during later or full-height Iroquois the water level extended south up the drowned canyon to the upper falls (see figure 11), and with such depth of water the lateral erosion must have been small.

There yet remains for description the lower part of the canyon, north of Seneca Park. The cemeteries, on the west side of the river, show only indefinite river work, in morainal deposits; for it



LOWER FALL, GENESEE RIVER, ROCHESTER, N. Y.
General view

must be understood that the glacier had left masses of drift on the old land surface, which the river encountered and had to remove in the canyon cutting.

The Rochester sheet and figure 12 show the channel features at the lower levels. The highest of these is the broad, fluted scourway on the west side of the canyon crossing Elizabeth Avenue. The altitude of this is 340 feet. It ends abruptly at the singular semicircular hollow or re-entrant in the canyon wall, one and one-half miles south of Charlotte. The remarkable curving channel, or meander, on the east side is over a mile long and one-third mile wide, with altitude under 320 feet. This curving hollow has been called "the flats," "sunken gardens" and "rifle-range hollow." It deserves a better name. The semicircular re-entrant in the west wall of the canyon is opposite the north and lower end of the east-side meander channel, which suggests that it was excavated, at least in part, by the impact of the river current that swept the meander. But as its swampy bottom is the present river level it seems probable that it has been partly excavated as a cataract of the small stream which flows north across Elizabeth Avenue.

The Elizabeth Avenue scourway and the meander channel do not correlate with any recognized water level. They are below the lowest Iroquois and much above the marine plane. Unless they are due to some unknown element in the history, which is possible, they probably represent a phase in the down-draining of Lake Iroquois. They would not require a long pause, or stand-still of the receiving waters, since they are cut in the soft deposits of the Iroquois delta. But the wide swing of the meander channel, with the island left at its center, deserves tentative explanation. This is about the locality where the Genesee River debouched into the early Iroquois lake. The fine river-borne detritus was swept far and wide by the lake currents, even to Irondequoit Bay. But the large volume of coarse material, derived from the cutting of the rock canyon, was dropped close by the river's mouth. During the lowering of the lake waters this mass of coarse detritus was for a time an obstruction to the direct flow of the whole river, and probably caused partial diversion, first by the Elizabeth Avenue course, and later through the meander channel. The island-like mass at the road corners contains much coarse material, represent-ing either the coarse delta stuff or glacial drift, or both. Finally, with the lowering of the base-level waters and the increased velocity of flow the river was able to straighten its course and to intrench itself in the canyon.

The level of the meander channel, 300–320 feet, is also suggested in smooth stretches of silt plains east of Summerville and toward Sea Breeze, and at the east of Forest Lawn. These plains might have been shaped rapidly out of the fine silt of the delta fronts.

Sufficient pause in the falling of the sub-Iroquois waters might have been caused by some little hesitation or increased push of the waning ice margin on the north face of Covey Hill, which was the dam that held in the Iroquois waters.

The larger curves in the canyon, which appear in the maps, plates 2, 4, were probably initiated by inequalities in the land surface which the river discovered in its extension northward, during the fall of the lake waters from Dawson to Iroquois, through 120 feet.

Some minor re-entrants and salients along the sides of the canyon, which the map does not indicate, represent lateral cutting by the river in the soft rocks during times of sluggish flow. Under-cutting of one of the soft shale members of the rock strata would bring down all the overlying strata. The more striking curves are seen looking north from the bridge at Driving Park Avenue. Plate 4 shows the point of rock projecting from the east wall.

Future intensive study of the canyon and the correlating features will doubtless add interesting details to this brief description; and perhaps will discover new elements in the history and new facts. The present account of the canyon history appears to be well attested by all observed facts. It may appear complicated, but any new discoveries can only increase the complexity. As stated in the introduction, the story is not simple and cannot be made easy reading for a sleepy hour.

The numerical data given in the above writing are subject to some future revision, when some one shall have made more intensive study of the Pleistocene features of the Rochester district. But the main facts appear certain and the Genesee River history must be substantially as here given and as depicted in the diagrams.

UPPER MAPLEWOOD CHANNEL, WEST BANK

Deserted bed of Genesee River. View looking north over the music ground and band pavilion

Associated Geologic Features

Plates 2, 3.

Waters Previous to Lake Dawson

This writing deals especially with the water bodies which touched the City of Rochester and which limited the flow of the Genesee River; and the history of the Rochester canyon. But there are a number of related geologic features not yet described; while the maps, plates 2 and 3, show some unrelated but very interesting phenomena.

It has already been stated, page 12, that Lake Dawson was a late member of a long series of glacial lakes in the Genesee drainage area; not only earlier in time but higher in altitudes (23). As three of these earlier water levels have left records on the Rochester and Macdon quardrangles, combined in the map, plate 2, they deserve at least brief mention. The fuller description is printed in papers number 14 and 23.

Lake Warren. The highest and oldest records of wave work on the map are of Lake Warren. These lie about the top of Baker Hill at elevation of 890–900 feet. Lake Warren was an extensive water body held up by the ice sheet. It occupied all of the Erie basin, part of the Huron basin and a strip of territory in New York. Its outlet was westward across Michigan, pouring into the glacial Lake Chicago, and finally to the Mississippi. When the south edge of the ice sheet receded from the high ground north of Batavia the Warren waters penetrated into central New York as far as the Syracuse district, forming a narrow strip of lake along the south face of the glacier, with southward extensions up the valleys of the lower Finger Lakes. Subsequently the ice front receded from the steep north-facing slopes in the Syracuse region and the lake found a new and lower escape eastward to the Mohawk-Hudson. Then the waters ceased to be "Warren." The falling waters, tending toward Lake Iroquois have been called the Hyper-Iroquois. Some of the earliest channels of the east-leading drainage have been mapped in paper 23. Lake Dawson was only the latest stage of the Hyper-Iroquois waters, and a very brief pause.

