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OF THE

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DRUMLINS

Upper view, one mile south of Lincoln, Wayne county. Looking south of west.
Lower view, three miles north of Walworth. Looking east of north.

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PROCEEDINGS OF THE ROCHESTER ACADEMY OF SCIENCE
VOL. 7, PP. 1-37 PLATES 1-20 OCTOBER, 1929

NEW YORK DRUMLINS

By Herman L. Fairchild

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Foreword

The singular hills of glacial origin which we now call drumlins were noted by James Hall in his report of 1843 on the geology of the Fourth New York District. Sir James Hall of England had referred to the English forms as early as 1815. They came under active study in Europe in 1864, and in America from about 1878.

Previous to 1907 considerable literature on the subject had accumulated, but there had been no comprehensive publication in description and explanation. And owing to considerable variation in the characters and relations of the hills, as seen by geologists in different regions, the question of their origin or manner of construction was yet under debate.

In the year 1907 the writer published a detailed description of the west-central New York drumlins, richly illustrated, as Bulletin 111 of the New York State Museum. Because the State has the finest group of drumlins in the world, exhibiting the greatest range in all of their features, that paper was the most comprehensive and conclusive on the subject. Moreover it was the only writing which proved from observed features the subglacial construction of the hills, and discussed the complex mechanics of their upbuilding.

Unfortunately that Bulletin 111 was in limited edition, and with scanty distribution, and in a short time was "out of print." Because of this condition it appears desirable to publish the present writing, and in the proceedings of a scientific society which has particular interest in the earth features of western and central New York. No apology is made for making large use or even repetition of matter in the former paper, and with regrets that it is not feasible to reproduce the elegant three-color maps.

General Characters; Terminology

Drumlins are the most massive, singular and interesting of all the varied products of glacial agency. In their occurrence, attitude and relation, form and structure they are not only the most remarkable of ice-sheet deposits but in their size, convex surfaces and graceful outlines they are the most striking of the drift-forms; and perhaps the most beautiful of all earth-forms of moderate size.

Previous to the discovery of continental glaciation these hills were the greatest geologic enigma. There composition, like that of moraines and the veneer of till, classed them with the "drift," the mass

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DRUMLINS

Upper, between Sennett and Skaneateles Junction. Looking north of east.
Lower, west of Skaneateles Junction. Looking west.

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of heterogeneous earth-stuff then supposed to have been drifted down from arctic regions by overwhelming yet mysterious cataclysism of polar waters. And when glacial science arose, much less than a century ago, these mounds and ridges were confidently cited as fatal to the glacial theory. They were inconsistent with the assumed leveling and planing effect of a sliding ice-sheet. And even down to the year 1906 the mechanics of their construction was in doubt.

The glacial genesis of drumlins is evident. They occur only in glaciated territory and their composition, at least in New York, is compact till or "ground-moraine."

The conspicuous superficial characters of drumlins are the smooth surfaces, convex profiles, and their axial direction parallel with the ice-flow direction of the locality. Their topographic expression is so distinctive that they are readily detected on topographic maps having the contours with a vertical interval of 20 feet. (See plates 3, 5–7.)

Their molded forms attest the overriding effect of the ice-sheet, while their internal structure proves that they were built up from the bottom by a plastering-on process. Their relation to moraines, described below, indicates that they were built and shaped under the relatively thin border of the continental glacier, in the peripheral zone where the transporting energy of the ice-sheet had become incompetent to carry any farther its heavy load of rock-rubbish borne in the lower strata of the ice, the "subglacial" drift.

Definition of drumlins must be in rather general terms because of their varying characters. They are smoothed-surface hills of till, built and shaped by the overriding action of an ice-sheet, and elongated in the direction of ice movement. More tersely, they are smooth, convex masses of drift, built and shaped beneath an ice-sheet.

Terminology. Previous to 1884 various names for the drift hills were used by different geologists, suggestive of the form and relations. Some of these names were parallel ridges; lenticular, mammillary and elliptical hills; parallel drift hills; whalebacks and sowbacks.

In 1877 James Geikie used the term "drum," celtic for hill or ridge. The name "drumlin," diminutive for drum, was applied by H. M. Close in 1866 for the units in a large and very interesting

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group in northern Ireland; and the name was given greater publicity in a paper by Kinahan and Close in 1872. Professor W. M. Davis, who has introduced many very useful names in earth-science, first made use in America, in 1884, of the term drumlin, since which time it has universal usage.

Occurrence in General

As these masses of drift were accumulated beneath the continental ice-sheets it might naturally be expected that they would be of universal, or at least of very general, occurrence. But such is not the fact. Over vast areas of glaciated territory they are entirely wanting. They are not reported from Ohio, Indiana, Illinois, Minnesota, the Dakotas, southern Michigan and Iowa. They are at least very infrequent in other states.

Some forms interpreted as drumlins have been noted in southern Canada, Nova Scotia and in the western provinces.

The drumlins of Ireland are the type forms, which are similar in all essential features to the New York forms. They occur also in Scotland and England; and a large group in northern Germany.

In the United States there are three large districts of drumlin development. The New England area includes southern New Hampshire, with toward 700 examples; Massachusetts, with 1,800; and a southward extension into Connecticut. The Wisconsin-Michigan area was estimated by Chamberlin to hold 5,000 drumlins. The third and largest area is the subject of this writing.

The apparently capricious distribution of drumlins in the glaciated territory of Europe and America was one cause of the uncertainty and debate regarding their origin. However, when it is recognized that the typical or well developed drumlins and drumlin ridges are only the most emphatic of a variety of forms produced by the rubbing effect of the ground-contact ice under horizontal thrust (see page 29); and that on the one hand these forms shade off into indefinite flutings or moldings of the drift, and on the other hand are represented by scoured or rounded rock hills (rocdrumlins) (see page 25) it is probable that this class of glacial phenomena is more widely distributed than has been supposed. But the requisite conditions for production of typical drumlins were not commonly fulfilled, as great areas of glaciated lands seem never to have been subjected to the drumlinizing effect of the ground-contact ice.

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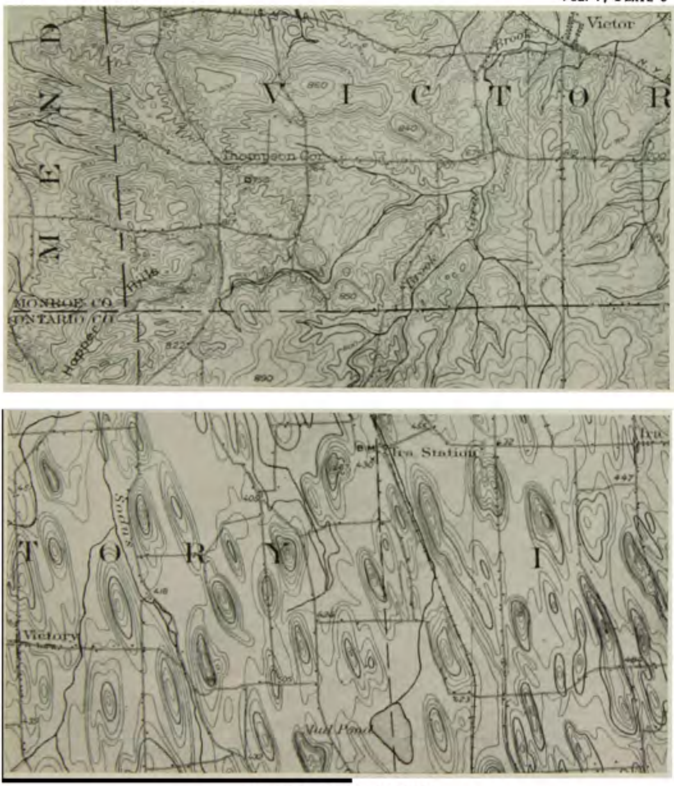

GLACIAL TOPOGRAPHY
Upper, moraine. Part of Canandaigua sheet.
Lower, drumlins. Part of Weedsport sheet.

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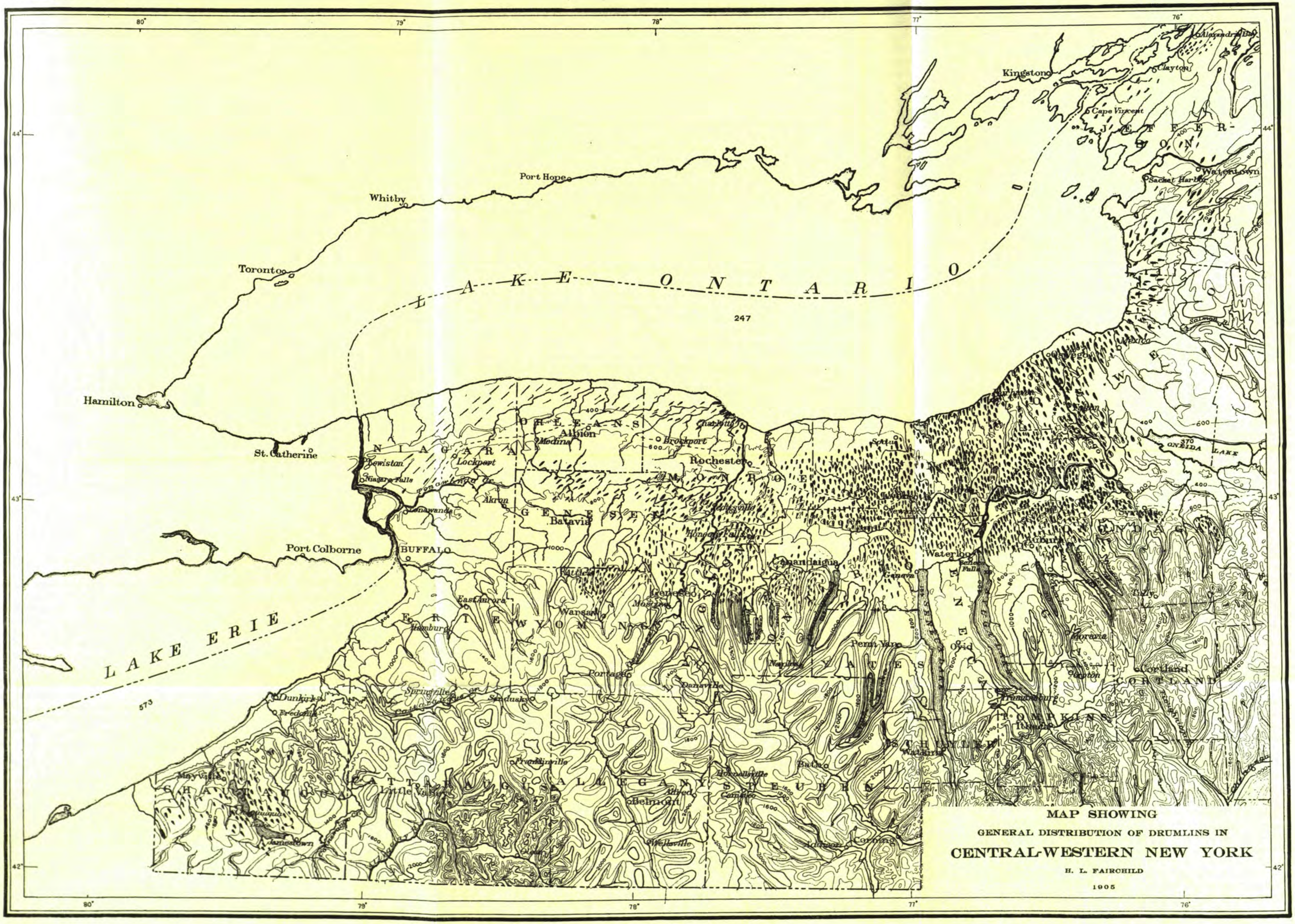

DISTRIBUTION AND ORIENTATION OF THE NEW YORK DRUMLINS

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Display in New York

Favoring Conditions. The drumlins of western and central New York form the largest group in the world, and with their varied characters and relations are the most remarkable and instructive.

It is recognized that no single group or area is likely to illustrate all possible features pertaining to these drift forms; but this New York field includes such a great variety in form, attitude and relationship that they fully exemplify this class of glacial phenomena and clearly reveal the manner of their making.

The great development of the New York drumlins was due to the conjunction of favoring conditions, as (1), character of the rock strata in supplying an abundance of pasty till; (2), topography of the Ontario basin and lowland; (3), deployment of the ice body, as controlled by the land surface; and (4), thrust-movement of the ground-contact ice. These factors will be discussed below.

Distribution; Area. The map, plate 4, shows fairly the location of the drumlins and also their relative abundance. The topography of the map is not reliable.

The principal area is the Ontario field, a belt about 35 miles wide bordering the south side of Lake Ontario; with an east-west extent, from Syracuse to the Niagara River, of about 140 miles. At least half of this territory, or about 2,500 square miles, carries many thousands of typical drumlins.

The field of greatest development may be defined as the low ground of the Ontario plain north of the Finger Lakes, and reaching southward on the flank of the north-facing slope of the highland. Between Honeoye and Canandaigua lakes they lie as high as 1,700 feet elevation.

The heart of this drumlin area is shown in plate 5, which includes the Palmyra and Clyde quadrangles of the New York topographic map.

A somewhat distinct group of drumlins borders the Ontario shore, eastward from Sodus Bay. The eastward extension of this field swings around the east end of the lake, as a belt five to ten miles wide, reaching past Watertown into the St. Lawrence valley. These have peculiarities of attitude and form to be described later. They are shown on the Pulaski, Sacketts Harbor and Watertown sheets.

The main drumlin field extends westward in well-defined forms to beyond the meridian of Batavia, the termination being shown on the Batavia and Attica sheets.

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Another drumlin field of remarkable character lies west of the Genesee River and bordering the Ontario shore, where the waters of Lake Iroquois were too deep for effective erosion. On the Niagara-Genesee prairie in Orleans and Niagara counties these drift forms become elongated ridges, fading out southwestward, in the direction of the ice flow, as faint and invisible swells of the till veneer. This drumlinized fluting of the land surface has given northeastward direction to the streams of the district, which singularly are flowing oblique to the general slope of the land. This feature is shown in plate 4, and by the topographic sheets bordering Lake Ontario.

In the southwest corner of the State a group of handsome drumlins surrounds Chautauqua lake. These point southeast, having been formed by the deployment in that direction of the lingering ice body in the Erie basin. Their genesis and history are distinct from those of the great Ontario display.

A small group stands about the north end of Cazenovia lake, some 12 miles southeast of Syracuse. See plate 4.

Numeration. This New York area probably includes over 10,000 drumlin crests, of which on a conservative estimate at least 6,000 are indicated on the topographic sheets. Where they are close set from 20 to 35 can be counted in a square of four square miles. Five drumlins to the square mile is common. Three to the mile is not more than the average, counting large and small, and on the 2,500 square miles of strong drumlin topography this would give 7,500 examples. Estimates have been made by counting the distinct drumlin summits or crests indicated by the contour lines in certain districts and using the figures for larger areas, with a result giving about 5,000 crests for the fifteen topographic sheets that cover the best parts of the drumlin area. On the 216 square miles of the Palmyra quadrangle (plate 5) the estimated number of crests was 800, but the actual count gave 955. Great number of minor ridges are beneath the recognition of the 20-feet contours, but are conspicuous to the field observer.

Boundaries. A clear distinction must be drawn between the natural or original limits of drumlinizing work and the induced boundaries produced by erosional effects of river and lake. A glance at plates 4, 5, 6 and 17 will show sharp northern boundaries, and passageways more or less distinct across the larger field. The northern limits have been produced by wave erosion of the glacial Lake Iro-

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THE HEART OF THE DRUMLIN AREA

Palmyra and Clyde quadrangles. Shore features of Lake Iroquois in the upper part of the map. Channels and deltas of glacial drainage in lower part of map. Amount of land uplift, in feet, since glacial time is shown by the lines of equal rise (isobases). Other numerals give the present height above ocean.

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quois and the existing Lake Ontario. The breaks are partly due to eastward flow of rivers of the copious glacial drainage. (For the latter see Bulletin 127 of the New York State Museum.) The subject of drumlin erosion will be treated later.

The southern limits of the drumlin groups are original or constructive, and of course somewhat indefinite. On higher ground the drumlins disappear as scattered mounds in the bolder relief of the rock hills. On low ground they fade off as smooth flutings in the drift sheet (see page 16), and in one stretch clearly correlate with a frontal moraine (plate 13 and page 21).

Southeastward the main drumlin field terminates in a tongue or point at Syracuse, with the detached Cazenovia group twelve miles further. The maps show no drumlins north and northeast of Syracuse, over the Oneida lake depression, nor on the high ground south of the Syracuse district. This extension of the drumlins as a tongue in an otherwise barren territory becomes yet more striking if the Cazenovia group is included in the work of the Syracuse ice lobe.

East of Syracuse, at Fayetteville, Canastota and Oneida, the soft Salina shales, which compose the irregular ground surface, exhibit no effect of ice-rubbing and carry only just enough drift to prove the former presence of the ice-sheet. The topography is easily mistaken for morainal, but is really due to atmospheric erosion.

Further description of the natural borders of the drumlinized drift surface would be of slight value to the reader. But the study of the topographic sheets with reference to drumlin forms will be found very interesting. And precise mapping in the field would be fine exercise in the discrimination of land forms and the interpretation of geologic processes. Very interesting surface relief is not expressed by the map contours with only 20-feet vertical relief.

Erosion Features. Plates 6–8, 14–16, show that the waves of Lake Ontario are dissecting the heavy drumlins which happen to stand at the water level. Of course the incoherent drift composing the drumlins cannot stand up against storm waves like solid rock.

Similar destructive wave-work was done by the great glacial lakes that preceded Ontario (See *Geologic Story of the Genesee,* Rochester, 1928.) Along the straightened, mature shore of Lake Iroquois, extending from Niagara River to Sodus Bay (plate 5), no drumlin was able to survive the wave erosion; although they survived where immersed in more than 30 or 40 feet of water; and also in the region toward Syracuse where the lake was shallow.

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At Sodus village the Iroquois beach, the "Ridge Road," is an erosion cliff in strong drumlins. Eastward the Iroquois shore with less maturity curves southward around Sodus Bay, but yet marks a north limit of close-set drumlins. The villages along this border are South Sodus, Wayne Center, Rose and West Butler; the line passing two miles southeast of Wolcott (plates 4, 5).