The wave-smoothed areas on Baker Hill are the most northerly inscription in New York of Lake Warren. The north shore of the lake was the front of the Labradorian glacier. As Baker Hill lies on the isobase of 235 feet it appears that the lake stood about 665 feet above the sea.

Lake Dana. This lake was the longest pause in the Hyper-Iroquois waters, the level being determined by the capacious channel leading east from Marcellus village. Description of the lake and outlet is given in paper 23.

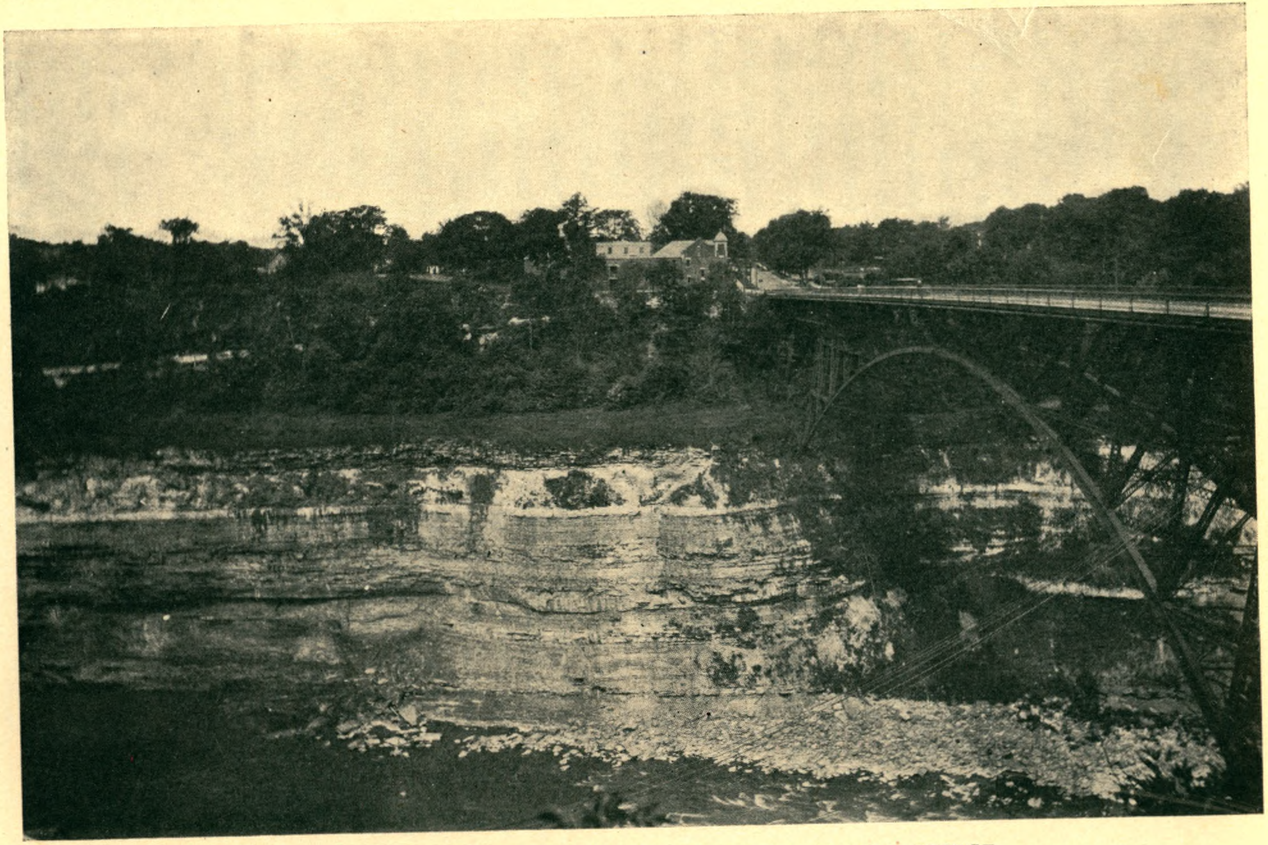
The Dana wave-work records are much more abundant in our territory than the Warren, because they lie some 200 feet lower and with wider areas of drift for registering the wave action. The deltas occur especially on the southwest flank of Baker Hill, and wave-smoothed surfaces on the Mendon gravel hills. In general the Dana features lie along the south border of the map, with altitude at 700–720 feet. Lake Dana was extinguished when the waning glacier uncovered passes in the Syracuse district lower than the Marcellus escape, and it is probable that this took place when the ice front was lingering south of Fairport and Pittsford.

In the Niagara folio (31) this body of water is improperly called Lake Lundy.

Lake Scottsville. Eventually, by recession of the ice front in the Syracuse region, the waters of the Irondequoit and Genesee valleys were lowered to the level of the low pass at Victor. Either by the Victor control or the Syracuse control the waters certainly stood for a time at altitude below the Dana and above the Dawson. Sometime during this episode of uncertain control, and probably fluctuating levels, the Pinnacle kame-moraine appears to have been built. Some wave-smoothed areas in the Irondequoit Valley at about 600 feet and wide silted plains and clay-sand flats in Henrietta at 600 down to 500 feet must correlate with the Victor pass. When the ice front melted from the Fairport-Lyons valley then Lake Dawson came into existence.

Dawson Drainage Channels

The outlet channel of Dawson is mapped in plates 2 and 3, and needs no particular description. This great channel, which carried a river comparable to the St. Lawrence, and was actually the latter's predecessor, graded a path for railroads and canal, and is a part of the most favorable route of commerce between the Atlantic seaboard



ROCK TERRACE, WEST END OF DRIVING PARK AVENUE BRIDGE

Deserted bed of the Genesee River

and the upper Great Lakes and Mississippi Valley. The outflow of Lake Dawson helped to produce the commercial supremacy of New York State and City.

The drainage of Dawson, through Fairport, Macedon, Palmyra and Lyons, was not directly into Lake Iroquois, but into a shallow intermediate body of water that occupied the Cayuga-Montezuma depression. This glacial lake, hemmed in on the north by the waning front of the ice sheet, we may call Lake Montezuma. It had its outlet past Jordan, Memphis, Warner and Amboy, pouring into Lake Iroquois which then lay over the region of Syracuse and the present Onondaga Lake. Lake Montezuma was probably some 30 to 40 feet higher than Iroquois.

It is an interesting fact, illustrating the complexity of the history, due to the effect of land uplift, that at a later time all the Montezuma lowland and even the Dawson outlet channels east of Newark were flooded by the later and higher Iroquois waters. The lower surface shown in the map, plate 3, had its finishing touches given by Lake Iroquois.

The altitude of the bottom of the Dawson channel east of Fairport was about 215 feet, declining to about 140 feet at Lyons (see tables below). The delta sandplains built in the low areas at Lyons and southeast of Clyde, in the Montezuma waters, give us the approximate level of the Montezuma waters, which appear to have been about 145 feet; while the Iroquois waters farther east were about 110 feet. With the help of the map of isobases, figure 6, we are able to calculate approximately the height of the channels and deltas at the time they were formed. By deducting from the present altitude the amount of land uplift we find the altitude during Dawson time. Following are some estimates.

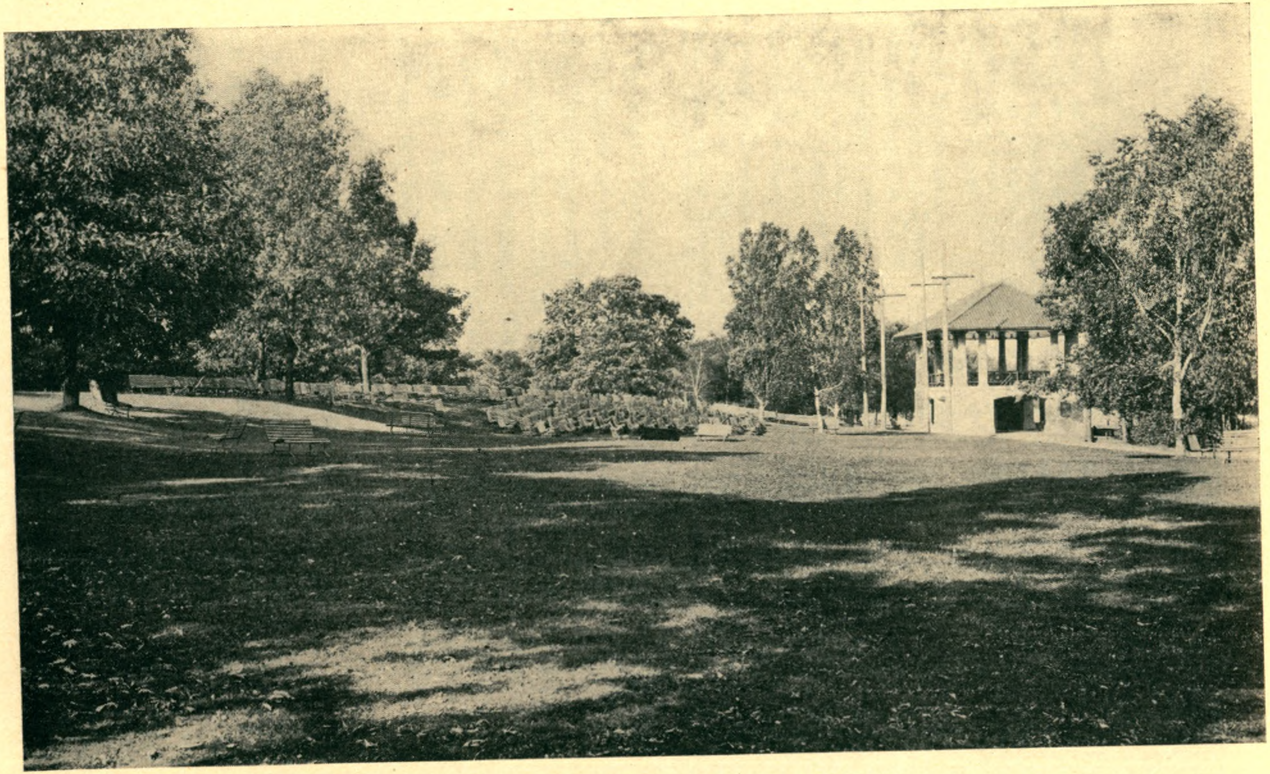
	Present Altitude.	Land Uplift.	Height in Dawson Time.
Dawson outlet; bottom of channel.			
Channel at Fairport	460	245	215
Channel at Macedon	450	245	205
Channel at Palmyra	440	250	190
Channel at Newark	415	250	165
Channel at Lyons	400	260	140
Channel at Clyde	400	270	130
Lake Montezuma.			
Delta southeast of Lyons	400	255	145
Delta southeast of Clyde	400	260	140
Montezuma outflow.			
Channel at Jordan	400	280	120
Channel at Memphis	408	285	123
Channel at Warner	400	285	123
Channel at Amboy	404	290	114
Primitive Iroquois; Syracuse district.			
Delta plain at Belle Isle	400	290	110
Delta plain under Syracuse	400	290	110

The above figures for the Post-Glacial land uplift are taken only in multiples of five. A more precise determination of the amount of uplift is impracticable.

The delta sandplain on which stands the City of Syracuse and the plains east and west of Onondaga Lake were probably mostly laid in the early Iroquois waters, and at about 110 feet above the sea. It will be noted that this is the theoretic initial plane of Iroquois, south of the isobase of Rome. See the tabulation, figure 7.

Dawson Extinction

Lake Dawson was drained down to the Iroquois level when the ice front thinned and melted back over the drumlin area in Wayne County, between the old channel described above and the Iroquois plain on the north. The maps, plates 2 and 3, show the more or less definite valleys between the drumlin hills, with southeastward direction, toward the old channel, or to the lowland between Lyons and Rose. These channels of the down-draining waters are too numerous and uncertain to map with channel convention without more careful field study. Apparently the drainage was distributed instead of being concentrated in a few large or conspicuous courses.