South and east from Sodus Bay, over the Montezuma and Oneida lowlands, groups of drumlins stood as islands in the Iroquois waters, and are notched more or less at the ends. To the observant traveller between Rochester and Syracuse the statement that the longitudinal drumlin profile is always convex seems untrue, because decided concave notching may occasionally be seen on both north and south ends. But these are erosional features, due to Iroquois wave action (See plate 9). They are most evident between Clyde and Savannah.

Passing northward in the Sodus embayment, into what had been deeper waters of Lake Iroquois, a group of drumlins appears which is abruptly terminated by the present Ontario beach. It is probable that the Ontario waters hide drumlins in their depths. The series of heavy drumlins that are opposing the waves all the way from Sodus to Oswego suggest that other northern members of the group are submerged. However, these drowned members had been subjected to wave erosion in the lower levels of Lake Ontario, because the lake level has risen from zero to its present elevation of 246 feet over ocean. And previous to Ontario the long-lived Gilbert Gulf, sealevel waters, occupied the basin.

Of the series of glacial lakes which bathed the receding front of the ice-sheet Lake Dana had such elevation and relation to the drumlins as to produce conspicuous erosion features. In the east-west belt between Honeoye Falls and Caledonia the tall drumlins stood as small islands in the Dana waters, and are notched at 700 feet elevation. The Rider Hill, at Industry, is a good example. Similar, and even clearer, examples are the high drumlins on the Albion quadrangle, seven miles north of Batavia in the town of Elba, east and northeast of East Oakfield. These were severely wave-cut and the debris was swept into gravel bars and spits, similar to the Iroquois features between Lyons and Syracuse.

The glacial Lake Warren, predecessor of Dana, left conspicuous wave work, especially south and east of East Avon. An eroded

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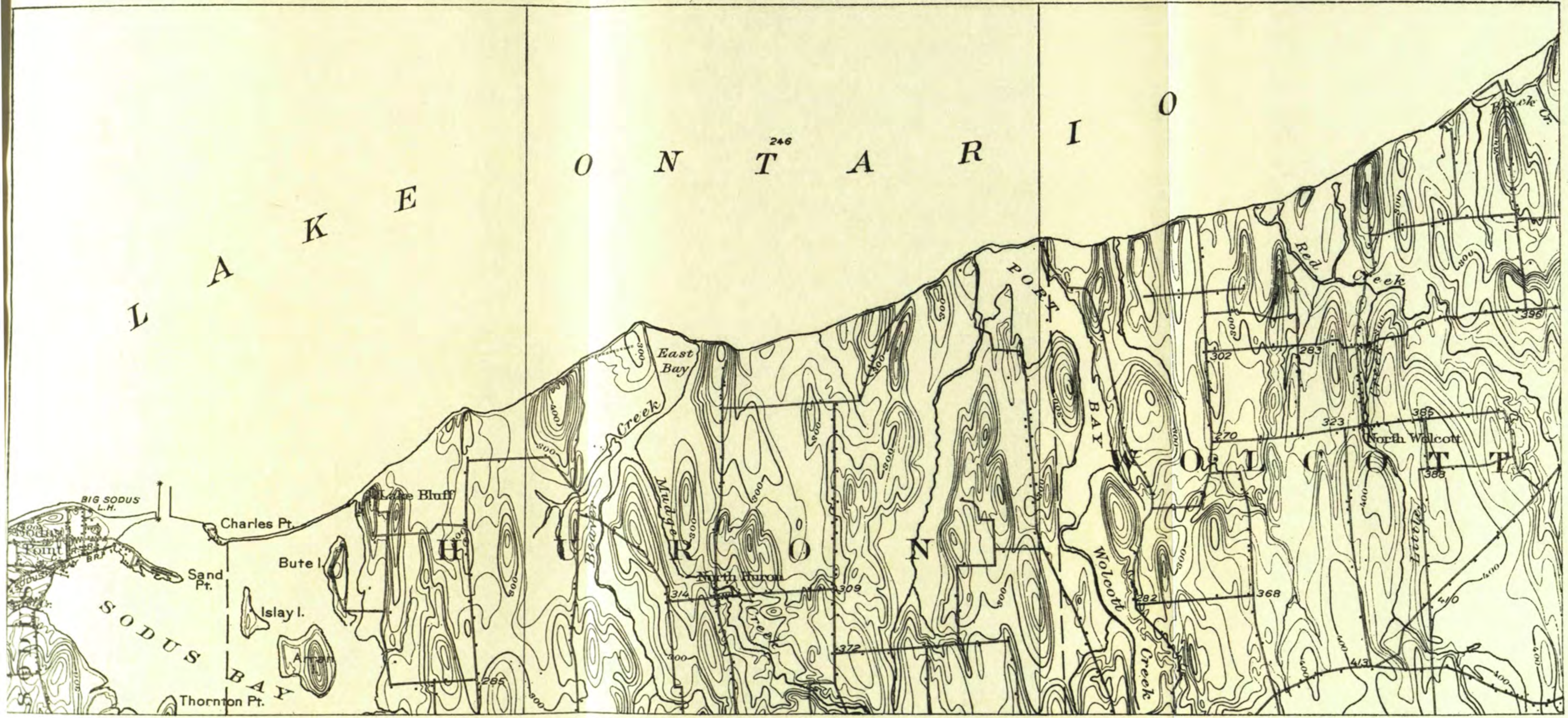

DRUMLINS ALONG THE SHORE OF LAKE ONTARIO
Sodus Bay sheet. Scale: one inch equals one mile.

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drumlin a mile south of East Avon has heavy gravel bars curving from both north and south ends, at 880 feet above tide.

Some drumlins exhibit vertical grooves, furrows and ridges running up and down their side slopes. These are regarded as erosional, due to atmospheric effects, especially stormwash. The rubbing and shaping effect of the ice in horizontal movement could not produce vertical irregularities.

In some cases the erosion on the side slopes has gnawed into the summit so as to produce a wavy or irregular crest line.

These erosion forms will be mentioned in a later chapter on the forms of the drumlins.

Subdivisions; Time Relation. The great drumlin field (plate 4) comprises some divisions with differences in time of their formation. The hills were built beneath the waning ice-sheet, and the complex dynamic conditions necessary for their production were migrating northward, along with the receding ice border. It is apparent that the extreme southern hills were constructed before the northern.

Considering both position and age the first series appears to be the group which may be named the Attica-Geneva, or the western Finger lakes series. These forms lie on higher ground, between the Tonawanda valley and Seneca lake.

The second, the main group, stretches from Oakfield eastward to the Oswego river. This includes the heart of the drumlin field (plate 5) with the most striking topography of close-set drumlins.

A third and late series includes the hills which border Lake Ontario eastward from Sodus. This we may call the Ontario series.

In the Genesee valley the first series blends with the second, the main group. And it is possible that the outlying drumlins at Syracuse and Cazenovia were formed contemporary with the first series.

The drumlinizing of the Niagara-Genesee prairie, in Orleans and Niagara counties, was perhaps contemporary with the second or main series.

The Chautauqua group, constructed by the Erian ice body, certainly antedates all the forms in western and central New York.

Attitude; Orientation. In its maximum development the Quebec ice cap had over central and western New York a flow direction west of south, or about southwest. At that time it was not influenced by the land relief. But in the thinning of the ice-sheet there came a phase when, as a plastic solid, its movement was affected by the

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larger relief or the gross topography of the overridden land. With the waning of the border and thinner ice its flow was more and more directed by the inequalities of the land surface.

The drumlins are the best criteria for the later ice-flow direction. The long axes of the drumlins indicate the direction of the latest vigorous movement of the ice-sheet in their locality. The variant directions of the drumlins throughout the whole field prove a radial or spreading flow of the ice body that filled the Ontario basin during the stage of its waning that is represented by the drumlin formation.

The attitude of the drumlins with reference to compass direction varies according to their position in the area. The angular directions of their longer axes cover nearly a half circle. In the district east of Lake Ontario they point east, that is they were shaped by a movement of the ice from the west. As we pass westward around the south side of Ontario we find the direction gradually shifting to southeast, then to south, and finally in the western part of the field to southwest. And on the Niagara-Genesee prairie, in the northwest corner of the state, the direction is even more westerly. This radial attitude is well shown by the map, plate 4.

The consonance of the drumlin attitude to the latest ice flow is strikingly confirmed by study of the drumlins in the outlying districts. The Chautauqua hills point southeast, with the spreading flow of the Erian lobe of the melting ice-sheet. On the other hand, the drumlins of the Watertown district point southwest, conforming to the latest flow of the thinning ice in the St. Lawrence valley.

Another interesting fact in this connection is that the axial direction is not always uniform along the same meridian. If the topographic control over ice movement changed with the varying latitude of the ice front, as the latter was receding, the drumlins record that fact. For example, twenty miles south of Rochester the ice margin was guided by the deep Conesus, Hemlock and Honeoye valleys, and the drumlins lie north and south. But on the same meridian, six to twelve miles south of the city the drumlins point to the southwest. The ice flow was then controlled by the broad Genesee valley and the thrust was from the northeast. This also indicates the relation in age.

The radial or spreading flow of the ice-sheet at any single stage must be found by comparison of the drumlin directions within a single series of forms, that is, drumlins which were built simultane-

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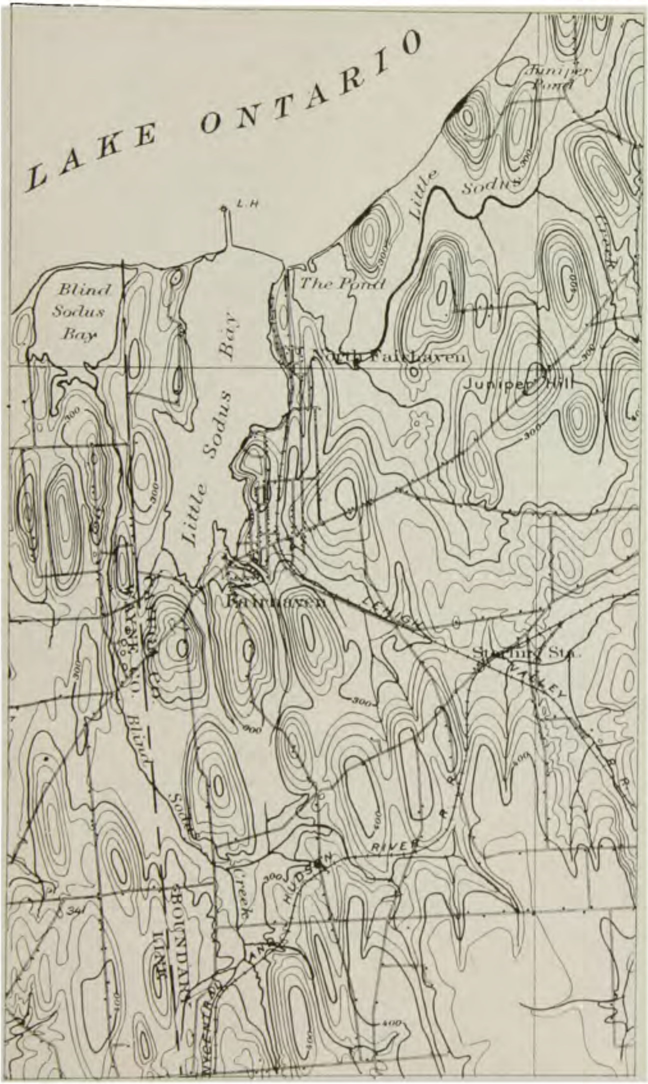

MASSIVE DRUMLINS

About Fairhaven (Little Sodus) Bay. Part of Oswego sheet.
Scale: one inch equals one mile.

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ously. This is so evident on the map that specific description is unnecessary.

The genetic relation between ice-flow direction and the attitudes of the drumlins finds singular confirmation in the district east of Lake Ontario, already noted. Passing eastward around the corner of the lake (Mexico Bay) we find that the drumlin axes veer from southeast to east. Passing on north some 10 miles, to Ellisburg and Belleville, we see the drumlins pointing southwest, nearly opposed in direction to the forms at Oswego and Mexico.

These opposing directions represent ice-flow movements during different stages of the same body of ice. The ice-sheet did not entirely disappear and then return in different direction. While the Ontarian lobe yet covered the Mexico Bay district the radial flow produced the forms pointing southeast at Oswego and east at Sandy Creek. But during a final stage of the glacier in the same region a thrust of the ice lobe from the St. Lawrence valley produced the southwest-pointing forms between Ellisburg and Watertown.

Recognizing that if the southeast-pointing forms were made by an earlier flow of the same waning ice body that produced the later southwest-directed forms, then somewhere between the two opposing forms the drumlinized drift should indicate a turning, swinging or pivotal motion of the ice; and such is found. Seen in the field the drumlins of the Pulaski district show peculiarities of form which the map contours do not suggest and which appeared inconsistent and puzzling. From whatever direction we may view some of these hills the convex drumlin form appears. In some cases one detects a faint but distinct molding of the hill in direction highly inclined to the main mass. Sometimes an irregular surface which has been regarded as morainal becomes equivocal, or even clearly ice-molded, with a change in the point of view.

An important fact which has a bearing on the origin of drumlins and the mechanics of their construction must be noted. The secondary or contrawise forms just noted do not seem to have been made by cutting or carving of the primary forms, but to have been produced by the addition or plastering-on of material during the later molding. The work was constructional not erosional.

A singular form of drumlin is found in the district south and southwest of Rochester. This suggests one drumlin superposed on another; a sort of two-story drumlin. The feature is related to the present topic of orientation. Examples are seen in the Hosmer hill,

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four miles northwest of Scottsville (Plate 10); Cushman hill, two and one-half miles northwest of Scottsville; and Martin hill, one mile east of West Rush.

Some of the concave slopes on these "double-deckers" may coincide with the Lake Dana level, and it is possible that they have been accentuated by wave erosion. But the molding is found at other levels, and the surfaces have the characters of ice-molding. The lines are out of horizontality and erosional phenomena are wanting. The explanation is found, it is thought, in a slight change in the direction of the ice movement during the construction process. Such change in the ice-flow direction was apparently due to the directive influence of the wide Genesee valley on the thinning ice-sheet. The later flow was changed from west of south to south and east of south.

A suggestion that the superposed drumlins might be the product of a second ice invasion, or of a large readvance of the ice front, appears to be ruled out by the fact that the peculiar feature is found only in the northern portion of the Genesee valley, where it widens out into the Ontario plain.

Relation to the Land Surface. A glance at the map, plate 4, shows that the general drumlin area covers ground of all altitudes from the level of Lake Ontario (and perhaps in the depths of Ontario) up to about 1,700 feet, west of Canandaigua Lake. West of the Seneca valley they reach up to high ground, 1,100 to 1,500 feet. In the low north and south depression of the Seneca and Cayuga valleys, where we might expect them to be well developed, they are weak or absent above 500 or 600 feet.

While scattering drumlins in poor form may occur between the eastern members of the Finger lakes it appears that the area of close-set and well developed forms does not reach south on the high ground east of Seneca Lake; but that extensions of the field do reach up on the high ground west of Seneca Lake, and as far west as the Tonawanda valley.

The greatest development of the drumlins is on the low ground north of the Finger Lakes, and chiefly under 500 feet altitude. This great development on the low Ontario plain, and their comparative absence on the higher ground which faced the ice-sheet, is most striking in the central and eastern part of the drumlin belt.

This distribution of the drumlins indicates that altitude and gross-

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DISSECTION OF DRUMLIN

Undercutting by storm waves of Lake Ontario. Chimney Bluff, four miles east of Sodus Point. Looking southeast.

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er topography were not the only controlling factors in the drumlin formation. The direction of ice-flow was another important factor.

The dominant topographic feature was, and yet is, the wide and deep Ontario basin. Previous to the epoch of drumlin formation this feature had little influence on the glacier movement. The ice over New York was then subject to a push or thrust-movement from the northeast by the central mass of the Quebec ice-cap. However, during the drumlin phase the push from the northeast had ceased, and the Ontario lobe of the glacier had been left as a semi-stagnant body of ice, which as a plastic solid spread by its own weight and deployed over the Ontario lowland and its borders. The effects have been described in the preceding chapter.

The valleys of the Finger Lakes were carved in Preglacial, Tertiary, time by a remarkable series of parallel rivers which flowed northward to join a great master river, the Ontarian, in the bottom of the west-leading Ontario valley. As shown in plate 11 the northern sections of all these ancient valleys are now filled with drift and entirely obliterated. The basins produced by the northern blockade now hold the series of parallel Finger lakes.

The belt of "open valleys," plate 11, with small amount of drift on the slopes, suggests that the deeper ice in the valleys had been comparatively stagnant, and served as a bridge over which the upper ice rafted its load of drift and piled it into the "valley-heads" moraine. Later the ice-sheet thinned and its front backed away, northward, without leaving conspicuous drift masses either as moraine or drumlin. But the abundant drift held in the deeper ice was used to fill the northern portions of the ancient valleys, and then to heap the drumlins on the plain.

As stated above the land surface east of Syracuse did not feel the rubbing effect of the ice-sheet. The Syracuse district was subjected to the thrust of a tongue of ice which pushed southeastward from the spreading Ontarian mass. The southward and southeastward flow did not affect the land surface in the Oneida lake region, nor over the high ground east of the Seneca valley.

Relation to the Rock Strata. The glacial stuff built into the drumlins was mostly derived from the exposed or outcropping strata adjacent on the north. Exceptions will be noted below.

The central area of the drumlin field is the low ground north of the belt of limestones, known as Helderberg and Onondaga. Beneath these limestones, and extending northward down under Lake

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Ontario, the very thick strata are chiefly shales, with some Niagaran limestone and Medina sandstone. It is estimated that of the total thickness of some 3,700 feet over 3,100 feet are shale. Through millions of years of exposure in Preglacial time with atmospheric weathering the old land surface had acquired a mantle of residual clay. This became the first grist of the glacial mill. All of the thick rock strata have a southward downslope, or dip, which gave the outcrops a northward projection, opposing the impact of the ice movement. The abrasion of the bed rock, after the removal of the decay product, produced a second grist of clayey material.

It is probable that the bulk of the rock-rubbish in the drumlin area was not carried far away from its source by the bottom ice, but on the contrary was plastered into the drumlin hills. The thick shale and limestone rocks supplied a load of unusually clayey and adhesive drift. It is quite certain that the plastic and adhesive character of the subglacial drift was an important factor in the upbuilding of the massive, close-set drumlins.