LOWER SENECA PARK CHANNEL, WEST BANK

Deserted bed of the Genesee River. View looking north over music ground and band pavilion

Dawson Plains

Lake Dawson was too short-lived to produce extensive and conspicuous sandplains. But in the narrow Irondequoit Valley about Bushnell Basin and south to Railroad Mills the inwash of detritus by Irondequoit, Allen and other streams was sufficient to build the narrow plains shown on the map. The higher and broader delta plains west of Railroad Mills and Fishers, at 580 to 600 feet, correlate with the Victor pass, and are credited to the Scottsville waters.

Another area of Dawson deposits are the rolling sand hills at and north of Pittsford and west of East Rochester (Despatch). The surface expression and composition of the knolls, with the enclosed basins or "kettles," indicate that these fine sands were laid down at the ice margin. The material was contributed in part by the outwash from the glacier. The latter origin appears certain for the high knolls, up to 480 feet, lying between the Rochester and Syracuse Electric R. R. and the New York Central R. R. Professor Chadwick has mapped them as an "esker fan." (32) The whole area may be regarded as kames, rather than land-stream delts, and more or less leveled by the Dawson waters.

The flats south and southeast of Brighton are mapped as Dawson, being under that level; but westward, at the Twelve Corners and south of the Pinnacle moraine, those rising above the theoretic Dawson plane must be credited to earlier waters, or to the early Dawson before it was adjusted to the eroded Fairport outlet.

Some small areas in Greece are outliers of the beach or else are wave-smoothed kames.

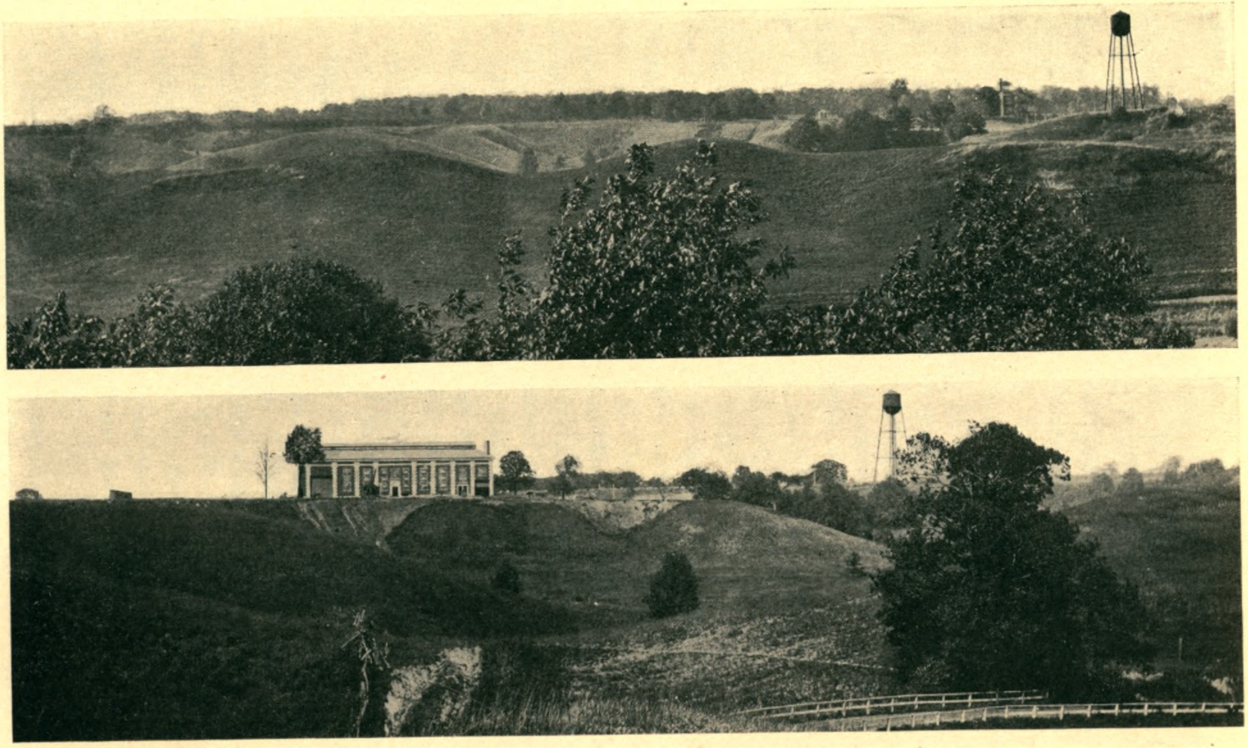
Early Iroquois Plains

It has been shown that the Dawson waters dropped away to the initial Iroquois too rapidly to leave any good record except the extinction channels in Wayne County. Even at the summit plane the Dawson beaches are weak. But, on the contrary, the rise of the Iroquois waters was slow, depending on the rise of the land at the Rome outlet. This slow lifting of the water surface, and of the zone of wave-work, gave opportunity for the production of the smooth, up-sloping plain characteristic of rising waters.

The earliest Iroquois deposits or delta plains were formed, naturally, at the primitive or lowest level of the lake; in the Rochester region at, or perhaps slightly above, 110 feet. The theoretic figures for the initial Iroquois at different localities in the State are given in figure 7, line "G"; and the present uplifted altitude of the same plane in line "H." South of the Rome isobase the latter is found either by deducting the amount of flooding from the present altitude of the highest beach, or by adding the total uplift of the station to the initial Iroquois altitude (110 feet). North of the Rome isobase the height at which the Iroquois water reached the station is indeterminate. There the vertical range of "split" beaches, shows excess of land uplift over rise of water, after land uplift began, and the higher beaches are the earlier.

It will be seen that at Rochester and Charlotte the present theoretic height of the early plains. uplifted, is 360 and 370 feet. The earliest widespread lake deposits would naturally lie 10 to 20 feet below the water surface as long as the material was fine enough to be carried into quiet water, or the currents strong enough to distribute it. When the sandplains at Charlotte are examined, with the topographic map, it is found that the plain, with a rather abrupt north border, has height at the margin of about 340 feet. On the east side of the river the broad lower plain is 360 feet. On both sides of the river the plains rise steadily, with no bars or cliffs, southward to the base of the beach ridge, at about 420 feet. The smooth surface of the plains, with no bars, but with gentle rise toward the closing beach, is the character to be expected in a broad deposit made in rising water. If made in lowering level, such a wide plain, with decline of 80 feet would demand very slow change in water level, with the production of deserted bars of wave construction, or cliffs of wave erosion. Close-set bars are the common feature on shores of relatively falling water, like the splendid series of bars on the Iroquois shore between Richland and Adams Center. The subordinate bars or swells on the flanks of the main ridge on the southern shore of Iroquois, (see plates 2, 3) were formed as off-shore bars, similar to those now forming along the shore of Lake Ontario, and lay in water less than 20 or 25 feet in depth.

The early plains of the lower Iroquois are indicated on the map by oblique-line convention. On account of the land uplift being



LOWER IROQUOIS PLAINS, IN IRONDEQUOIT

Upper view, looking west from west edge of Durand-Eastman Park

Lower view, looking north over sewage disposal plant greatest in direction 20° east of north the present, uplifted, altitude of the early deposits falls off to the west and rises toward the east. The approximate present height of the early water surface is given in the tabulation, figure 7, line, "H." The surfaces of the sandplains are below these figures, as the plains were not built up to the water level.

The remarkable sand plain in Irondequoit town, lying between the Genesee River and Irondequoit Bay, now deeply dissected by the numerous small streams flowing lakeward, has long been recognized as the delta of Genesee River built in Lake Iroquois. The deposit is finely laminated sand or clayey sand (silts), indicating quiet waters, which must therefore have been deep enough to escape vigorous wave action. Any earlier and coarser detritus is buried under the later and finer sediment. This delta plain is now so eroded that people often speak of the area as "hilly," but it is a district of "valleys," excavated in a plain. The summits of the ridges between the hollows are flat-topped and uniform in height east-west, as may be well seen anywhere in the Durand-Eastman Park. It is not correct to term the valley-slopes "hills." (See plate 12).

The surface of the Irondequoit delta plain rises from about 340 feet near Lake Ontario to 420 feet along the north flank of the Ridge Road gravel ridge. The greater mass of this delta plain must have been accumulated during the earlier portion of Iroquois time. The river then had its heaviest burden of detritus, for the reason that the land surface with its sheet of loose glacial drift was then freshly exposed, with no protective mantle of vegetation as in later time; moreover the river was then excavating its valley in the soft lake deposits, and a considerable part of the Rochester Canyon was then being cut but subsequently flooded by the rising lake waters. Some contribution to the plain, in diminishing amount, must have been made during all Iroquois time, as the volume of the river and wind-produced currents were sufficient to carry fine, suspended silt far out in the lake. But such fine material was not large in relative amount, and the coarser material as sand and gravel that was pushed along by the river was probably brushed shoreward by the deeper wave work and now constitutes the massive beach ridge.

A pertinent question is, why the delta plain is so much more extensive east of the river than on the west? In brief the reply is that it was the effect of prevailing westerly wind and the volume of suspended detritus. This involves some meteorology, and a fuller explanation is needed. As wind directions in this latitude are chiefly controlled by the passage of cyclones the most effective winds are from the west and northwest, following the storms; and this is when the river is running muddy. Today when the river is muddy the discoloration of Lake Ontario is much more often to the eastward. The great atmospheric currents were doubtless the same in the Glacial Period that they are at present. During the life of Lake Iroquois the suspended silt were mostly swept eastward. The fine texture of the upper silts may be observed in any excavation in the Park or at Sea Breeze.

The frontal portion of the delta plain appears to have been partially destroyed, for the southward curvature or concavity of the shore between Summerville and Forest Lawn is probably due in part to wave-erosion of the finer and weaker marginal deposits.

Early Iroquois Deposits East and West of the Rochester District

Plate 2.

In the belt of country between the Iroquois beach (Ridge Road) and the shore of Ontario,—the "Niagara-Genesee prairie,"—is a peculiar relation of surface deposits which is now explainable. The farmers have long recognized three soil belts in this plain. Immediately north of the Ridge Road, after the beach sands are passed, is a smooth belt, about a mile wide, of thin, hard, heavy, stony soil, often with rock near the surface. Beyond this belt of poor farming land is a belt of varying width of level sands, which near the stronger streams are conspicuous plains. This is recognized as an orchard or peach belt. Northward to Lake Ontario is the stretch of general farming, where the soils are chiefly glacial drift or till, with rolling or irregular surface.

The explanations of this belted country is now clear. The northern belt of drift soils with good agricultural quality was under such depth of Iroquois water as to be little affected by either wave-work or deposition of detritus. Here there is little evidence of

HIGHER IROQUOIS FEATURES, BY ALLEN CREEK

Upper view, Iroquois shore-cliff, by Linden Road

Lower view, later Iroquois plain, on north side of Corbett's Glen, 420 feet standing water. The sand belt includes the deltas of the streams which poured into the early and lowest Iroquois, when the streams had their heaviest load of detritus. In other words this belt represents the primitive level of Iroquois which received the contribution of the copious primitive drainage. With the rise of water level, due to the lifting of the Rome outlet, the delta sands were submerged and protected. The belt facing the Ridge Road was smoothed by wave erosion and transportation of the rising waters.