The occasional occurrence of numbers of far-traveled bowlders in some of the drumlins, crystalline rocks from the western Adirondacks and from Canada, qualifies the conditions stated above and emphasizes the complexity of the glacial history. A fine example of the occurrence of foreign bowlders was found in the Ely drumlin, on the eastern edge of the city of Rochester. In 1928 the cutting for a street, Hurstbourne Road, across the crest of the handsome drumlin exposed large numbers of huge bowlders of crystalline rocks of various kinds derived from far northeast. Their well rounded forms and smoothed surfaces attest severe abrasion during their long journey, and this implies grinding pressure under great depth of ice. But these far-journeyed bowlders occur chiefly at or near the surface of the drumlins. Some of the coarse subglacial material of the northeast highlands had been rafted into the district and incorporated with the bottom drift of the thinning ice-sheet.

Form; Dimensions. The characteristic form of the New York drumlins is that of an elongated oval, with the length three to five times the breadth. This shape prevails in the crowded areas (plate 5), and also in the detached and scattered hills. Apparently this dolphin-back form is typical and normal for all drumlins wherever found, when the mechanical factors involved in their construction were normally balanced.

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WAVE-ERODED DRUMLIN

Two miles west of Savannah; looking east. The south end is deeply cut by the wave-work of Lake Ontario. The farm residence and orchard are on the shelf, north of the road.

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All the outlines or profiles of typical drumlins are convex. The lengthwise profile is an elegant, convex curve, characteristically more abrupt or steeper at the north end. The south ends, except of the steeper ovals and domes, normally taper off into the mantle of till, unless eroded by waves or other agency..

The crest line of the longer ridges is commonly a straight line, which may appear as true as if cut to a straightedge. In cross-section the variation in profile for single and typical drumlins is more limited than in longitudinal section. The summits naturally have a symmetric curve. But in close-set or crowded areas the drumlins have a common habit of coalescing or uniting by growth, and a cross-section may show two or three or perhaps more ridges. Not infrequently this welding of ridges produces quite irregular masses (plate 6). The Mormon Hill, four miles south of Palmyra is such example.

The blending of drumlin ridges is generally from a position of overlapping, as they usually lie in eschelon. Sometimes they build side by side in even ranks.

The junction of the convex drumlin with the horizontal ground surface naturally gives a concave slope at the drumlin base. Above this basal concavity all drumlin surfaces are normally convex, and departures from convexity are due to some interference or to some subsequent effect. As noted above two or more drumlins may overlap or coalesce so as to produce irregular or unusual forms. Morainal drift is frequently banked against the sides or bases of the drumlins so as to rarely change the true drumlin form. Erosion by the waters of glacial outflow may have cut the slopes and even the crests, but decided crest cutting by glacial flow is rare in New York. Vertical ridging or ribbing of the slopes is thought to be positively erosional, either by glacial waters or by postglacial storm wash and weathering. On the other hand, longitudinal fluting or molding is regarded as a constructional effect of the drumlin-making process.

With few exceptions the drumlins are cleared of timber and their surfaces are under cultivation, as they afford excellent soils. Some minor irregularities of surface may be subdued by farm cultivation, but when the atmospheric elements contributing to their erosion are considered it is surprising that they are so well preserved. In the great majority of cases the original form is preserved with little change.

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The type of drumlin form least displayed in New York is the dome shaped or mammillary. Judging from the topographic sheets the group which most nearly approaches the dome lies about Fairhaven bay, partly shown in plate 7.

The most common variation in New York from the normal type is in the way of elongation. Long ovals and even-crested ridges are characteristic. They are well shown on the Clyde (plate 5), Auburn, Oswego and Brockport sheets. Quite extreme examples are shown in plate 12.

The most extreme forms in elongation are the slender, attenuated flutings which are too small to be represented on the maps. Plate 13 is the best mapping. This form will be described below.

It is an important fact that the several variations from the normal drumlin form are not intermingled, but are grouped distinct. Certain areas display only a particular form. For example, the type form with moderate elongation is seen in plates 5, 6; rounded masses in plate 7; very long ridges in plate 12; and attenuated ridges in plate 13. It is evident that some definite unbalancing of the several mechanical factors results in the production of a particular form.

The very extreme form of elongated ridges is so unlike the typical drumlin that it deserves a different name. It is a fluting or ribbing of the drift surface, a "wash-board" structure. Existing apart from true drumlins this drift form would not be recognized as of the same genesis. The term "drumlinized" has been given by the writer to this product of the sliding ice-sheet. On first thought it might appear that this fluting of a broad till surface was the more natural effect than the heaping of the drift into oval hills. And it is probable that this structure may be found in wide areas where typical drumlins do not occur.

We can discriminate three varieties of the drumlinized surfaces. The larger form includes the broad, low rolls which may not be recognized by the map contouring. They have been partially described on page 6. These low, broad moldings of the till mantle are the common and only form produced by the rubbing of the ice-sheet over most of the surface of the Niagara-Genesee prairie. Passing westward by railroad or highway the change can be seen from quite typical long drumlins near the Genesee river to the long swells of low relief. When not indicated by the topographic maps they may be recognized by the transverse, shallow cuts for the railroad grade. Westward these rolls gradually fade into gentle undulations of the

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SUPERPOSED DRUMLIN

Hosmer Hill, three and one-half miles northwest of Scottsville. Looking southeast. The superior or superposed ridge is wholly in the maple grove.

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surface, quite imperceptible except by the up and down grades of the railroad. Large areas appear quite flat to the eye.

This northeast by southwest fluting of the land has directed the postglacial stream flow in a wide belt south of Lake Ontario, as noted above. The fluting is well developed southwest of Alden and west and southwest of Buffalo over the lower and smoother plain. The contouring on the Erie county sheets, Attica, Depew, Buffalo and other quadrangles to the south, fail to indicate the drumlinizing of the land surface.

Of the smaller drumlinized form there are two varieties. One of these has been described, page 16, and is suggested on plate 13. The other form is a subordinate, secondary or parasitic fluting. This structure is displayed in the Lyons, Clyde, Savannah district, where the primary drumlins carry on their slopes, and in the intervening hollows, a secondary or minor order of ridges. These are very straight, parallel, close-set, and often not larger than a small railway embankment. They are difficult subjects for photography and no picture is here included. But they are conspicuous from any highway in the district.

These intermediate, and attenuated ridges clearly prove the molding effect of the moving ice and its drumlin-forming tendency, even in the hollows between the primary structures. The major and minor ridges taken together suggest comparison with a piece of wood molding struck by the planer. And the comparison is closer if we take the long drumlins which carry longitudinal ribbing along their sides and bases. It is perfectly evident that this longitudinal molding of the drift structures was constructive, and a part of the general process of drumlin building.

The size and dimensions of the drumlins are variable, within limits, according to the quantity and quality of the drift carried in the lower ice and the depth and movement of the ice-sheet.

There appears to be a limit to the height of individual drumlins. In New York this limit is about 200 feet. Using the map contours for determining the altitudes of the bases and summits (an inexact method, with maximum error of 40 feet) only one drumlin has been found with height over 200 feet. At some elevation the upbuilding process is antagonized by the eroding and leveling effect, and a balance is struck between the two opposing factors which limits extreme height, and results, apparently, in the production of multiple ridges of moderate size instead of one huge ridge. This principle

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appears to be illustrated in the shape of the peculiar island groups in the Syracuse region, described later.

The most conspicuous drumlins, striking because of their isolation, like those rising out of the Montezuma marshes, are not the highest.

Using the map contours, as noted above, for approximate data, along with precise figures given by the map for some higher drumlins, following are figures for a few of the highest hills. A longer list is given in Bulletin 111, N. Y. State Museum.

	FEET
On the Rochester meridian.	
Rider hill, at Industry	180
Palmyra meridian.	
Pigeon hill, 2½ miles northwest of Marion	185
Sodus meridian.	
Zurich hill, 5 miles south of Sodus	200
Baker hill, 6 miles south of Sodus	220
Clyde meridian.	
Chimney hill, 1 mile northwest of Rose	180
Triangulation station, hill 2½ miles south of Clyde	180
Fairhaven meridian.	
Hill 4 miles southeast of Montezuma	180
Oswego-Auburn meridian.	
Three hills, each	180

An interesting fact is that the prevailing maximum height of 180 feet is the same as of the type drumlins in north Ireland.

The length of drumlins is as variable as their height. It cannot be closely determined from the map contours, as a relief of less than 20 feet may carry a distinct ridge for a long distance. Scores of drumlins can be found on the maps with a contoured length of a mile or more. A length of one and one-half miles is not rare, but two miles is extreme for a typical drumlin. The close welding of overlapping ridges may give great length. Perhaps the longest well contoured forms are in the Oswego district, plate 12.

The drumlinized flutings in the northwest part of the state, described above, may have unit length of several miles, but have not been measured.

Composition. The drumlins are composed of very compact till and represent the subglacial or "ground-moraine" drift. The material is decidedly harder and more compact, especially the deeper layers, than the ordinary till mantle. The included stones of all

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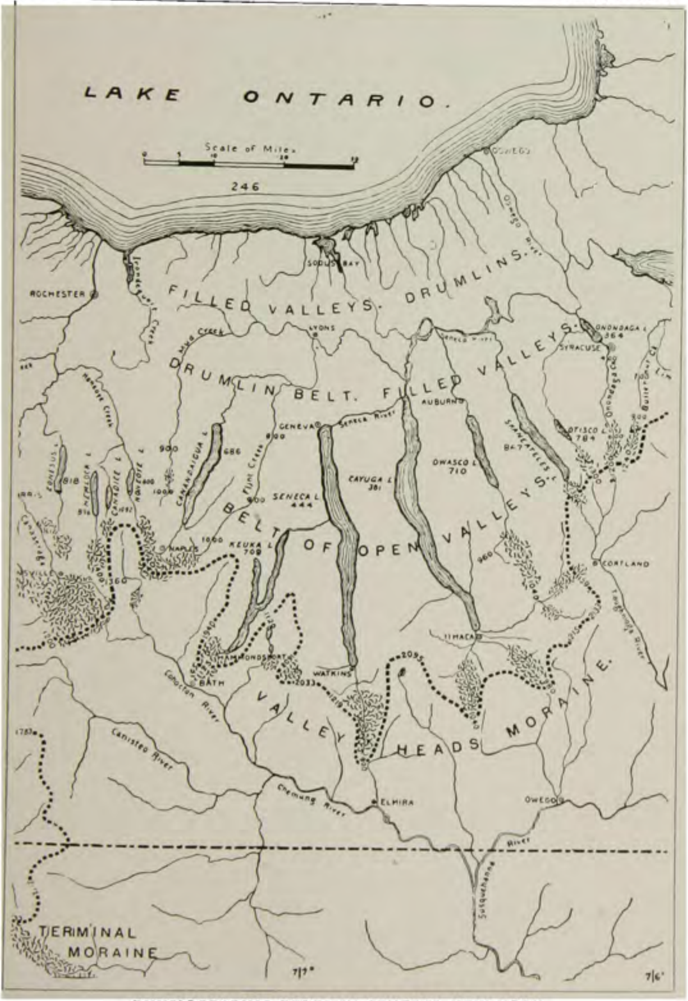

PHYSIOGRAPHIC BELTS IN CENTRAL NEW YORK

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sizes are very commonly abraded or glaciated. All the characters of the drumlin till indicate movement under pressure. The material is emphatically the grist of the glacial mill.

The occurrence of water-laid drift, sand or silt, within the drumlin body is very rare. In extended examination of the internal structure only two cases were found of sand layers in the interior of drumlins, exposed by erosion on the shore of Lake Ontario. Some cuttings made by the electric railway between Rochester and Syracuse showed sand and sandy till as occasional upper beds.

As the drumlins were built under the thinner border of the ice-sheet it would seem very probable that streams on the surface of the glacier might sometimes carry sand down through crevices; and the sand become buried in the subsequent growth of the drumlin. The chances of such inclusion would increase as the thickness of the ice diminished.

The rarity of included water-borne material in the New York drumlins is conclusive evidence against the old supposition that they had been produced by overriding and reshaping of older moraine drift masses. In New York the moraines are largely water-laid materials, while the drumlins are hard till. It may be possible that in some other region of drumlin occurrence they might be produced by overriding of moraine drift during considerable readvance of an ice front. The relation of the New York drumlins to moraines will be noted later.

Water-laid materials on the surfaces of drumlins is to be expected, as the deposit of glacial stream work and of the subsequent glacial lakes. Most of the New York drumlin area was buried in standing water after the ice was removed.

As the ice melted away over the drumlins it sometimes left marginal or morainal drift on and among the drumlins. Rarely this might be so abundant as to partially bury or obscure the smaller drumlin forms. Such a case is found in the Junius kame-moraine, midway between Geneva and Lyons. However, such superficial morainal drift must not be mistaken for nor confused with the drumlin material. It is not only emphatically distinct in its genesis from the subglacial drumlin substance but subsequent in its deposition.

The proportion of far-brought and crystalline rocks is theoretically less in drumlins than in terminal moraine deposits. In any belt it probably will be found that the proportion of drift derived from the subjacent strata, or from the rocks immediately northward, is

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larger in drumlins than in the moraines; for the reason that the drumlins are built beneath the ice-sheet, of the subglacial or ground-moraine rock-rubbish.

However, the far-traveled bowlders sometimes occur in large numbers in the capping layers of drumlins (see page 14).

In some districts in central New York the base of the drumlins and perhaps large portion of the mass is soft shale rock. This is discussed below under the topic of Rocdrumlins.

Structure; Concentric Bedding. If the drumlins are constructional, or built up by a plastering-on process, then it must be expected that on a cross-section they would reveal some bedding or onion-peel structure, with the upper layers parallel to the drumlin surface. Theoretically such stratification would not be conspicuous, as variation in the building process would not be great as compared with the work of water, in either kind and quality of material or in the rate of deposition. The comparative steadiness in the action of the glacier taken in connection with the heterogeneous character of the material would seem unfavorable to the production of any very conspicuous bedding.

Artificial cuttings in drumlins do not expose large sectional areas, and these can usually be seen only at close range, which is not favorable for inspection of indefinite and large-scale structures.

Fortunately for this study Nature has assisted. We have a splendid exposure of the interior structure of drumlins along the south shore of Lake Ontario, specially between Sodus Bay and Oswego. In this stretch of about 28 miles not less than a score of drumlins, many of large size, are dissected to the core, sliced from top to bottom, by the wave erosion. The constant undercutting by storm waves yields continually fresh sections, and fortunately in different directions. Some of the drumlins are cut in direct cross-section; some in oblique section; and some quite longitudinally.

The erosion cliffs vary in height from 20 feet up to 140 feet. The growth of vegetation rarely is enough to obscure the structure, but in some cases is a proof of bedding in the till, as it lies in zones. The higher cliffs are bare. (See plates 14–16.)

A majority of the cliffs show undoubted concentric bedding, and in several it is surprisingly distinct. Unfortunately, some lines of bedding which appear to the eye are not recorded in the photographs. At distances which minimize the irregularities of the cliff faces, in salients, reentrants, amphitheaters and monuments, the

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ELONGATED DRUMLINS

Part of the Fulton sheet. On the north the drumlins are overlapped by moraine deposit. Scale: one inch equals one mile.

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fact of bedding parallel with the drumlin surface is strikingly evident, and is shown by different features. Even at close range a difference in the texture of the beds is evident. Distinct lines or zones of bowlders are frequent. Some difference in shade of color is common, and such color difference due to varying capacity for moisture is pronounced. The latter is also shown by patches of vegetation clinging along certain lines.

A striking proof of stratification is the differences in weathering, indicated, as in plate 16, by uniformity in elevation on the cliff face of irregular weathering and conical buttresses.

In cross-section view the concentric bedding decreases in convexity passing downward toward the base of the drumlin. Near the base the bedding is nearly horizontal, and the arching increases toward the top. A good test and confirmation of the concentric structure is found in the oblique and the nearly longitudinal sections. The stratification exposed in these different sections has directions that pertain to concentric structure. The application of these facts of drumlin structure to the problem of drumlin origin will be considered in a later chapter.

To aid the study of the subject by any one who wishes to examine the drumlins personally the following notes are given. West of Sodus Bay (Pultneyville sheet) the cliffs are partly morainal and only two good drumlin sections occur, one of them shown in plate 16.

East of Sodus Bay the lake shore and the dissected drumlins are mapped in plates 6 and 7. The dissections which displayed the bedded structure in the clearest manner at the time when plates 15–17 were made, in 1905, are in order eastward, using local names; Lake bluff, by Sodus Bay; Cline's bluff, one mile east; Blind Bay bluff, one mile west of Port bay (plate 16) ; two cliffs either side of Juniper pond, three miles east of Fairhaven (Little Sodus) bay.

It should be understood that the distinctness of the structures in the drumlin till will vary with the degree of moisture in the surface, and with the illumination. Probably the appearance of the cliff sections may change with deeper cutting, and so vary as time passes.

Relation to Moraines. If the drumlins represent vigorous movement of the ground-contact ice during episodes of either advance of the ice front or halts in its rescession then each drumlin belt should correlate with a line of frontal moraine. Such relationship appears definite for the main drumlin field, north of the Finger lakes. Where the drumlins fade out to attenuated ridges, from

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Geneva westward to Auburn, a distinct belt of moraine drift lies two or three miles in front, on the south. This, the Waterloo moraine, is well shown in plate 13.

Morainic belts, like the weak Waterloo moraine, represent only the superglacial and higher englacial drift, carried to and passively dropped at the extreme margin, while at the same time the drumlins were forming beneath the ice-sheet in the rear of the moraine, from the subglacial and the lower englacial drift.

Theoretically the moraines should be weak in front of heavy drumlins, and in central New York the facts are in accord. But there is another reason. During the drumlin-making epoch the ice-sheet in central New York was faced by deep lakes. These were held up by the ice itself acting as a dam on the north. The drift in the terminus of the ice-sheet was dispersed by flotation of the ice and by the waves and currents of the lakes.

While definite lines of moraine are lacking a few kame-areas are strong. At the termination of the rivers which drained the melting ice-sheet very heavy deposits of water-laid drift was piled into kame-moraine hills, as the Mendon, Victor and Junius.

During rescession episodes of the ice front, by increased melting or diminished thrustal movement, the drift in the ice was quietly lowered on the drumlin territory. Not infrequently we may find a patch of irregular surface among the drumlins which can readily be discriminated and mapped as moraine. Rarely this may obscure the half buried drumlins.

Sometimes the volume of morainal drift increases northward so as to give decided moraine topography, as in the Walworth district in Wayne county. Plate 12 shows how a subsequent land-laid moraine laps on the north limit of the latest drumlins.

Island-like Groups. These remarkable masses are partly illustrated in plates 17, 18. They occur in the main drumlin area, in the belt from Lyons eastward to Syracuse. They are partly bounded by river channels cut in soft Salina shales by the latest glacial drainage. North of Warners, plate 17, is an example of such drumlin massing not wholly surrounded by channels or open spaces.

One peculiar feature of most of these masses is an increase of height toward the center, which gives them an individuality or unity. If these drumlin masses have a core of rock reaching above the Salina shale, which forms their base or pediment up to about 500 feet in the more easterly groups (plate 17), it has not been found. But

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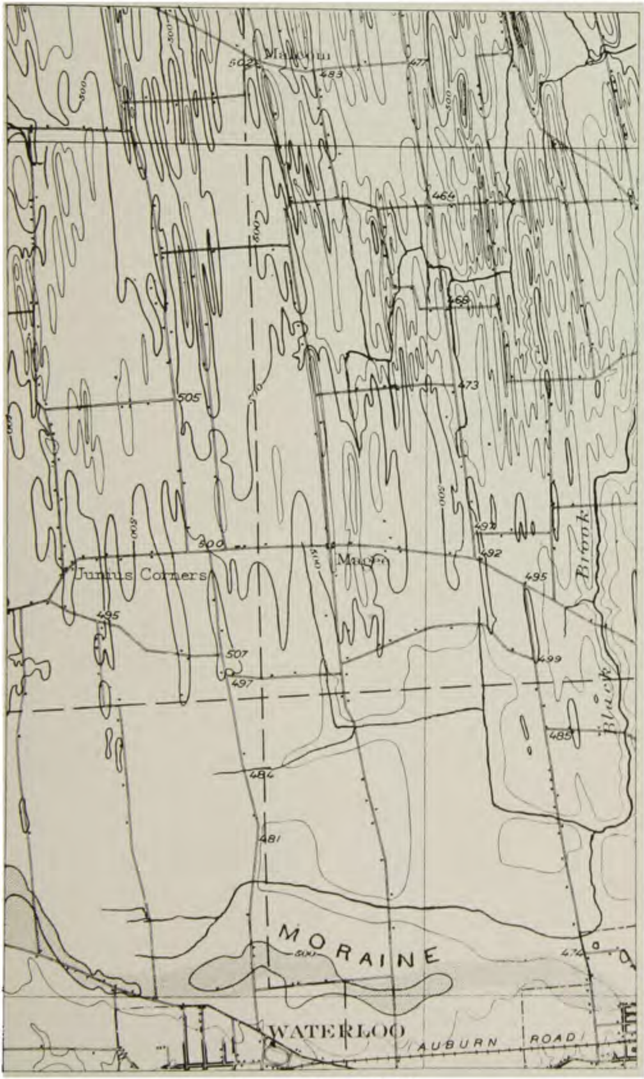

ATTENUATED DRUMLINS

South edge of the drumlin belt, with the correlating moraine. Parts of the Clyde and Geneva sheets. Extensive fluting of the drift is not shown by the 20-feet contours. Scale: one inch equals one mile.

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such rock core is not improbable for the more northerly groups.

Plate 18 shows the largest of several groups of drumlins which rise out of the marshes north of Cayuga lake. These are not so conical or cumulative as those eastward (plate 17), but are isolated groups of irregular form and size, even down to individual drumlins. In the Montezuma district these rise out of the broad marshes as if half drowned.

However, it does not seem probable that the absence of drumlins over wide tracts could be due to entire burial of the hills under lake and vegetal accumulations. More likely the low marsh areas are destitute of drumlins for the same obscure reason as others at higher levels. This leads to the next topic.

Non-Drumlin Spaces. An important fact, not previously noted in this writing, is that the drumlin area of central New York was from 270 to 290 feet lower during the period of glacial occupation and drumlin construction than it is now. The lines of equal post-glacial uplift (isobases) are drawn on plate 5. This depressed condition of the land continued during the earlier phase of Lake Iroquois.

Another element in the very complex history relates to the north and south depression from Sodus bay to Seneca lake. It is believed that in preglacial time the Susquehanna river turned north at Waverly-Elmira and occupied the Seneca-Sodus valley. It was the largest of the north-flowing rivers described on page 13. The ancient valley of the Susqueseneca river is indicated faintly in the low north and south tract west of Clyde (plate 5).

Another element in the history is the fact that all of the area from Lyons east to Syracuse was under the water of Lake Iroquois.

The lack of drumlins in the bare spaces shown in plates 4, 5 and 18 appears to be involved in the geologic conditions just stated. Wave erosion by Lake Iroquois was not responsible, although such erosion did remove the drumlins north of the Iroquois shore, shown in plate 5.

Apparently the lack of drumlins north and northwest of Clyde is due partly to non-construction and perhaps in some degree to burial under Iroquois deposits. The weak drumlins two to three miles northwest of Clyde suggest the tops of half-buried hills.

The open spaces of the lower ground, illustrated in plate 18, lie in the region of deep drift-filling of ancient valleys, the northward continuation of those now holding the Finger lakes, chiefly in the

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north and south depression of the Sodus embayment and the Seneca and Cayuga valleys.

Many suggestions in explanation of the drumlin-bare spaces are ruled out. We have to recognize the probable equality in both the drumlin and the non-drumlin tracts of the depth and pressure ot the ice; of its impact and rate of movement; and of its burden of drift. The inequality in the drumlin construction probably relates to unequal conditions in the land surfaces.

In the areas of deep valley-filling perhaps some depressions were yet below the average level, and consequently beneath the plane of vigorous thrust movement. In such case a plane of shearing might have been established over the depressions. With shearing action the initiation of drumlins would be discouraged, as they imply some obstruction or some degree of local drag in the bottom ice. The occurrence of drumlins within or along the open spaces might be due to casual obstructions, while the shearing process prevented creation of new obstructions.

The lowest of the open spaces have been partly filled with post-glacial lake silts, stream detritus and vegetal accumulation. And the very lowest are yet partly under water.

Open Channels. The channels or water courses with more or less direct eastward direction, like those from Fairport to Lyons, shown in plate 5, and between Montezuma and Syracuse, were occupied if not wholly produced by the copious ice-border drainage, escaping eastward to the Mohawk-Hudson. These channels are all cut in erodible Salina shale, and were effective when the land stood nearly 300 feet below the present level.

The uncertain and puzzling channels are those with windings and wayward indirection, and these may be related in their origin to some of the nondrumlin spaces. Seneca river is an example, with its northward turn east of Savannah, and from Cross lake (an open tract) around to Baldwinsville, and then south to near Onondaga lake. This is partly shown in plates 4 and 19. The Clyde river (plate 18) and Dead creek (plate 19) are other examples.

When the ice-sheet finally melted off from central New York it was succeeded by Lake Iroquois. The vagrant and erratic drainage lines must have been initiated, around and among the drumlins, as the lake waters were drained away. The land was then much lower than it is at present, and with more slope to northward. The sluggish stream-flow through many thousands of years has probably

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BEDDED DRUMLIN STRUCTURE
Lake Bluff, two miles east of Sodus Point. Looking southeast.

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BEDDED DRUMLIN STRUCTURE
Blind Bay Bluff; five miles northeast of Sodus Bay. Looking south.

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been influenced and perhaps diverted by organic growths and peat fillings.

Rocdrumlins. It is found that the molding effect of the overriding ice-sheet was not restricted to the drift masses, the drumlins, which were deposited during the rubbing process by the ice itself, but was felt by the hills of soft rock that were exposed to the ice erosion (plate 19).

The term drumlin cannot appropriately be applied to ice-shaped rock hills, even though the genetic relationship may be evident. The term "drumloid" is appropriate, but the word has long been used for hills of glacial stuff having an accidental resemblance in form to drumlins. A distinctive term with obvious meaning is needed, and such a term is *rocdrumlins,* using as a prefix the Celtic word for rock.

It must be very clear that rocdrumlins are an effect of a moderate amount of erosion, or removal of material, while drumlins are the product of upbuilding and shaping at the same time. The genetic distinction is important and fundamental.

Between Palmyra and Syracuse the foundation of the drumlins is Salina shale, mostly the soft red and green beds known as Vernon. All of the deeper valleys of the district are cut in this shale, which may be seen on the slopes as bare patches of bright colors, light green and red. In the area of Jordan and Memphis these shales, forming the walls and bottom of the broad valley, are eroded into forms simulating morainal topography. As far east as Oneida the rock forms might, as seen from a distance, be mistaken for moraine.

In the Jordan-Memphis district the Vernon shales reach up to over 500 feet elevation, while the lake and stream fillings in the valleys are about 400 feet altitude. The Vernon shale, therefore, extends upward about 100 feet above the lowlands and are overlain by the gypsum-bearing Camillus shales. East of Jordan they form the common platform from which the drumlins rise (plates 17, 19).

It appears that in the belt from Lyons to Weedsport the Salina shales belong in the same horizontal plane, or topographic horizon, as the drumlins, and the interesting question arises if the drumlin masses may not be partly shale beneath a veneer of till. One and one-half miles northeast of Port Byron, and three miles west of Weedsport, the red Vernon shale appears clearly on the slopes and on the summit of a drumlin-shaped hill with a summit contour of 460 feet. Here is certainly a drumlin form in rock, a rocdrumlin.

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It is very likely that other of the lower drumlin forms may be chiefly shale with only a varnish of drift; and it is more than likely that some of the larger drumlins have a base or a core of rock.

All the western-central New York rocks have a decidedly southward dip. It appears, therefore, that north of the Lyons-Syracuse parallel the rock strata must lie at increasingly higher elevations. And the vertical or stratigraphic range of the Vernon shale, several hundred feet in thickness, would include the whole height of the drumlin forms in a considerable belt of the northern territory. An examination was made of the hills west of Baldwinsville, with result not unexpected. It was found that all the drumlin forms are clearly composed of red shale, with only an apology of till coating. All of the hills in the upper half of the map, plate 19, and lying between the two north and south valleys, are not drumlins but rocdrumlins.

On first sight these hills would be regarded without question as true drumlins. But there are decided though refined differences which appear on close study. The rocdrumlins are not so symmetrical as the till forms. The slopes are less regular, and the struck ends are liable to be abrupt and irregular, and not so symmetrical as true drumlins. Even the 20-feet contours of the map reveal the differences. Looking at plate 19 it may be noted that the bases of the hills are indefinite, and that the hills do not have the clear-cut individuality of drumlins, as shown in plates 3, 5, 6, 7. The differences in form between the rocdrumlins and drumlins are clearly recognized in the field, and are fundamental.

Vernon shale is only hardened clay, without structure and easily decomposed. It yields readily to weathering and to erosion, and the product of the ice-rubbing was a plastic paste and lubricant, essentially like clayey till in its mechanical properties. In consequence the hills of Vernon shale which stood within the zone of drumlin formation were, in conflict with the moving ice, easily shaped into the drumlin form. And when given that shape they resisted the ice-impact. They were, like drumlins, both compliant and resistant. They became drumlin in form, in clever masquerade.

The Salina shales as a whole, many hundreds of feet in thickness in the drumlin territory, must have supplied a large amount of plastic and adhesive material for the drumlin-making process. Probably this was an important factor in the New York area.

Recognizing that glacial rubbing shaped the Salina shale hills, the rocdrumlins, it would appear likely that hill summits in other

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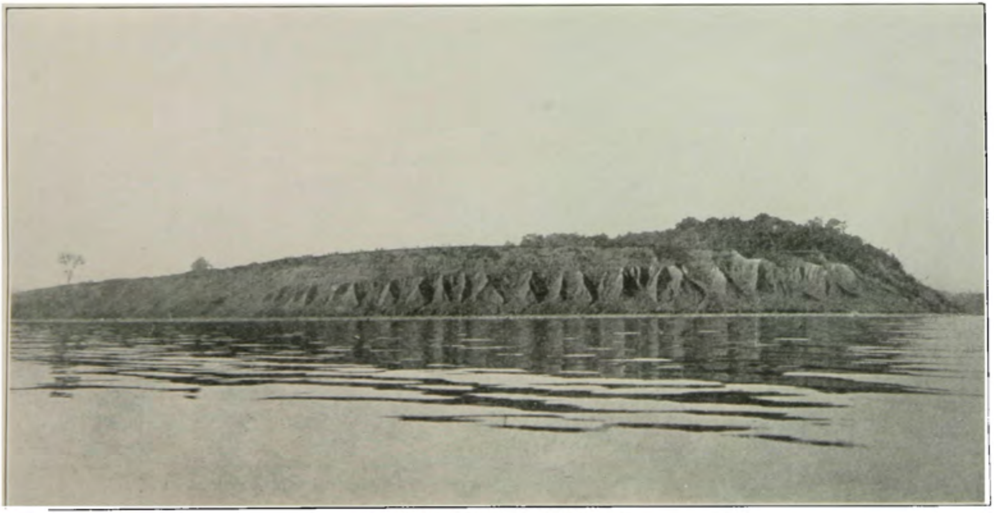

BEDDED DRUMLIN STRUCTURE
Dissected drumlin four miles west of Sodus Point. Looking southwest.

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districts beyond the drumlin area might, under exceptional conditions receive a drumloid expression. It is quite possible that such forms do occur. Some uplands, especially the intervalley areas in the Finger lakes region, exhibit some horizontal grooving. The smooth and graceful walls of the deep north and south valleys indicate a moderate amount of general sandpapering.

Some effect of ice abrasion and the shaping of land surfaces, where exposed to movement of the ground-contact ice, is probably more widespread than has been recognized. However, this does not at all imply that glacial erosion can excavate valleys or produce lake basins.

Physical Factors in Drumlin Formation

It is apparent that the drumlin-building process involves many factors, and most of them indeterminate and elusive. The problem is complicated, including not only the difficult subject of the behavior of plastic solids but the action of the ice under a complexity of geologic conditions.

In considering the mechanics of drumlin construction three sets of factors are recognized: those pertaining to the ice itself; those relating to the drumlin-forming drift; and the external influences of topography and atmosphere. These will be briefly considered in order.

Dynamic Factors Pertaining to the Glacier.

1. Vertical pressure. This is directly proportionate to the vertical thickness of the ice-sheet.

2. Horizontal pressure. At the periphery of the continental ice-sheet the horizontal pressure required to produce flow, on either level ground or on an upslope (as in the New York area), was mainly an effect of the vertical pressure in the rearward and deeper part of the ice-body. The depth of the ice along the drumlin-making zone was probably insufficient to greatly aid the forward movement. However, with plasticity effective the vertical pressure or weight might have had some local effect in modifying the movement or in producing differential flow.

3. Vigor and velocity of flow. This is due primarily to the thrust from the direction of the deeper ice. The horizontal displacement or mass movement of the ice border would be influenced by the larger features of the land surface, and by the local temperature and rainfall.

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4. Differential flow. Plasticity of the ice would theoretically allow unequal flow, or a tendency to flow in prisms or currents analogous to currents in water streams; and the drumlins are evidence of such local variations in the ice flow.

5. Plasticity. This property of the glacier ice would be increased by pressure, heat, and water as a lubricant. In the marginal, drumlin-forming zone plasticity due to vertical pressure would be reduced; that due to horizontal pressure would be fairly constant; while that due to heat and water, from rainfall or melting, would be increased.

Factors Relating to the Drift Held in the Ice.

1. Volume of the drift. It has long been recognized that the plastic flow of glacier ice diminishes with increase of rock debris. But the movement of the ice by rearward thrust would not be greatly affected by the contained drift. The influence of the load of drift toward producing rigidity might aid in producing differential flow in prisms or bolts. Whatever was the effects on the flow of the ice by variation in the load of drift, its abundance in the lower portion of the ice-sheet was a direct help in drumlin construction.

2. Position of the drift. The vertical location of the rock-rubbish in the ice is an important factor. Debris superficial to the ice-sheet could produce only frontal moraine. Drumlins were built from the debris carried in the lower layers of the ice.

3. Quality of the drift. It would appear that a clayey, adhesive character of the drift would facilitate the plastering-on process, by which the New York drumlins certainly were made. No drumlins are found composed largely of bowlders and friable material.

Factors of External Control.

1. General slope of the land. A down slope would favor movement of the ice both by thrust and by plastic flow, and perhaps by shearing of the upper over the lower layers. An upslope would retard or prohibit any motion at the bottom except by thrust. The drumlin area of New York has, in general, an upslope, though the central district of massive display is nearly level.

2. Minor topography. This element is indefinite because variable in many ways. It would appear that great irregularity of the overridden land surface would be unfavorable to movement of the lower ice; and in which case the drumlin-making process would lie more in the plane of the hilltops. This may have a bearing on the con-

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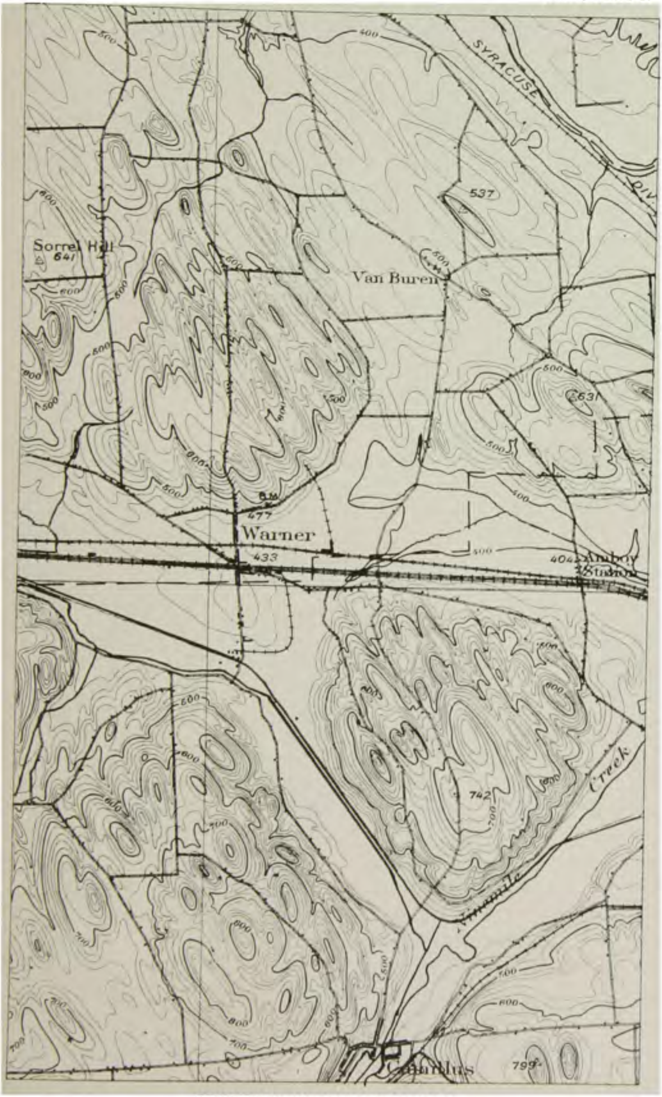

DRUMLINS IN ISLAND MASSES

Part of the Baldwinsville sheet. The valleys are cut in Salina shale, which also forms the bases of the groups.
Scale: one inch equals one mile.