During the early stage of the Iroquois waters the wave-work was relatively weak, because the waters were newly imposed on an irregular land surface where the waves and shore currents were impeded; and the ice front on the north was near, giving only a narrow belt of open and shallow water. With longer life the rising waters overcame these inhibiting conditions; the glacier front had receded northward, and the wave work had levelled the drift knolls and straightened the shoreline. The wave-smoothed belt adjacent to the Ridge has a vertical range of 40 to 60 feet. Over this stretch the effective wave work, always landward, in the steadily rising water, continuously swept the bottom and pushed the sandy detritus southward as a migrating beach and finally left it in the massive gravel and sand ridge of the Ridge Road.

These sandy plains of the intermediate belt of the Niagara-Genesee "prairie" may be observed along the larger creeks. We may note; on Johnson Creek at North Ridgeway; on Oak Orchard Creek at Kenyonville and Waterport; on Sandy Creek at Kendall Mills. Three-fourths of a mile south of Kendall Center the sands form a belt less than a mile wide. In general the sandy plain may be found along the contour of about 360 feet; and better developed along the streams.

The "Newfane" beaches (31) in Niagara County, towns of Wilson, Newfane and Somerset, at altitude 360 feet or higher, represent intermediate levels in the rising Iroquois.

Eastward from Irondequoit Bay the belt of sands is not so distinct, because the area of northward drainage is small and the stream deposits less in volume; but the sands are recognized southeast of Forest Lawn; north of Webster; at Lakeside; at Furnaceville; between Pultneyville and Williamson; north of Sodus; and in the low ground south of Sodus Bay. The north border of the eastern belt is theoretically about 340 north of Webster, rising to 370 or 380 at Wolcott.

In the wide depression of Sodus Bay, reaching south to Clyde, are the most extensive Iroquois flats, shown as the white spaces in the map, plate 3. These silted plains are mostly 400 feet, and thus far below the summit Iroquois. The spreading and smoothing of the materials must have been by the wave action of the early or middle stages of the lake.

Later Iroquois Plains

Detrital plains built up to near the surface level in the higher stand, and during the closing phase of Iroquois, are prominent only in two deep embayments of the lake, the Irondequoit and the Sodus valleys. As the rising waters abandoned the deposits of the earlier stage, leaving them submerged and thus protected, the wave work swept most of the coarser detritus southward into the summit beach ridge, as noted above. But in the secluded embayments of shallow yet quiet water the inflowing streams built plains at near the water surface. In the Irondequoit valley the contributing streams were Irondequoit Creek, Allen Creek, Thomas Creek and other small streams. The summit plain has its most southerly point a mile northwest of Bushnell Basin, this being about the area of Mr. A. M. Stewart's farm. The altitude is about 425 feet. The layer of cemented gravel, about two feet thick, exposed by excavation in the north end of the esker, by the Palmyra road crossing of the electric railway, appears to have been an effect related to the Iroquois lake surface.

There is no definite northern limit of the higher plain, as it shades into the the extensive plain outlined by the 400 feet contour both sides of the Irondequoit Valley. This widespread sandplain is the most important and interesting topographic feature in the valley. Its altitude by the Ridge Road is 400 feet, and is there 35–40 feet inferior to the closing level of the lake. Southward the plain rises to 420 feet at East Rochester (Despatch). It should be noted that while the land has received a northward uptilt of toward two feet per mile since Iroquois time yet the plain declines northward. Evidently its original northward decline was more than at present. As the wave-base, or the depth reached by wave

G. H. Chadwick, Photo.

THE ROCHESTER CANYON

View looking south, upstream, toward the city. The river at level of Lake Ontario, 246 feet agitation, could not have been over 20 or 25 feet, it appears that the portions of the plain either side of the bay do not represent much accumulation by the higher waters but must be credited to the earlier stages. East and southeast of Brighton the plain is higher, and the delta of Allen Creek, at 420 feet, was about the water level. The village of Penfield stands partly on the summit plain, the corners, at 429 feet by the map, being about the waters edge. In a generalized way the features are indicated on the map, plate 2. The limitation between earlier and later Iroquois deposits, shown in the conventions of the map, is somewhat arbitrary.

South of the bay and Float Bridge road the valley was entirely filled up to the 400 feet level. The proof of this is found in the flat-topped remnants of the plain, now out in the midst of the eroded valley, but constructed of horizontally-bedded fine silts.

The complex history of the Irondequoit Valley and its deposits has been described with more fullness by Professor Chadwick in a former paper by this society, and the reader is referred to that writing, number 32 of the appended list.

Glacial Features

The purpose and plan of this paper do not cover the whole of the glacial history nor include the phenomena produced directly by the glacier itself. But two classes of features, the drumlins and moraines, are so prominent on the map that a brief description may by appropriate.

Drumlins.—The Palymra-Clyde district, plate 3, is the heart of the most remarkable drumlin area in the world. These singular oval hills are not rock but compact till. They were built up and shaped beneath the ice sheet by the transporting and rubbing action of the ice itself. They are heapings of the subglacial and englacial drift. The drumlins of western New York have been described and the mechanics of their origin discussed in a former article.*

At Sodus village and eastward the map shows how the waves of the later Iroquois beat against the drumlins along the north border of the drumlin belt, producing a line of wave-cut cliffs and correlating wave-built gravel bars. This line of cliffs and bars was not

* In the Bulletin of the New York State Museum, No. 111, 1907; also in the Bulletin, Geol. Soc. Amer., vol. 17, pp. 702–706.

the actual shore of the lake, for the waters penetrated between the hills over the lowlands; extended up the old Dawson outlet channel as far as Newark; and reached southward over the Montezuma plains into the Cayuga Valley.

Moraines. While the drumlins are subglacial, having been constructed under several hundred feet of ice, and therefore some miles back from the glacier margin, the moraines were laid at the ice margin in the open air. On the map, plate 2, the prominent moraines are the Pinnacle Hills; the Mendon Ponds area; and in the upper Irondequoit valley, from Bushnell Basin to Fishers. The remarkable group of high hills between Fairport and Victor, the so-called Turk and Baker hills, appear to be partly drumlin, partly moraine. If they have any rock core it has not been found.