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struction of the island masses, page 22. Small prominences or obstructions in the floor of the ice-sheet might be favorable, as nuclei, for the initiation of drumlins.

3. Temperature and water supply. Plasticity of the ice was favored by heat and water. Cold and dryness favored rigidity. The margin of the ice-sheet must have had, especially in summer, nearly its highest possible temperature, and large supply of lubricating water from the ice melting and the rainfall.

Summary; Fact and Philosophy

Origin of Drumlins. It is certain that the New York drumlins were built up by a plastering-on process. The ice-sheet did not drop its drift burden in the depressions or low places, but plastered it on the obstructions. The plastic and adhesive character of the shale-derived drift of central New York was probably an important factor accounting for the great number, height and shape of the hills.

The rocdrumlins, or shale hills with the peculiar drumlin form, were shaped by a moderate amount of erosion or rubbing off of the soft rock.

The upbuilding of the drumlins by the plastering process was coincident with a rubbing-off and shaping effect. As masses or hills the drumlins were built by accretion of drift, but their singular form is due to the erosional factor. The whole process may be compared to the work of the sculptor on a clay model, a plastering on and rubbing off. The accretion was because of the greater friction between clay and clay than between clay and ice.

The hills of accretionary drift resisted the ice impact and its rasping effect just as did the hills of shale. The form possessed by both classes of hills is that which opposed successful resistance to the ice erosion, and the least resistance to the overriding movement.

Thrust Movement of the Ground-Contact Ice. Drumlins were shaped by the sliding movement of the bottom ice, that in contact with the land surface. This implies that the whole thickness of the ice-sheet participated in the movement. Such motion was not due to gravitational stress on the ice over the drumlin area, because the general slope was uphill, but it was produced by an effective thrust on the marginal ice by the pressure of the thicker rearward mass. As the ice-sheet became thinner by ablation there came a time when the drift-loaded ice in contact with the ground felt less vertical pressure but was subjected to greater horizontal push by the thick ice in

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the rear, and was pushed forward bodily. In this behavior of the ice-sheet lies the key to drumlin formation.

It does not follow that drumlins must always be formed where the bottom ice had a sliding motion, as other associated conditions are requisite. Such thrustal movement would be effective only where a border of the ice-sheet was backed by a thick and spreading rearward mass.

The combination of conditions requisite for effective thrust movement over a belt of country and for the considerable time necessary to create drumlins was not common. However, it may be assumed that wherever the ground-contact ice had vigorous movement of some duration it might be indicated by some molding of the ground surface, especially where that surface was comparatively smooth and composed of drift. The degree and form of the ice molding would vary with the strength and balancing of several factors. Some evidence of this ice work may perhaps be found where drumlins do not exist.

Dynamics. It appears that in the typical drumlin area the ice did not move as a solid mass, or even in wide sections, for such motion would have produced a planing or levelling effect. The typical drumlins are proof of a plastic and variable flow, while the long, straight ridges imply that the ice was pushed in comparatively rigid bolts or prisms that wavered and shifted.

In the balancing and adjustment of the several dynamic factors in the drift-burdened ice the two opposing forces of rigidity and plasticity seem to be the more fundamental. The amassing of the drift into drumlin form, or at least the nonremoval of the hills, implies that the depth of ice and the vertical pressure were so moderate as to allow the plastic ice to override and adapt itself to the obstructions, while at the same time the whole sheet of ice was sufficiently rigid to move under horizontal thrust.

Judging from the facts and the theoretical mechanics it would appear that the typical drumlins represent short lines of temporarily diminished pressure and of lagging flow. The lines of variable pressure and motion, though close set in the dominant drumlin area, must have been discontinuous, short and constantly shifting.

The drumlins could not have been determined, at least as regards location, by external influences, as atmospheric agencies above or topographic and geologic features beneath, but must have been pro-

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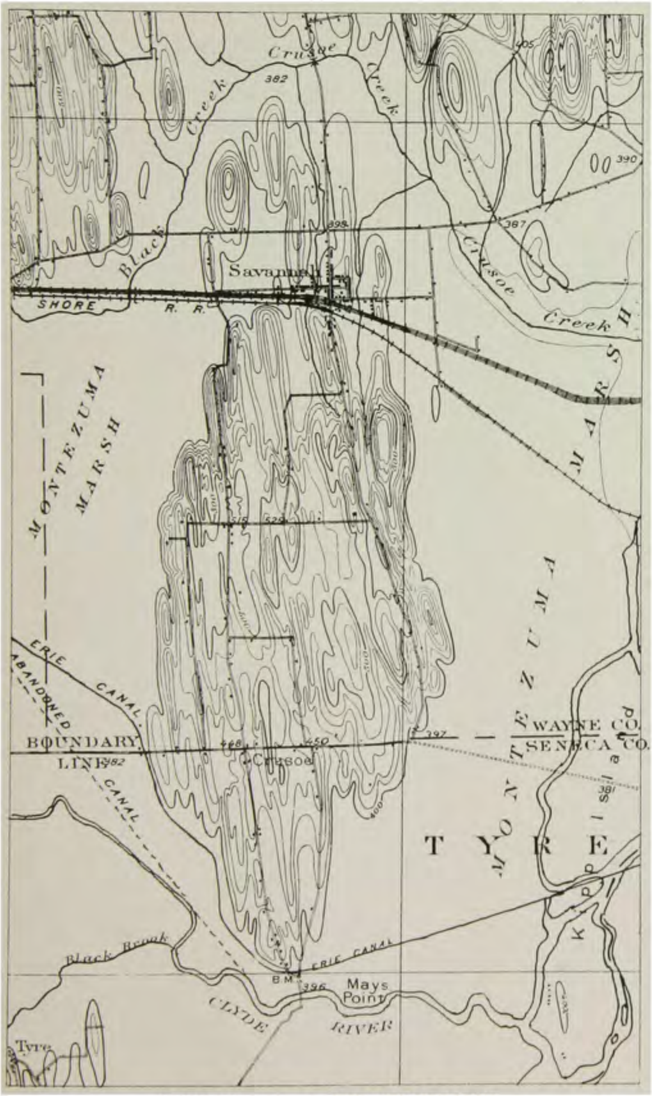

DRUMLIN MASS IN MONTEZUMA MARSH
Parts of Clyde, Weedsport, Geneva and Auburn sheets.
Scale: one inch equals one mile.

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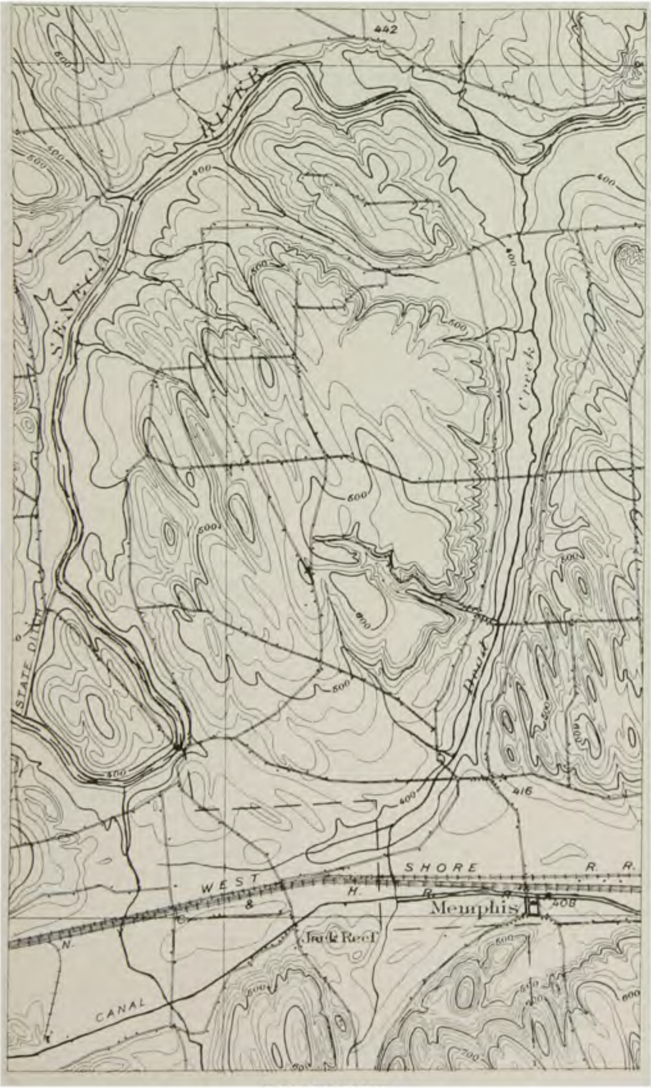

ROCDRUMLINS

Part of the Baldwinsville sheet. The drumlin-like hills in the upper part of the map are composed of Salina (Vernon) shale.
Scale: one inch equals one mile.

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duced by the interaction of the mechanical factors resident within the ice itself, the latter behaving as a plastic solid. The germ of each drumlin must have been some obstruction beneath the ice or a fortuitous massing of drift, or perhaps the lodgment and anchorage of a big bowlder.

The breadth of the main drumlin area, supposedly a unit in time of formation, is about 30 miles. If the northern and broader drumlins (plate 7) were built contemporaneously with the southern attenuated forms (plate 13), which appears certain, the physical conditions responsible for the different forms may be assigned. The broader and more widely separated forms, those about Fairhaven (plate 7) were under greater vertical pressure because of the greater depth of the ice. This might have given greater potential plasticity, but the effective plasticity and differential flow should have been less than in the central part of the belt. On the other hand the attenuated drumlins near the extreme border and under the thinner ice were subject to less vertical pressure. Here the ice had freer movement; it was less burdened with drift, having already built the drumlins in the rear; and probably it had less effective plasticity and less differential movement. In other words, the attenuated, border forms were molded beneath ice moving with greater freedom, greater relative rigidity, and with more uniformity and continuity.

The culmination of the drumlin-making process appears to have been in the middle of the belt, where the several dynamic factors were well balanced and working together at the maximum of efficiency. There the drift was abundant and plastic; the rigidity and the plasticity of the ice were active and balanced; and the differential flow was at its maximum, that is to say, the ice was not moving in long rigid bolts nor in wide masses but in short and wavering prisms.

The very long and flat ridges of the Niagara-Genesee prairie (plate 4) were the product of steady and long continued movement of more rigid ice than that which built the shorter, steeper and crowded drumlins in the middle of the area. The ice had less burden of drift, less differential flow and less effective plasticity. The effect was similar to the production of the attenuated flutings in the Waterloo-Seneca Falls district (plate 13), but the work was on a much larger scale. The direction of the drift molding in the western district is that of the prevailing direction of the continental glacier over the state.

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Relative Age. The attitude and form of the drumlins in the Pulaski district, due to the change in the direction of the ice flow, prove that they were shaped during the latest phase of the ice work in that locality. The same conclusion is reached by theoretic considerations and is enforced by all facts of observation.

The peculiar distribution of these New York drumlins and their orientation prove that they were built under the spreading flow of the semistagnant ice body reposing in the Ontario basin. The correlation of moraine with the ultimate flutings of the drift shows that the drumlins were built under the thinning border of the ice-sheet. This relation has been noted in other drumlin regions, as Wisconsin, Massachusetts, Ireland and Germany. The drumlins of north Ireland, the type forms, lie in curving lines of ice flowage; and in all essential characters are strikingly similar to our New York forms.

Form and Relations. The interaction of the mechanical and geologic factors has produced a great variety of drift forms which may be covered under the class of ice-molded or drumlinized drift. Following are the typical forms:

1. Domes, or mammillary hills and low broad mounds (plate 7).
2. Broad oval drumlins (plate 6).
3. Oval drumlins with definite outline and high relief (plates 3, 4).
4. Long oval drumlins; the dolphin-back hills (plate 5).
5. Short ridge drumlins (plate 5).
6. Long and low swells of drumlinized drift, having the southwestward direction of the principal movement of the glacier.
7. Minor drift moldings on the flanks of and between the typical, close-set drumlins.
8. Slender ridges at the attenuated edge of the drumlin belt, with correlating moraine (plate 13).

The more striking relations in the distribution and association of the New York drumlins are as follows:

1. The drumlin area is practically on the north-facing or ice-opposing slope of the land (plate 4).
2. The region of greatest development is on the low Ontario plain (plate 5).
3. The greatest development of typical, close-set drumlins is in the region of the greatest thickness of the Salina shales, which supplied clayey and adhesive drift.
4. The predominant drumlin area is where the ice flow was south

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and east of south, or at a high angle with the preceding, southwestward movement.

5. The drumlins are not placed in any orderly sequence or regular disposition, but are spaced in irregular manner.

6. The several varieties in form are not intermingled, but similar forms are grouped together.

7. Within the same belt, or what is regarded as a formational unit, the south forms, or those nearer the ice front, are the more attenuated; while the north forms, those beneath the deeper ice, are broader (plates 13, 7).

8. A belt of moraine lies in front of the attenuated border of the central drumlin area (plate 13).

9. The greater height of the drumlins, steepness of slope and regularity of form occur in the middle of the drumlin area, and characterize the maximum and most effective work of the constructive process.

10. The development of the broad, low swells in the northwest part of the great drumlin area is where the ice flow had only one direction, and where it had less volume of very clayey drift.

Depth of the Drumlin-Making Ice. No conclusive or definite data are available on this matter. The following calculation is merely suggestive.

The Waterloo-Seneca Falls moraine (plate 13) was laid under the water of a glacial lake which bathed the glacier front, with its control or outlet on the east. It is believed that the highest elevation of that water was about 700 feet, the height of Lake Dana.

The moraine lies at about 500 feet elevation, which implies 200 feet depth of water. As the moraine is weak, because the drift load had been incorporated into the drumlins in the rear, it may be assumed that the ice was not heavily anchored in the lake water by a load of rock-rubbish. In order to retain its position against the buoyancy of the water the ice should have been at least 25 feet over the lake, or with a thickness of 225 feet. Taking this as the minimum depth of ice at the glacier margin, and assuming a surface slope of 30 feet to the mile, the elevation of the surface of the glacier over Clyde, 12 miles north of the moraine, would be $(725 + 30 \times 12)$ 1085 feet. As the floor of the Clyde drumlins is about 400 feet elevation the depth of ice in the center of the drumlin belt was 685 feet. And as the tallest hills there are 180 feet the depth of ice over their summits was about 500 feet.

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Northward to the parallel of the massive hills (plate 7) is about 15 miles. Allowing for a reduced slope of the glacier surface, say to 20 feet per mile, the ice surface over the Fairhaven district would be 1,385 feet. And the depth over the hill summits over 1,200 feet.

Drumlins in Eastern New York

While the drumlin display in west-central New York, as described above, is by far the largest and richest it is not the only field in the state. Very interesting areas of drumlins and molded land surfaces are found in the eastern and northern parts of the state. The occurrences are widespread, with singular forms and relations, and a fair description of the features would make an extended paper. During over thirty years in the study of the Pleistocene geology of the state the writer has seen nearly all of the drumlin areas, and fain would describe them in detail, but only a brief outline is fitting here, which may however serve as a guide.

For the geographic references the quadrangles of the New York topographic map, or the corresponding sheets, will be named. The reader should have available a full set of the topographic sheets.

In the eastern half of the state there are three principal regions of ice-shaping phenomena. These are the great valleys which during the waning phase of the Quebec glacier held tongues or lobes of the ice sheet. During favorable stages these lobations had the dynamic conditions requisite for the molding of the land surfaces.

The regions possessing drumlins will be noted as follows: (1) the St. Lawrence valley, with southwestward direction; (2) the great Champlain-Hudson valley, with southward direction; (3) two diversions along the west side of the lower Hudson; and (4) the Mohawk valley, which held a westward lobation of the Hudson ice body.

The stronger flow of ice through the St. Lawrence valley fed the Ontario ice body (page 13) and in a later stage the weaker flow aided in producing some peculiar features described on page 11.

The best drumlin features in the St. Lawrence valley proper are found on the Alexandria Bay, Hammond, Clayton, Cape Vincent, Watertown and Carthage quadrangles. The northeast by southwest alignment of the land relief is quite clearly shown by the map contours. The ice streamed through the valley with force for ages, during both the advance and recession of the Quebec ice cap. Even the crystalline rocks show the rasping process, and some granitic bosses may perhaps be regarded as rocdrumlins.

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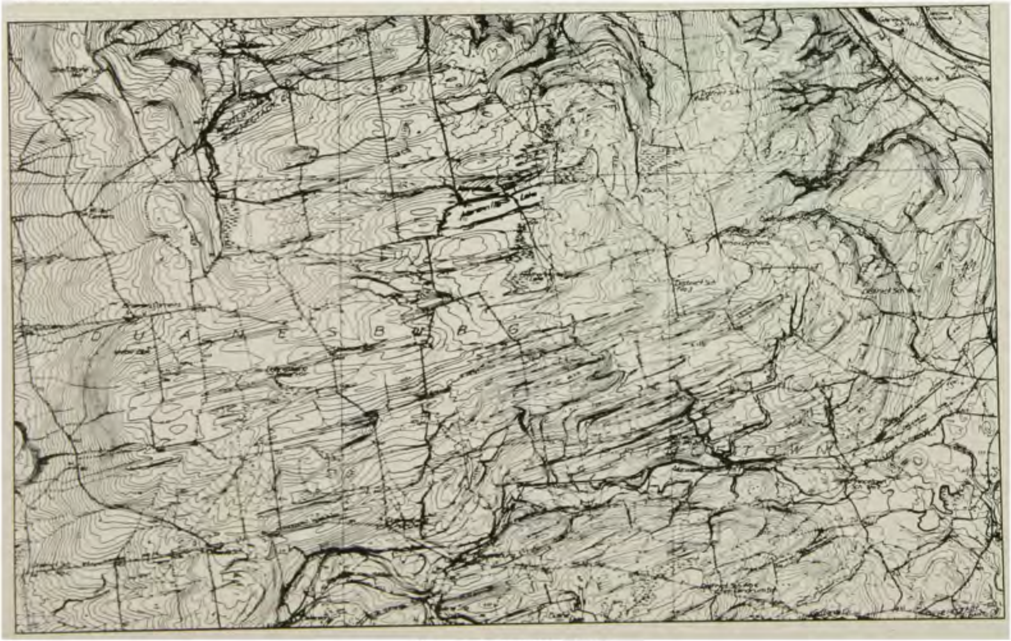

DRUMLINIZED SURFACE
Southern part of the Amsterdam sheet.
Scale: one inch equals nearly two miles.

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On the Carthage sheet a large number of small but typical drumlins with north and south directions are seen some miles west of Lowville, in the town of Harrisburg. Others with similar direction lie in the southeast corner of the Watertown quadrangle. A few forms occur about the village of Redwood.

An extension of the large but irregular St. Lawrence field is found on the Antwerp and Lake Bonaparte quadrangles, especially north and west of the lake, in Diana and Antwerp towns.

On the Canadian side of the St. Lawrence valley no examination has been made in drumlin study, but a good development of drumlin forms may be confidently expected.

Throughout the long stretch of the great Champlain-Hudson valley some detached or sporadic drumlins may be found outside of the well drumlinized fields. They have not been recorded by the writer in the Champlain valley. And apparently the dynamic conditions requisite for the shaping of land surfaces did not effectively occur north of Glens Falls. But in the main and lower Hudson valley drumlin features are handsomely developed.

The Saratoga, Schuylerville and Cambridge quadrangles supply many good examples. A group of drumlins lies east and southeast of Saratoga lake. Others are seen about the village of Argyle, in the northeast corner of the Cambridge sheet. This irregular field in the upper main valley blends on the south with that of the Mohawk valley, described later.

Southward, beyond the Mohawk embayment, the valley carries splendid display of ice-shaping, especially on the west side. On the east side some north and south shaping of the land surfaces, with some east of south, appears on the Kinderhook and Copake sheets, but stronger on the Rhinebeck, Clove, Carmel and West Point quadrangles. The northern part of the Carmel sheet depicts heavy north and south forms, and others are seen on the southeast corner of the West Point sheet. East of Poughkeepsie some suggestive forms due to possible ice-shaping require examination.

The ground west of the Hudson river has superior display of ice-shaped topography. The parallel alienation of the contour lines is as much, or more, in evidence on the topographic sheets than are the oval drumlins. (See plate 20.) The physical conditions or dynamic factors in the broad ice stream appears to have often favored the fluting or drumlinizing of the land surface rather than the local piling of the perhaps scanty drift into typical drumlins.

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The long Hudson ice tongue was limited along the west side of the valley and crowded against the Catskill, Shawangunk and Ramapo highlands. This probably intensified the southward thrust, which also intensified the rubbing-down as against the upbuilding process.

The land surface of the Coxsackie, Catskill, Kaaterskill and Newburgh quadrangles is clearly drumlinized in southerly direction. The receding terminus of the ice tongue had some spreading flow, which along the borders of the valley caused diversion from the prevailing southward movement. As the highland wall receded the ice deployed westward so that on the Ellenville, Goshen and Port Jervis quadrangles the excellent drumlin development east of the mountains has southwestward direction. Yet farther south the Ramapo quadrangle carries heavy north and south drumlins along the east face of the Ramapo mountain.

A definite diversion of the ice to the southwest took place in the Kingston district. An ice lobe moved up the three adjacent valleys of the Rondout and Wallkill rivers and Esopus creek. The Rosendale sheet depicts the handsome features. East of the Wallkill river the alignment of the topography is north and south.

The most pronounced diversion or offset from the main Hudson ice lobe flowed westward up the Mohawk valley. On the Albany and Berne quadrangles the flow was southwestward. Beginning some five miles southwest of South Schenectady the ground up the Normans Kill valley is strongly molded in southwestward direction to Delanson and Quaker Street, and on toward Gallupville. This is shown on the north part of the Berne sheet and the south part of the Amsterdam sheet, plate 20. The south part of the Fonda sheet depicts some drumlins with similar direction.

This Mohawk lobe pushed far west, up the valley to beyond Richfield Springs, seventy miles from the Hudson river. Surprisingly, this wayward ice tongue built a group of excellent drumlins north and northwest of Richfield Springs village, all pointing west. These well-spaced drumlins appear on the Richfield Springs and Winfield sheets. They are also depicted, in color, on plate 5 of the New York State Museum Bulletin No. 160, year 1912.

The explanation of these drumlins, in such singular location, requires the narration of a bit of Pleistocene history. In some middle stage of the waning of the Quebec ice-sheet a heavy belt of ice was left in the Mohawk valley. This strait of ice, connecting the

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Hudson and Ontario ice bodies, and lying between the Allegany highland on the south and the foothills of the Adirondacks on the north, has interesting relation to the glacial history and especially to the glacial drainage.

At some undetermined stage in the shrinking of the Mohawk ice strait the westward push, from the Hudson, prevailed as far as to the meridian of Utica. Under such conditions, with a vigorous push on the ice from the east, were the Richfield-Winfield drumlins constructed.

The guidance of thinner ice by the larger topography is well shown on the plate 5. A few ultimate drumlins, northwest of West Winfield, point to the southwest. The point of the ice lobe was guided by the gross topography and was pushed southwest between the hills into the head of the Unadilla valley.

Under the theory of multiple glaciation of New York, or at least of very great recession and readvance of the ice sheet margin, it might be held that these drumlins were built during a later and final episode of Mohawk glaciation.

Plate 6 of Bulletin 160 shows why there are no drumlins in the Albany-Schenectady district. The weight of the ice cap had depressed the continent, and on removal of the ice the Albany district was about 350 feet lower than it is today. Whatever drumlins were formed there are deeply buried in the delta of the great glacial Mohawk (the Glaciomohawk river) built in the wide Hudson estuary.

Complexity in the History

It is possible that there are undiscovered and unsuspected elements in the Pleistocene history of New York, and that it is more complicated than now recognized. It is possible that the oscillations of the ice front, recessions and readvances, have covered distances sufficient to amount to multiple glaciation, with important changes in physical conditions and geologic processes. While we must take the phenomena as we find them, and study them as they are, we may not deny the possibility that our New York drumlins and other glacial features are final products of geologic changes not now realized. However, it would be unscientific to minimize the truth before us and magnify the unknown and purely hypothetical.

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DURAND-EASTMAN PARK
View looking north along Pine Valley

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PROCEEDINGS OF THE ROCHESTER ACADEMY OF SCIENCE
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ARBORICULTURE AT ROCHESTER, N. Y.

BY MILTON S. BAXTER AND THOMAS P. MALOY

CONTENTS

DEFINITION; LOCAL RESTRICTION

Arboriculture is the science which deals with the cultivation of trees and shrubs, especially for timber or for ornamental purposes. In this vicinity the term has been applied almost wholly to the cultivation of trees and shrubs for ornamental purposes. Land as a rule has been too valuable, and the natural woodlands too abundant, to make it feasible to do much forest planting.

Exception to this may be found in the large grove of natural hardwoods in Cobb's Hill Park within a short distance of the center of the City, and the large woods at Durand Eastman Park. The City has also established a 4000-acre forest on the lands surrounding Hemlock and Canadice Lakes. These lakes, adjacent to each other, are about forty miles from Rochester and furnish the water supply for the City. The land originally supported a good stand of white pine, some red pine, hemlock and such hardwoods as oak, maple, basswood and chestnut. The first forest plantation was set out in 1902 and consisted of 8700 spruce and 4300 white pine. Forest planting has been kept up continuously on that area until at present there are over a million trees planted on the City's forest.

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Primeval Forest

The history of the village and city of Rochester is closely interwoven with the tree and forest growth of this vicinity. The village of Rochester was indeed actually carved out of the forest and there was no need of extensive tree planting in the early days. The first engineers who surveyed the country in this section had considerable difficulty in running their survey lines because of the dense mass of trees and forest undergrowth. Abelard Reynolds, in his diary, writes about coming to Rochester from Pittsfield, Mass., in 1812, and he frequently refers to Rochester as the village of trees. Mention is also made in early histories of the long lanes of trees down which the traveler drove when coming into Rochester from the east, west or south. Soil and climatic conditions were especially adaptable to plant growth of all kinds and our ancestors were quick to see the advantage of protecting and fostering their cultivation.

Early Tree Culture; Nurseries

As Rochester continued to grow from a struggling village to a small city, interest in tree and shrub cultivation grew with it. New homes were being constructed, which then as now required certain trees and shrubs to give them the proper setting. Various nurseries and seed firms came into existence which supplied not only the city and vicinity with their products but also carried the name of Rochester to the four corners of the earth.

Some of these early companies were the James Vick Seed Co.; the Ellwanger & Barry Nursery Co.; the Hooker Nursery Co.; the William S. Little Nursery; the Frost Nursery; the John Charlton Nursery; the Gould Bros. Nursery; and coming down to later years, Chase Bros. and Brown Bros. Nurseries. All of these above firms have in turn left their imprint upon that part of the city in which they happened to be located. Striking examples of this are Oxford, Cambridge, Wellesley and Brighton Streets, which were laid out by the Hooker Nursery Co. in the eastern part of the city, and the Browncroft subdivision, a recent development of the Brown Bros. Nursery.

In 1870 the Hooker Nursery Co. operated in the present vicinity of Oxford and adjacent streets and in their demonstration grounds, among other things, rows of European weeping white birches had been set out. These had reached a size and development where

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they were objects of especial interest and beauty at the time that it was decided to subdivide the nursery proper into residential streets. This collection of white birches became one of the most picturesque of its kind in this part of the country and remained so until about fifteen years ago. Since that time the bronze birch borer has caused the death of nearly all of these trees.

The Browncroft subdivision, laid out on the grounds of Brown Bros. Nursery Co., is unique in its almost lavish display of choice trees and shrubs of all kinds. Tall, stately specimens of spruce, fir and pines can be found in front of each lot. Interspaced with these are beds of species of spirea, viburnum, roses, kerria, mock orange, forsythia and other shrubs. In back of these are rows of elms and maples and on the lamp-posts, the wisteria and trumpet vines climb to such profusion as, in many places, to completely hide the concrete poles. This subdivision is visited annually by many landscape architects and nurserymen as well as students from the various agricultural schools. It can be said of this development that it has influenced tree and shrub planting in the entire city.

Ellwanger and Barry Nursery

The Ellwanger & Barry Nursery Co. was preceded in the field by several other nurseries but carried on its work to a degree far beyond any nursery before or since. It was established in 1840 by George Ellwanger and Patrick Barry. Both of these men were trained nurserymen and were imbued with the desire to render service of the highest quality. It was a matter of personal pride with these two men that all trees and shrubs sold by them should be of the highest quality, should be true to name and should represent all that their catalogue claimed for them. In an early description of the company, the statement is found that in 1858, the season's budding numbered about 800,000 buds. To insure complete accuracy, one of the proprietors cut all of these buds himself and then passed them on to the workmen about him.

Many rare species were first propagated in these grounds and from there distributed throughout the country. Most notable of these were trees of the *Sequoia gigantea*, the big tree of California. The story is that in 1850 a miner named G. H. Woodruff came across these trees in his quest for gold. He gathered some of the seed, placed them in a snuff box and sent them by pony express to Ellwanger & Barry. They sowed the seed in their greenhouse,

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raised plants and sent them all over the world. In 1856 they had succeeded in raising about 4,000 trees of which 400 were shipped to England.

A row of these big trees was set out on the nursery grounds in 1857. They grew to a considerable size but always suffered during a hard winter. They became the largest and finest specimen trees of their kind in the east however, and were visited by many people. They failed to survive the hard winter of 1917–1918 and the last of this row of big trees died that winter.

Ellwanger & Barry trees have been shipped to the four quarters of the globe, and today are growing in China, Japan, New Zealand, Australia and Arabia. The imperial gardens at Tokio, Japan were supplied with trees from this nursery.

In the early days experiment stations and agricultural colleges were not as plentiful as they are now and in order to further the interests of the nursery business and to test out new species it was necessary to devote a large part of their grounds to strictly experimental purposes. These test grounds, which were maintained for over fifty years, enabled Ellwanger & Barry to give accurate and reliable descriptions in their catalogues, and made these publications valuable guides to gardeners and planters as well as books of reference for agricultural schools. Trees grown on the nursery grounds for exhibition purposes represented almost perfect specimens of their kind. Many of these can still be found in the yards of the residences along Mt. Hope Avenue as well as on the present grounds of the Ellwanger & Barry Realty Co. This firm wished to be able to show the customers who visited them, specimen plants of everything represented in their catalogue. Their collection of trees and shrubs was famous throughout the country.

The Ellwanger & Barry Nursery Co. was spread out over about 600 acres. They employed between 400 and 500 men each year. The men employed were practically all of them drawn from the citizens of the city, and it was indeed difficult in the early days to find a man who had not at some period in his life spent some time in their nursery. The lessons learned there were carried into the home and did considerable towards spreading the name of Rochester as a flower city.

Patrick Barry and George Ellwanger were succeeded in the management of the business by William C. Barry, a son of the former. He was trained in the Universities of both this country and Ger-

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many, and maintained the nursery on the same high standard as his predecessors. He went still further than they and entering into public life gave freely of his advice and assistance whenever occasion demanded. He was a leader in the Horticultural and Nursery associations of the country and was identified with the Rochester Park Board from the early days of its organization. Shortly after the death of William C. Barry, the Ellwanger & Barry Nursery Co. ceased to exist but its influence is still felt in the city.

Development of the City Parks

Most of this writing so far has dealt with the commercial side of Arborculture since it was only in the nurseries that any systematic collection of trees and shrubs had been made. Rochester had no Park system at that time. There were, to be sure, certain small Park areas such as Wadsworth Park and Washington Park which had been given to the city at the time that some certain section was developed, but these were under the control of the Department of Public Works and were kept up by that Department. The cemeteries were the only public places of any size where grass, trees and shrubs could be found and the people were accustomed to take their lunches and visit them much as they today visit the Parks.

In 1887 the Ellwanger & Barry Nursery Co. offered twenty-two acres of land adjoining the Mount Hope Reservoir (now called Highland Reservoir) to the City of Rochester for a public park. They also agreed to furnish the trees for its planting and to construct certain new streets adjoining said Park. This offer was accepted by the city in 1888 and a Board of Park Commissioners of twenty-one men was appointed by Mayor Cornelius R. Parsons. The members of this first board were Dr. E. M. Moore, who was elected President, William C. Barry, James H. Brown, Joseph Cauffman, Richard Curran, John E. Durand, George Elliott, James G. Gillis, James G. Graham, Halbert S. Greenleaf, John Greenwood, Henry F. Huntington, William S. Kimball, Mathias Kondolf, Rev. Bernard J. McQuaid, George H. Newell, Daniel W. Powers, Mortimer F. Reynolds, William See, Hiram W. Sibley and Alfred Wright.

These men met, committees were appointed and in June 1888, Calvin C. Laney, a practising civil engineer, was employed to make a survey of the present and the proposed Parks. On April 1, 1889, Mr. Laney was appointed Superintendent of Parks. The selection of Mr. Laney as the first Park executive proved in later years to

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be the most outstanding development of those early days. Mr. Laney possessed a vision far beyond that of ordinary men and from that day to this over a period of forty four years has placed the interests of the City of Rochester and the Park Department above everything else.

After consultation with various Landscape Architects, Frederick Law Olmsted was hired by the city to lay out the park system. He was at that time the most prominent Landscape Architect of the country and he and Mr. Laney laid out Highland Park, Genesee Valley, Seneca and Maplewood Parks.

On April 1, 1891, Mr. Laney, feeling the need of an assistant, employed John Dunbar, a Horticulturist, who was then working on Long Island. The employment of John Dunbar marked another milestone in the Park Department. An indefatigable worker, a great student and possessed of an almost inexhaustible knowledge of trees and shrubs, Mr. Dunbar threw himself heart and soul into the work. The remarkable combination of these two men working together, Laney the engineer and Dunbar the Horticulturist quickly brought forth results far beyond the expectation of any one.

Aided and advised by the Board of Park Commissioners, Messrs. Laney and Dunbar commenced planting operations on a large scale. At the start they used more common trees and shrubs, those which were easiest to obtain, and very soon our Parks began to lose the appearance of farm lands and to show some semblance of the beauty which they ultimately attained. In the minds of both of these men the idea was always uppermost, that eventually Rochester should have more than an ordinary Park, that it should have an arboretum second to none in the country, in which would be found specimens of all the trees and shrubs that could be grown in the climate and under the soil conditions of this section. This idea of a collection of trees and shrubs of all species and varieties was nothing new. Such collections have found a place in the botanic gardens of all countries since the physic gardens at Tokyo were first founded eight hundred years ago, and for more than three centuries individuals have made such collections for the decoration of estates or for purposes of study. The first arboretum in this country was established by John Bartram, in 1728, a Pennsylvania farmer, who purchased a piece of land about three miles from Philadelphia in which he set out his collection of trees. Various other collections were started at different times but as most of these

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were the work, and followed the whim, of individuals their period of usefulness and greatest value was usually measured by the life of that individual. In 1872 about 125 acres were set aside for the Arnold Arboretum in connection with Harvard College, in which the University undertook to grow a species of every tree and shrub able to support the climate of Massachusetts. Under the leadership of Dr. Charles S. Sargent, the Arnold Arboretum quickly attained the foremost place in tree and plant work, and the identification of a tree or shrub by the Arnold Arboretum was considered as almost final. Special mention is made of the Arnold Arboretum because of the close working connection which was developed between that institution and the Rochester Park system, and because of the assistance in both plant materials and advice that was constantly received from it.

In developing their arboretum, Messrs. Laney and Dunbar first used the trees and shrubs which were on hand and were easy to obtain. They next reached out to the nurseries, and from them obtained any of the rare species which they happened to have in their collections. About the year 1900 a contact was made with the Arnold Arboretum and from that time the Rochester Parks have been the recipient of an almost endless flow of rare trees and shrubs from that institution, until today there is in the Rochester Parks a duplicate of nearly all of the trees and shrubs that can be found in the Arnold Arboretum. Dr. Sargent for years sent botanists and plant collectors to the four corners of the earth. E. H. Wilson, who succeeded Dr. Sargent as Director of the Arnold Arboretum, was the most famous of these explorers and to him we are indebted for many rare plants, especially those of Chinese origin.