All these moraines are largely gravel and sand, the product of glacial stream outwash. Technically the gravel knolls are termed kames, and these masses of terminal or peripheral drift are termed kame-moraine.

The Mendon kames are very striking, and with the two partly-buried eskers (33) form a most interesting geologic feature. A westward extension of the Mendon kame-moraine is found in the scattered drift, giving irregular surface, between the Mendon knolls and the Genesee River. The 20-feet interval between the map contours does not properly recognize or show the morainal surface.

The most interesting moraine to Rochester people is the range of hills along the southern part of the city, known as the Pinnacle Hills. As a definite, bold range it extends from Brighton to the Genesee River, and an extension of the terminal moraine belt occurs west of the river, along Brooks Avenue and south of Lincoln Park, reaching past Churchville and Holley to Albion. The moraine is properly called the Albion-Rochester moraine. It marks a line of readvanced position of the oscillating ice front, during the waning of the glacier and the general recession of the ice margin. The moraine has been partially described in two former articles, numbers 12 and 25.

A complication in the glacial lake history of the Rochester district is registered in the structure of the Pinnacle Hills. The lower portion or base of the hills, up to or over 600 feet, is horizontal sands. This base was laid in standing water higher than Lake

Dawson and earlier. This implies that either the Fairport pass was yet closed by the ice sheet or that the waters were held up by ice-front control in the Syracuse district.

When the lower or basal portion of the hills was laid the ice front was backed away, northward, some small distance. But the higher materials of the hills are largely till, or ice-laid, which proves the later presence of the glacier front, and therefore a re-advance of the ice front. In places, as south of Brighton along the Winton Road, the till charged with a multitude of large bowlders may be seen capping the fine, horizontal sands. The latter in some sections, like the cut at South Clinton Street, has been so pushed, mashed and kneeded by the overriding ice as to show none of its originad bedded structure. We have here positive evidence of some oscillation of the ice front; a backing away, by melting, of the edge of the ice sheet to some uncertain, but probably small, distance north of the line of the hills; deposition of fine sands, from the glacial outwash, in the waters leaving the ice front; then re-advance of the ice, with overriding of the lake deposits. Blocks of local limestone, plucked from the Rochester plain, are seen on the very top of the Pinnacle, having been lifted over 240 feet. Evidently the ice front then stood at the readvanced position for some time, permitting the piling of the hills of gravel at the mouths of the streams emerging from the glacier. Such oscillation of the glacier margin is thought to characterize the waning stage of continental glaciers.

The structure of the Pinnacle Hills, their position, and their peculiar relation to the general topography of the region, suggest a complication in the history of the Rochester region which needs further study.

As the only heights giving commanding views of Rochester City, and with the unusual character and geologic history, the whole Pinnacle Range should have been incorporated in the city's park system, and so preserved for the scenic and educational value. Fortunately most of the higher parts are now so occupied as to be preserved from destruction, but the highest point, the "Pinnacle" is yet outside the city and not secure. Some interesting sections have been destroyed for their gravel and others graded for building lots. The "Pinnacle" especially, should be made a public park for the people of all the future.

Kettles. The singular basins or bowls, called "kettles" in geologic parlance, are impossible effects of surface drainage and are attributed to late melting of buried ice blocks. Detached or isolated masses of the stagnant ice margin became so buried in the drift that they sometimes persisted for centuries or even thousands of years, outlasting the waters which may have covered their sites. When the ice blocks did finally melt the slumping of the drift cover and surrounding materials produced the depressions. They are handsomely represented in the Pinnacle range; in Reservoir Park; between South Clinton Street and Goodman Street; and especially in Mount Hope Cemetery. The Mendon kame area and the district of Bushnell Basin show even more and larger kettles. The reader is referred to papers 13, 16 and 28.

Eskers. These are singular ridges of gravel which were accumulated in the beds of rivers flowing beneath the glacier. The nearest one to Rochester is the bold, high gravel ridge two miles southeast of Pittsford which the electric railroad skirts on the east side. They are perhaps the most peculiar and anomalous features produced by glaciation. Those of western New York have been well described and mapped by Professor Giles in a paper by the Academy, number 33 in the following list.

Gilbert's Story of Niagara

The first geologist to appreciate the complexity of the Pleistocene history of the Ontario basin was Grove Karl Gilbert.* As early

* By birth and education Mr. Gilbert belonged to Rochester. His father was the eminent portrait painter, Grove S. Gilbert. In 1862 he graduated from the University of Rochester, after which for five years he assisted Henry A. Ward in the Ward Museum. The Ward Collections in Geology, which became the Museum of the University, bear his pen work on many thousands of the labels. After two years on the Ohio Geological Survey he was, from 1871, continuously attached to the national geologic survey until his death, May 1, 1918. He was universally recognized as one of the great geologists of the world. A brief memoir was printed in Volume 5 of these Proceedings, pages 251–259. More extended memoirs, with bibliography, will be published in the Bulletin of the Geological Society of America, and in the Proceedings of the National Academy of Sciences.

When the American Association for the Advancement of Science held its annual meeting in Rochester, in 1892, Mr. Gilbert was selected by the Rochester Academy of Science to give the public lecture complimentary to to the Association. The model of "Coon Butte" (now the Meteor Crater) which he used in illustration on that occasion, is in the University Museum. The University gave him the degree of LL.D. in 1898.

as 1885 he recognized the three factors; (a), the damming effect of the waning glacier and the glacial-lake character of the earlier waters; (b), the succession of water levels due to opening of different outlets or places of escape for the impounded waters by the recession of the glacier front; and (c), the dislocation and canting of the water planes by the tilting uplift of the land. In 1890 his important and very interesting paper was published which is here listed as number 2 of the bibliography. This writing had special reference to the history of the Niagara River; but Niagara is a sister of the Genesee, and their histories are comparable in all essential elements; while the receiving water-levels were identical.

It is thought desirable to reproduce here one of Mr. Gilbert's diagrams and some parts of his description. The presentation of the essential facts in his clear diction will help the reader to grasp the complex geologic history. While his quantitative data are not precise (and were not meant to be exact) they are very good considering his work as a pioneer.

"The waves of the new-born Lake Ontario (Iroquois) at once began to carve about its margin a record of its existence. That record is wonderfully clear, and the special training of the geologist has not been necessary to the recognition of its import. The earliest books of travel in Western New York describe the Ridge Road, and tell us that the ridge of sand and gravel which it follows was even then recognized by all residents as an ancient beach of the lake. In the Province of Ontario the beach was examined and described by the great English geologist, Charles Lyell, during his celebrated journey in America, and afterward received more careful study by Mr. Sandford Fleming, and by the geologists of the Canadian Survey. In western New York it was traced out by the great American geologist, James Hall, during his survey of the geology of the fourth district of the State. Within a few years more attention has been given to detail. Professor J. W. Spencer has traced the line continuously from the head of the lake at Hamilton past Toronto, Windsor and Grafton to the vicinity of Belleville, beyond which point it is hard to follow. South of the lake, I myself have traced it from Hamilton to Queenston and Lewiston; thence to Rochester, and all about the eastern end of the basin to Watertown, beyond which point it is again difficult to trace. Southeast of the present margin of Lake Ontario there was a great bay, extending as far south as Cayuga Lake, and including the basin of Oneida lake, and it was from this bay that the discharge took place, the precise point of overflow being the present site of the city of Rome. For this predecessor of Lake Ontario Professor Spencer has proposed the name of Iroquois." (2, pages 67–68).

"The Ontario basin has been subjected to a very notable change of attitude, and the effect of this change has been to throw the ancient shore-line out of level. When the shore-line was wrought by the waves, all parts of it must have lain in the same horizontal plane, and had there been no change in the attitude of the basin, every point of the shore-line line would now be found at the level of the old outlet at Rome. Instead of this, we find that the old gravel spit near Toronto—the Davenport ridge—is forty feet higher than the contemporaneous gravel spit on which Lewiston is built; and at Belleville, Ontario, the old shore is 200 feet higher than at Rochester, N. Y.; At Watertown 300 feet higher than at Syracuse; and the lowest point, in Hamilton, at the head of the lake, is 325 feet lower than the highest point near Watertown. From these and other measurements we learn that the Ontario basin with its new attitude inclines more to the south and west than with the old attitude.

The point of discharge remained at Rome as long as the ice was crowded against the northern side of the Adirondack mountains, but eventually there came a time when the water escaped eastward between the ice and the mountain slope.

* * * * * * * * *

An attempt has been made in Pl. III., to exhibit diagramatically the relations of ice dams and basin attitudes to one another and to the river. (Niagara). The various elements are projected, with exaggeration of heights, on a vertical plane running a little west of south, or parallel to the direction of greatest inclination of old water-planes. At N is represented the Niagara escarp-

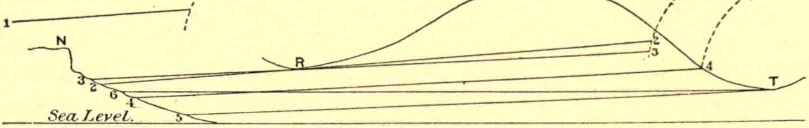


PLATE III.—Diagram to illustrate the relations of Water Levels in the Ontario Basin to attitudes of the land and to outlets.

FIGURE 15. *Gilbert's Diagram of Tilted Water Planes*

ment and the associated slope of the lake basin; At A the Adirondack mountains. R and T are the passes at Rome and at the Thousand Islands. Successive positions of the front are marked at I^1, I^2 and I^3. The straight line numbered 1 represents the level of lake water previous to the origin of the Niagara river; 2 gives the first position of the water level after the establishment of the Rome outlet; and the level gradually shifted to 3; 4 is the first of the series of temporary water levels when the water escaped between the mountain slope and the ice front; 5 represents the first position of the water level after the occupation of the Thousand Island outlet; and 6, the present level of Lake Ontario." (pages 68–70).

* * * * * * * * *

"It is easy to see that these various changes contribute to modify the history of the Niagara river. In the beginning, when the cataract was at Lewiston, the margin of Lake Ontario, instead of being seven miles away as now, was only one or two miles distant, and the level of the water was about seventy-five feet higher than at present. The outlet of the lake was at Rome, and while it there continued, there was a progressive change in the attitude of the land, causing the lake to rise at the mouth of the Niagara until it was 125 feet higher than now. It fairly washed the foot of the cliff at Queenstown and Lewiston. Then came a time when the lake fell suddenly through a vertical distance of 250 feet and its shore retreated to a position now submerged. Numerous minor oscillations were caused by successive shiftings of the point of discharge, and by progressive changes in the attitude of the land, until finally the present outlet was acquired, at which time the Niagara river had its greatest length. It then encroached five miles on the modern domain of Lake Ontario, and began a delta where now the lead-line runs out thirty fathoms.

While the level of discharge was lower than now, the river had different powers as an eroding agent. The rocks underlying the low plain along the margin of the lake are very soft, and where a river flows across yielding rocks, the depth to which it erodes is limited chiefly by the level of its point of discharge. So when the point of discharge of the Niagara river—the surface of the lake to which it flowed—was from 100 to 200 feet lower than now, the river carved a channel far deeper than it could now carve. When afterward the rise of land in the vicinity of the outlet carried the water gradually up to its present position in the basin, this channel was partly filled by sand and other debris brought by the current; but it was not completely filled, and its remarkable present depth is one of the surviving witnesses of the shifting drama of the Ontario. Near Fort Niagara twelve fathoms of water are shown on the charts." (pages 70–71).

Note.—The writer makes grateful acknowledgment of assistance from many friends; especially from Professor George H. Chadwick for helpful criticism and suggestion, and to Dr. E. B. Angell, Cogswell Bentley, Ralph Boardman, W. H. Boardman and J. Foster Warner for transportation in the field study.

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