Not content with merely securing rare plants by gifts and purchase, the Rochester Park Department sent out its own collectors. John Dunbar, Bernard Slavin, the present Superintendent of Parks, and Richard Horsey collected specimens in various portions of this country and in Canada. Many of the species that we have in our Parks are the product of the explorations of these men in Canada, Texas, Oklahoma, Kentucky and other sections. Closer to home, but none the less valuable, collections were made by Calvin C. Laney, Patrick Slavin, the present Director of Parks, and Henry T. Brown the Park Engineer. When the Ellwanger & Barry Nursery Co. ceased doing business in 1917, the Park Bureau secured the services of Frederick Ahrens, their chief propagator. He had a life long ex-

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perience in the business and proved invaluable to the city in the work he did of raising many of the rare species. The result of the work both individually and collectively of all of these men has been to make Rochester and its Parks a by-word the world over wherever Park men and Horticulturists gather. It can truthfully be said that Rochester's Parks are better known away from home than they are by the inhabitants of this city. The arboretum which was started in a modest way on the hills and valleys composing Highland Park has long since outgrown that area and is now spread over the entire Park system of about 1800 acres with the result that today there are over 5,000 different kinds of trees, shrubs and perennials in the Park system. In Highland Park alone there are 3,931 kinds of plants. Space will not permit the separate listing of these various species and varieties, but mention will be made of a few of them. The lilac collection of which there are 363 different kinds presents one of the outstanding floral displays of the year. The plums and cherries make an especially attractive showing as do also the mock-oranges, the crab apples, the spireas, the viburnum, the deutzia, the weigelias, the dogwoods, the barberries and the cotoneasters. The Rhododendron and Azalea display, which follows closely after the lilac show, presents an array of color which would defy any artist to match. The collection of magnolias represents all of the native species which will grow in this climate and in addition there is a southern magnolia, Magnolia grandiflora, growing in the greenhouse. There are also twenty-one species of magnolia growing outside which are native of China and Japan, or hybrids of Chinese and Japanese species, and in addition, there is also Magnolia Delevayi from S. W. China growing in the greenhouses. The seven hundred different species and varieties of Crataegus which are in the collection at Genesee Valley Park present a beautiful display at all times of the year. The foliage and fruit of these shrubs are especially attractive and even in their dormant state in the winter time the bare twigs and branches have a natural symmetry which makes them most conspicuous.

Genessee Valley Park is the largest in area of our City Parks. It consists of rolling meadows, landscaped mostly with native trees and shrubs. This natural growth of trees has been supplemented by a planting of trees and shrubs of both native and introduced species.

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The oldest collection of the conifers is in Highland Park. These trees, set out years ago along the Pinetum Road, have now grown into large specimens. Each individual variety or group is labeled so that this Park is a convenient place in which to study and to find out just what the various conifers are capable of doing. This method of labeling is used on all trees, shrubs and plants in the entire Park system. Each group has a label which bears on it both the scientific and the common name.

In the large lake shore park, the Durand Eastman, there is a much larger collection of evergreens than at Highland. While they are much younger plants, they have clothed the hillsides there to an extent which is surpassed by no other Park.

It is difficult to select any of the species of trees for special mention. The collections of Oaks, Elms, Maples, Lindens, Buckeyes, Willows, Ash and Poplars are each one of them distinctive in themselves and worthy of especial study by the individual.

The City of Rochester at present possesses as a part of its Park system, an arboretum, which started in a modest way at Highland Park, spread to Genessee Valley Park, Seneca Park and is now crowding even the vast acres of Durand Eastman Park. Utilizing the entire Park system instead of one particular Park for the arboretum has permitted wide latitude in the choice of soil conditions and surroundings. Practically every kind of soil from heavy clay to fine sand can be found in some sections so that if the plant will live at all in this locality, it is merely a question of deciding on which Park the soil and conditions are best suited for that particular species.

Rochester is today suffering the growing pains of a large and progressive city. Many trees are being cut down because of street widening and for other improvements. There is not the room now for large planting that there was fifty years ago. It is therefore even more important now than then that every encouragement be given to the practice of tree and shrub cultivation. The Park Bureau must have co-operation from the citizens as a whole if we are to keep our City from suffering the fate of other large cities of seeing the trees and shrubs disappearing from our streets and our Park areas being reduced in size. Stephen Girard once said: "If I knew I should die tomorrow, I should plant a tree today." Let us keep that statement always before us.

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In order of time the principal city parks are, Highland, Genesee Valley, Seneca, Maplewood (lower and upper) Cobbs Hill, Durand-Eastman, Edgerton, Webster and Ontario Beach. Many small parks are distributed through the residential districts.

Later Administration

The Board of Park Commissioners which so ably assisted in the building up of the Rochester Park system was abolished by act of legislature on March 3, 1915. Mr. A. B. Lamberton was appointed to be the first Commissioner of Parks with William S. Riley as Deputy Commissioner. Mr. Riley later succeeded Mr. Lamberton as Park Commissioner and held that position for a number of years. He was then succeeded for a brief interval by William Blackwood.

Calvin C. Laney succeeded Mr. Blackwood, with Gertrude M. Hartnett as Deputy Commisioner; and when the City Manager form of government went into effect they were appointed Director and Deputy Director. When obliged to retire because of age limit Mr. Laney was succeeded for a brief interval by Charles B. Raitt, who was followed by Patrick J. Slavin, the present Director of Parks. During the period between the resignation of Mr. Laney and the appointment of Mr. Raitt, and again between the resignation of Mr. Raitt and the appointment of Mr. Slavin, Miss Hartnett was Acting Director.

Mr. Slavin has, as his present associates, Miss Gertrude M. Hartnett, Deputy Director of Parks, Bernard H. Slavin, Superintendent, Henry T. Brown, Engineer and Thomas P. Maloy, City Forester. All of these various officials have fostered the spirit initiated by the first Board of Park Commisioners and have given their utmost assistance in keeping Rochester's Parks in the front rank where they have so long been, and in making them an object of beauty as well as a place in which to study and enjoy plant life.

Favoring Physical Conditions

The variety and excellence of the arboreal flora of Rochester is partly due to the combination of favorable conditions of climate, soils, exposure and altitudes.

For its latitude the City of Rochester claims the finest all-the-year climate of any American city; as shown by the meteorologic statistics. Its northern position relieves it from excessive and long-

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continued summer heat; while the winter protection provided by Lake Ontario prevents severe cold. The moderate temperatures are well shown by the monthly normals. For the summer months these are, in Fahr. degrees, June, 66.1; July, 70.7; August, 69.2; September, 62.4. For the winter months, December 29.3; January 24.6; February, 24.6. The highest temperature ever recorded at the Rochester station is 101; and the lowest, on two rare occasions, –12, –14.

The fact that a row of Sequoia gigantea flourished here for sixty years, attaining a height of about seventy feet, is good evidence of a moderate northern climate.

The soil conditions provide great variety, all with excellent drainage. Directly, or indirectly all the soils are due to glaciation. Highland Park, with its great pinetum and its remarkable display of flowering shrubs, has gravel and sand soils, being part of the Albion-Rochester, or Pinnacle Range moraine, with accented topography. The Cobbs Hill Park is on the eastward extension of the glacial hills.

Maplewood Park, upper and lower, is on erosion shelves of the Genesee River canyon, west side, with soils deposited by the river and the glacial lakes which buried the area. Seneca Park is wholly on shelves and channels of the east wall of the river canyon; with varied soils that include residuals from the weathering of the sandstone and shale rocks.

The Durand-Eastman Park, facing Lake Ontario, is wholly silts and clay of the great delta built in the glacial Lake Iroquois by the Genesee River when the latter was excavating the Rochester canyon, and the Mount Morris and portage canyons on the south.

Genesee Valley Park lies on the river flood plains, on the south border of the city.

The different locations and the varied topography of the several parks provide both exposure to and shelter from the sunshine, the wind and the cold storm in any direction.

In elevation above ocean the parks range from 260 feet in Durand-Eastman Park, by Lake Ontario (246 feet), to cover 600 feet in Highland and Reservoir parks. The two high points are, the Pavilion in Highland Park, 652 feet; and the Cobbs Hill Reservoir, 636 feet. The highest point of the moraine, the "Pinnacle," rises to 748.7 feet.

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Native Trees and Shrubs of Rochester and Vicinity [1]

Pinus Strobus L. White Pine
Pinus rigida Mill. Pitch Pine
Larix laricina Koch. Tamarack
Picea mariana B S P. Black Spruce
Tsuga canadensis Carr. Hemlock
Thuja occidentalis L. Arbor Vitae
Juniperus communis L. Juniper
Juniperus virginiana L. Red Cedar
Taxus canadensis Marsh. American Yew
Smilax rotundifolia L. Green-brier
Smilax hispida Muhl. Hispid Cat Brier
Juglans cinerea L. Butternut
Carya ovata K. Koch. Shag-Bark Hickory [2]
Carya glabra Sweet. Pignut
Carya cordiformis K. Koch. Butternut
Carya ovalis Sarg. Small-fruited Hickory
Myrica carolinensis Mill. Bayberry
Myrica asplenifolia L. Sweet Fern
Populus tremuloides Michx. American Aspen
Populus grandidentata Michx. Large-toothed Aspen
Populus balsamifera L. Cottonwood
Populus tacamahacca Mill. Balsam Poplar
Salix nigra Marsh. Black Willow
Salix amygdaloides Anders. Peach Willow
Salix lucida Muhl. Shining Willow
Salix serissima Fernald. Autumn Willow
Salix longifolia Muhl. Long-leaved Willow
Salix cordata Muhl. Heart-leaved Willow
Salix pedicellaris Pursh. Bog Willow
Salix discolor Muhl. Glaucous Willow
Salix petiolaris Sm. Slender Willow
Salix humilis Marsh. Prairie Willow
Salix sericea Marsh. Silky Willow
Salix Bebbiana Sarg. Beaked Willow
Salix candida Fluegge. Hoary Willow
Corylus americana Walt. Hazelnut
Corylus cornuta Marsh. Beaked Hazelnut
Ostrya virginiana K. Koch. Ironwood
Carpinus caroliniana Walt. Blue Beech
Betula lenta L. Black Birch
Betula lutea Michx.f. Yellow Birch
Betula papyrifera Marsh. Canoe Birch
Alnus incana Moench. Speckled Alder
Alnus rugosa Spreng. Smooth Alder
Fagus grandifolia Ehrh. Beech
Castanea dentata Borkh. Chestnut
Quercus alba L. White Oak
Quercus macrocarpa Michx. Bur Oak
Quercus bicolor Willd. Swamp White Oak
Quercus Muhlenbergii Engelm. Yellow Oak
Quercus borealis Michx. f., var. maxima Sarg. Red Oak
Quercus coccinea Muench. Scarlet Oak

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[1] In former volumes of these Proceedings lists of the arboreal and arborescent flora were published that covered a much wider territory than does the present writing. Those papers are as follows:

Plants of Monroe County and Adjacent Territory; in Volume 3, 1894, pages 1–150.

Supplementary List; in Volume 5, 1910, pages 1–38.

Second Supplementary List; in Volume 5, 1917, pages 59–121.

[2] Additional species, varieties and hybrids of Carya have been described from this region.

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Quercus velutina Lam. Black Oak
Ulmus fulva Michx. Slippery Elm
Ulmus americana L. American Elm
Ulmus racemosa Thomas. Cork Elm
Celtis occidentalis L. Hackberry
Celtis pumila Pursh. Low Hackberry
Morus rubra L. Red Mulberry
Clematis virginiana L. Virgin's Bower
Magnolia acuminata L. Cucumber Tree
Liriodendron Tulipifera L. Tulip Tree
Asimina triloba Dunal. Papaw
Menispermum canadense L. Moonseed
Sassafras officinale Nees & Eb. Sassafras
Benzoin aestivale Nees. Spice Bush
Hamamelis virginiana L. Witch Hazel
Ribes americanum Mill. Wild Black Currant
Ribes Cynosbati L. Prickly Gooseberry
Ribes hirtellum Michx. Smooth Gooseberry
Platanus occidentalis L. Buttonwood
Spiraea latifolia Borkh. Meadow Sweet
Malus coronaria Mill., var. elongata Rehd. Wild Crabapple
Malus coronaria Mill., var glaucescens Rehd. Wild Crabapple
Sorbus americana Marsh. American Mountain Ash
Aronia arbutifolia Ell., var. atropurpurea Schneider. Red Chokeberry
Aronia melanocarpa Britton. Black Chokeberry
Amelanchier sanguinea DC. Round-leaved June Berry
Amelanchier humilis Wiegand. June Berry
Amelanchier stolonifera Wiegand. June Berry
Amelanchier canadensis Medic. Shad Bush
Amelanchier laevis Wiegand. Shad Bush
Crataegus Crus-galli L. Cockspur Thorn [3]
Crataegus punctata Jacq. Large fruited Thorn
Crataegus macracantha Lodd. Long-spurred Thorn
Crataegus succulenta Schrader. Long-spined Thorn
Crataegus Boyntoni Beadle. Boynton's Thorn
Crataegus pruinosa K. Koch. Waxy-fruited Thorn
Crataegus beata Sargent. Dunbar's Thorn
Crataegus macrosperma Ashe. Variable Thorn
Crataegus Holmesiana. Ashe. Thin-leaved Thorn
Crataegus coccinea L. Scarlet Thorn
Potentilla fruticosa L. Shrubby Cinquefoil
Rubus odoratus L. Flowering Raspberry
Rubus idaeus L., var. strigosus Maxim. Red Raspberry
Rubus occidentalis L. Black Raspberry
Rubus pubescens Raf. Dwarf Red Raspberry
Rubus hispidus L. Running Blackberry
Rubus canadensis L. Mountain Blackberry
Rubus allegheniensis Porter. Common Blackberry
Rubus flagellaris Willd. Dewberry
Rosa setigera Michx. Prairie Rose
Rosa blanda Ait. Smooth Rose
Rosa palustris Marsh. Swamp Rose
Rosa carolina L. Dwarf Rose
Prunus americana Marsh. Wild Plum

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[3] The species of Crataegus here noted are the more conspicuous forms. Over one hundred have been described by specialists from this territory.

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Prunus susquehanae Willd. Dwarf Cherry
Prunus pennsylvanica L.f. Pin Cherry
Prunus virginiana L. Choke Cherry
Prunus serotina Ehrh. Wild Black Cherry
Zanthoxylum americanum Mill. Prickly Ash
Ptelea trifoliata L. Three-leaved Hop Tree
Rhus copallina L. Dwarf Sumach
Rhus typhina L. Staghorn Sumach
Rhus glabra L. Smooth Sumach
Rhus canadensis Marsh. Aromatic Sumach
Rhus Vernix L. Poison Sumach
Rhus Toxicodendron L. Poison Ivy
Ilex verticillata Gray. Winterberry
Nemopanthus mucronata Trel. Mountain Holly
Evonymus atropurpureus Jacq. Burning Bush
Celastrus scandens L. Bittersweet
Staphylea trifolia L. Bladdernut
Acer saccharinum L. Silver Maple
Acer rubrum L. Red Maple
Acer saccharum Marsh. Sugar Maple
Acer nigrum Michx. f. Black Sugar Maple
Acer pennsylvanicum L. Striped Maple
Acer spicatum Lam. Mountain Maple
Acer Negundo L. Box Elder
Rhamnus alnifolia L'Her. Swamp Buckthorn
Parthenocissus quinquefolia Planch. Virginia Creeper
Vitis aestivalis Michx. Summer Grape
Vitis vulpina L. Frost Grape
Tilia americana L. Basswood
Dirca palustris L. Leatherwood
Shepherdia canadensis Nutt. Canadian Buffalo Berry
Cornus rugosa Lam. Round-leaved Dogwood
Cornus Slavini Rehder. Slavin's Dogwood
Cornus Amomum Mill. Silky Cornel
Cornus Baileyi Coulter & Evans. Bailey's Cornel
Cornus stolonifera Michx. Red-osier Dogwood
Cornus candidissima Marsh. Panicled Dogwood
Cornus alternifolia L.f. Alternate-leaved Dogwood
Cornus florida L. Flowering Dogwood
Nyssa sylvatica Marsh. Pepperidge
Ledum groenlandicum Oeder. Labrador Tea
Rhodendron nudiflorum Torr., var. roseum Wiegand. Pink Azalea
Rhodendron maximum L. Great Laurel
Chamaedaphne calyculata Moench. Leather Leaf
Andromeda glaucophylla Link. Bog Rosemary
Gaylussacia baccata K. Koch. Black Huckleberry
Vaccinium vacillans Kalm. Late Upland Blueberry
Vaccinium pennsylvanicum Lam. Early Upland Blueberry
Vaccinium canadense Kalm. Velvet-leaf Blueberry
Vaccinium stamineum L. Deerberry
Vaccinium corymbosum L. Swamp Blueberry
Fraxinus americana L. White Ash
Fraxinus pennsylvanica Marsh. Red Ash
Fraxinus pennsylvanica Marsh., var. lanceolata Sarg. Green Ash
Fraxinus nigra Marsh. Black Ash
Cephalanthus occidentalis L. Button Bush
Diervilla Lonicera Mill. Bush Honeysuckle.
Sambucus racemosa L. Red-berried Elder
Sambucus canadensis L. Common Elder

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Viburnum alnifolium Marsh. Hobble Bush
Viburnum Opulus L., var. americanum Ait. Highbush Cranberry
Viburnum acerifolium L. Maple-leaved Viburnum
Viburnum affine Bush, var. hypomalacum Blake. Downy-leaved Arrowwood
Viburnum dentatum L. Arrowwood
Viburnum cassanoides L. Withe-rod
Viburnum Lentago L. Nannyberry
Symphoricarpos albus Blake. Snowberry
Lonicera canadensis Marsh. Fly Honeysuckle
Lonicera oblongifolia Hook. Swamp Fly Honeysuckle
Lonicera hirsuta Eaton. Hairy Honeysuckle
Lonicera dioica L. Smooth-leaved Honeysuckle

Introduced Trees and Shrubs

Pinus sylvestris L. Scotch Pine
Populus alba L. White Poplar
Populus candicans Ait. Balm of Gilead
Populus nigra L. var. italica DuRoi. Lombardy Poplar
Salix fragilis L. Crack Willow
Salix alba. L., var. vitellina L. White Willow
Salix alba L. White Willow
Salix blanda Anders. Wisconsin Weeping Willow
Salix Caprea L. Goat Willow
Salix purpurea L. Purple Willow
Betula alba L. White Birch
Betula populifolia Marsh. Gray Birch
Alnus vulgaris Hill. Black Alder
Quercus robur, var. pedunculata L. English Oak
Ulmus campestris L. English Elm
Ulmus glabra Huds. Scotch Elm
Maclura pomifera Schneider. Osage Orange
Morus alba L. White Mulberry
Berberis vulgaris L. Barberry
Ribes nigrum L. Garden Black Currant
Ribes sativum Syme. Garden Red Currant
Ribes odoratum Wend. Missouri Currant
Physocarpus opulifolius Maxim. Ninebark
Spirea tomentosa L. Hardback
Spiraea salicifolia L. Meadow Sweet
Sorbaria sorbifolia A. Br. Meadow Sweet
Pyrus communis L. Common Pear
Malus pumila Mill. Common Apple
Malus baccata Borck. Siberian Crab Apple
Sorbus Aucuparia L. European Mountain Ash
Crataegus monogyna Jacq. English Hawthorn
Rubus idaeus L. European Red Raspberry
Rosa cinnamomea L. Cinnamon Rose
Rosa Eglanteria L. Sweet Briar
Prunus Persica Stokes. Peach
Prunus domestica L. Garden Plum
Prunus cerasus L. Sour Cherry
Prunus avium L. Sweet Cherry
Prunus Mahaleb L. Mahaleb Cherry
Gleditsia triacanthos L. Honey Locust
Amorpha fruticosa L. False Indigo
Robinia Pseudo-Acacia L. Common Locust
Ailanthus altissima Swingle. Tree of Heaven
Acer platanoides L. Norway Maple
Aesculus Hippocastanum L. Horse Chestnut
Rhamnus cathartica L. Common Buckthorn
Daphne Mezereum L. Spurge Laurel
Syringa vulgaris L. Lilac

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Ligustrum vulgare L. Common privet
Lycium halimifolium Mill. Matrimony Vine
Viburnum Lantana L. Wayfaring Tree
Symphoricarpus albus Blake, var. laevigatus Blake. Snowberry
Symphoricarpus occidentalis Hook. Wolfberry
Lonicera tatarica L. Tartarian Honeysuckle
Lonicera Xylosteum L. European Fly Honeysuckle
Lonicera sempervirens L. Trumpet Honeysuckle

Noteworthy Trees Mostly of Early Introduction

A survey of the rare trees of early introduction was undertaken by Mr. John Dunbar and the results were published.[4] The summary here given is essentially correct at the present time, except for the increase in size and the changes caused by building operations and street extensions. Many of the rare species were also planted in various parts of the city and are in a flourishing condition. The measures given are girth, at four feet above ground, and the approximate height of the largest specimens, with localities and other information.

Ginkgo biloba L. Maiden-hair Tree. Circumference 8.1 feet, height 60 feet, 455 Lake Avenue, planted about 1855.

Pinus excelsa Wall. Bhotan Pine. Circum. 4.2 feet, height 40 feet, 421 East Avenue.

Pinus ponderosa Dougl. Bull Pine. Circum. 6.9 feet, height 65 feet, Ellwanger & Barry Nurseries, Mt. Hope Avenue.

Abies Nordmaniana Spach. Nordman's Fir. Circum. 4.9 feet, height 75 feet, Ellwanger & Barry vineyard, Highland Avenue, planted about 1855.

Abies pectinata DC. Silver Fir. Circum. 6.5 feet, height 75 feet, Winton Road south of Subway, planted about 1860.

Sequoia gigantea, Torr. Big Tree of California. Circum. 7.9 feet, height 70 feet, Ellwanger & Barry Nurseries, Mt. Hope Avenue.

Ulmus nitens Monch. Smooth Elm. Circum. 7.2 feet, height 60 feet, east of Avenue B, about one hundred feet from the bank of the river on the south side of the Avenue.

Ulnus americana L. American Elm. A fine example of the umbrella form grows on the state highway two miles east of the village

[4] Proc. Roch. Acad. Sci. Vol. V. pp. 64–74, May 1917.

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of Avon, 16.2 feet, 110 feet high. The "Markham Elm" on the farm of William Markham near Avon was mentioned in 1764. A large portion was destroyed by a storm in 1893. It was estimated to be six hundred years old. The girth was forty-five feet, three feet above the base.

Maclura pomifera Schneider. Osage Orange. Circum. 7 feet, height 45 feet, Merchants Road, corner of Culver Road.

Magnolia acuminata L. Cucumber Tree. Circum. 6.5 feet, height 55 feet, 455 Lake Avenue.

Magnolia macrophylla Michx. Large-leaved Cucumber Tree. Circum. 4 feet, height 25 feet, near the Ellwanger & Barry Office. Mt. Hope Avenue.

Liriodendron Tulipifera Lam. Tulip Tree. Circum. 8.3 feet, height 80 feet. 5 Livingston Park.

Asimina triloba Adans. Papaw. Circum. 1 foot, height 25 feet, one mile north of Adams Basin.

Crataegus Ellwangeriana Sargent. Ellwanger's Hawthorn. Circum. 3.7 feet, height 25 feet, Grass Walk Nursery, Mt. Hope Avenue.

Libocedrus decurrens Torr. Incense Cedar. Circum. 2.5 feet, height 35 feet, Winton Road, Old Yale Nursery grounds, planted about 1860.

Chamaecyparis Lawsoniana Parl. Lawson's Cypress. Circum. 4.9 feet, height 40 feet, Ellwanger & Barry vineyard, Highland Avenue, planted about 1855.

Juglans regia Linn. Persian or English Walnut. Circum. 7.6 feet, height 45 feet, Ridge Road, village of Greece.

Juglans regia L. + *Juglans cinerea L.* English Walnut crossed with Butternut. Circum. 8.5 feet, height 50 feet, 1210 Culver Road.

Populus nigra L., variety *betulifolia* Torr. Black Poplar. Circum. 9.4 feet, height 80 feet, Edgerton Park.

Quercus cerris L. Turkey Oak. Circum. 5 feet, height 40 feet, Edgerton Park.

Quercus alba L. + *Quercus platanoides* Sudw. White Oak crossed with Sycamore Oak. Circum. 10.6 feet, height 70 feet, Maplewood Avenue near Driving Park Avenue.

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Ulmus campestris Smith. English Elm. Circum. 14.3 feet, height 102 feet, East Avenue corner Oxford Street, planted 1850.

Ulmus Hollandica, variety *vegeta* Rehder. Huntingdon Elm. Circum. 9.1 feet, height 80 feet, southeast corner of Goodman Street and Highland Avenue.

Ulmus Hollandica, variety *superba Rehder.* Huntingdon Elm. Circum. 18.35 feet, height 70 feet, in front of the Ellwanger and Barry Office, Mt. Hope Avenue.

Gymnocladus canadensis K. Koch. Kentucky Coffee-tree. Circum. 5.5 feet, height 55 feet. Genesee Hospital, Alexander Street.

Sophora Japonica L. Japanese Pagoda Tree. Circum. 7.4 feet, height 45 feet, 88 University Avenue.

Cladrastis lutea K. Koch. Yellow Wood. Circum. 6.5 feet, height 60 feet, near Ellwanger & Barry Office. Mt. Hope Avenue.

Acer campestre L. English Field Maple. Circum. 9 feet, height 40 feet. 360 West Avenue.

Acer cappadocicum Gled. Oriental Maple. Circum. 7.2 feet, height 50 feet, 973 East Avenue.

Acer opalus Mill. Italian Maple. Circum. 6.2 feet, height 35 feet, Highland Park, 200 feet east of Mt. Hope Avenue.

Acer macrophyllum Pursh. Large-leaved Maple. Circum. 9 feet, height 45 feet, Winton Road, old nursery grounds. T. B. Yale and Son.

Aesculus turbinatus Blume. Japanese Horse-chestnut. Circum. 5.5 feet—2 feet above base, height 35 feet. Ellwanger and Barry grounds, near South Avenue.

Tilia petiolaris DC. Weeping Linden. Circum. 8.3 feet, height 60 feet, Livingston Park.

Paulownia imperialis Sieb & Zuce. Paulownia Tree. Circum. 6.7 feet, height 55 feet, 66 James Street, planted in 1890.

Catalpa speciosa Engelm. Western Catalpa. Circum. 8.1 feet, height 60 feet. Highland Avenue in front of Ellwanger & Barry Vineyard, planted about 1855.

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Monroe County Parks

On October 2, 1926, interest in tree and plant life in Rochester and vicinity received a fresh impetus. On that date, the county of Monroe, by an act of legislature, was given authority to form a county Park Commission. This was done and a Board of Park Commissioners was appointed. The members of this board were: Charles J. Brown, President; Morris Clark, Vice President; J. Franklin Bonner, Alphonse Klem, William Kittleberger and Solomon Levin. Meade B. Rappleye was appointed Secretary and George Y. Webster, Counsel. Raymond E. Phillips was later appointed Superintendent. At the present time Theron E. Bastian, Fred Gleason and George A. Johnson are members of this board and Herbert W. Pierce has succeeded Meade B. Rappleye as Secretary.

These county Parks were not created with the purpose of duplicating the City Parks either in the æsthetic or recreational sense. Their purpose is to provide large open areas with attractive scenery, places where meals can be cooked and games and sports of all kinds can be enjoyed. These Parks are to be located in various places in the county where they will be most accessible to all users and will be connected by wide parkways varying in width from 100 to 1,000 feet.

In December 1926, a detailed survey was made of the Park needs of the county by Herbert Blanche, Landscape Architect, and Carl Crandall, Engineer. The major developments proposed by them consisted of six Parks and seven connecting Parkways. At the present time the Park Commission has under its jurisdiction five of these Parks, a total of 3,357.19 acres. The sixth park at Nine Mile Point has not yet been acquired.

These County Parks have been developed and opened to the public and in 1930 a total of 726,000 people used these Parks. They have already proved their worth and are filling a need long felt by the residents of this county. Progressing as they are, it will not be long before the Monroe County Park system is on the same high plane as the City Park system.

Editor's Note: The eminent horticulturist, Dr. Liberty Hyde Bailey, saw the proof of the above article, and made comment as follows:

"These large and well kept collections constitute a living museum of plant materials to which horticulturist, botanist, artist and nature-

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lover may go for study and retreat. They are an outstanding asset to the country at large, worthy of emulation in other geographical regions. Speaking for myself, I find these parks an unending source of information and inspiration. We shall all be glad to have this new report on arboriculture in Rochester from the Academy of Science."

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HEMLOCK LAKE
View looking southwest from Bald Hill

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PROCEEDINGS OF THE ROCHESTER ACADEMY OF SCIENCE
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HISTORY AND ENGINEERING OF ROCHESTER'S WATER SUPPLY IN ITS FIRST CENTURY

BY EDWIN A. FISHER

CONTENTS

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Introduction

The purpose of this paper is to make an available record of the water service in the first century of a prosperous American city. This city was incorporated in 1834 with an area of about 6¼ square miles and a population of about 15,000. Its domestic supply for the first 42 years until 1876, when its area had increased to about 7½ square miles and its population to about 75,000, was from wells and springs. The water for fire protection up to the year 1874 was from the Genesee River, the Erie Canal and the water power canals. These supplies were supplemented for a part of the time by cisterns located in different parts of the city and supplied through cast iron pipes connected with the Erie Canal and the power canals.

In 1872 the City was authorized by the Legislature to construct a public water supply, and after careful investigation very wisely selected Hemlock Lake, one of a series of four parallel lakes at a distance of about 30 miles from the City, having an elevation of nearly 400 feet above the general elevation of the City, as the source of supply. The quality of water for domestic use was unexcelled by any supply in America. Canadice Lake situated easterly and about 200 feet above Hemlock Lake, the outlet of which originally ran into Hemlock Lake, was also taken over as part of the domestic supply.

The other two lakes mentioned, Conesus Lake to the west of Hemlock Lake and somewhat lower in elevation, and Honeoye Lake to the east and lower than Hemlock Lake, were also considered as additional sources of supply. The paper details the work of increasing the original supply.

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The territory involved in this writing is mapped in detail in the following sheets of the Topographic Map of New York, published by the United States Geological Survey: Rochester, Caledonia, Honeoye, Canandaigua, Portage, Nunda, Wayland, Naples.

General Data

Rochester is situated in the County of Monroe, State of New York. The center of the city is about seven miles south of Lake Ontario. It lies in latitude 43° 8′ N. and longitude 77° 42′ W. The central portion of the city is about 263 feet above mean lake level of Ontario and 510 feet above mean tide water. The city is bisected by the Genesee River, which flows through it from south to north. The river has three falls and several rapids within the corporate limits, having an aggregate descent of about 257 feet, affording power to many manufactories. The drainage area of the river at Rochester is 2,365 square miles.

It is the third city in New York State, both in point of population and industrial importance. The total area is about 35 square miles; total length of streets about 520 miles, and the total length paved about 400 miles, or about 77 per cent.

Population by the U. S. Census 1930:

Rochester City	328,132
Metropolitan District	398,591

Water Systems in Use

There are three systems of water works supplying the City;

1st. A gravity system of potable water owned and operated by the City and commonly known as the "Domestic System."

2nd. A direct pumping system, taking water from the Genesee River, commonly known as the "Holly System," which is owned and operated by the City, for fire purposes only.

3rd. A pumping system of potable water taken from Lake Ontario, owned and operated by the Rochester and Lake Ontario Water Company and commonly known as the "Ontario System." This company supplies all of the 23rd and 24th wards, parts of the 20th, 15th and 10th wards on the west side of the City; also parts of the 18th, 21st and 22nd wards on the east side of the City.

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Domestic System

The source of the gravity system is Hemlock Lake, situated in the hilly district 30 miles south and about 386 feet above the general level of the city. (Frontispiece, plate 22.)

The area of this lake at ordinary low water is 1,828 acres.
Average depth in the middle—65 feet.
Catchment area, including water surface—48.00 square miles.
The total catchment area tributary to Hemlock Lake, including Canadice Lake is 66.20 square miles.
Capacity of present systems—30,000,000 gallons per day.
(Hazen, Eddy and Fisher Report)

Use in 1930	30,100,000 gallons per day
Use in 1929	31,527,000 gallons per day

There are three reservoirs connected with the system: A storage reservoir at Rush, about nine miles south of the center of the city and 224 feet above the general elevation thereof, having a capacity of 63½ million gallons; and two distributing reservoirs, situated on the southern border of the city, and both about 110 feet above the general elevation of the city.

The old distributing reservoir, known as Mt. Hope or Highland Reservoir, has a capacity of 22½ million gallons; the new Cobb's Hill Reservoir, put into service August 20, 1909, has a capacity of 144 million gallons.

This potable water supply is brought to the city by three gravity conduits:

Conduit I, from Hemlock Lake to Rush Reservoir, constructed during the years 1873–1875, is composed of 9.62 miles of 36-inch riveted wrought iron pipe 3/16 inch thick, and 2.92 miles of 24-inch riveted wrought iron pipe 3/16 inch and ¼ inch thick, and the balance, 6.83 miles, is 24-inch cast iron pipe. The second section, from Rush Reservoir to Highland Reservoir consists of 8.86 miles of 24-inch cast iron pipe. The total length is 28.23 miles and the daily capacity about 6,500,000 gallons.

Conduit II, from Overflow No. 1, about 2¼ miles north of Hemlock Lake, to Highland Reservoir, with connections at Rush Reservoir, is a 38-inch riveted steel pipe 26.19 miles in length and was built during the years 1893–1894. This pipe is made of steel plates ¼ inch, 5/16 inch and ⅜ inch thick. Water is brought from Hemlock Lake to Overflow No. 1 through a 6-foot brick horseshoe shaped

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tunnel 2.25 miles in length. The daily capacity of Conduit II is about 16,500,000 gallons.

Conduit III, from Overflow No. 1 to Pinnacle T, with connections at Rush Reservoir, was built during the years 1914–1918 and is composed of 7.75 miles of 37-inch cast iron pipe and 17.74 miles of 37-inch Lock Bar steel pipe ¼ inch and 5/16 inch thick. From Pinnacle T to Cobb's Hill Reservoir the pipe line consists of 1.57 miles of 36-inch cast iron pipe laid in 1905–1906. The total length of Conduit III is 27.06 miles and the daily capacity is about 19,000,000 gallons. The total daily delivering capacity of the three conduits is 42,000,000 gallons.

Two lines of 36-inch pipe lead from each of the distributing reservoirs, extending in a generally northerly direction, with successive reductions to 30, 24, 20 and 16-inch pipe. Secondary feeders of 12 and 16 inches in diameter complete loops about generally large areas. Minor distributors are of 10, 8, 6 and 4-inch pipes. The so-called Charlotte System consists of the mains in the former village of Charlotte which were acquired by annexation. Water is purchased by the City from the Rochester and Lake Ontario Water Co. and distributed to the consumers.

The total miles of distributing mains to January 1, 1931, are as follows:

Domestic System	492.75 miles
Holly System	25.40 miles
Charlotte System	9.75 miles
Ontario System	32.90 miles
Total	580.8 miles

Meterological Observations, Runoff Record and Conduit Gaugings by the Water Department

Rainfall records have been kept for 52 years at Mt. Hope Reservoir, Rush Reservoir and Hemlock Lake, the average for 48 years, Mt. Hope Reservoir 29.15 inches; Rush Reservoir 26.47 inches; Hemlock Lake 28.45 inches (Compared with U. S. Station at Rochester, N. Y., of 32.41 inches).

Temperature records for the same period and for the same average, 48 years, Mt. Hope Reservoir, air 48.14°F. and water 49.76°F.; Rush Reservoir, 41 years, average of 37 years, air 45.57°F.; Hem-

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lock Lake 52 years, average 48 years, air 48.32°F., water 50.86°F.

Evaporation records at Mt. Hope Reservoir commenced in 1896 and have been continued to date. The average evaporation for the floating tub for 31 years was 31.83 inches. The average precipitation for the same time was 32.58 inches.

Runoff records of Hemlock and Canadice lakes, based on gaugings maintained for 30 years, is an average of 37,000,000 gallons per day. Hazen, Eddy and Fisher Report.

Gaugings of Water Works Conduits

The different sections of each of the three Rochester Water Works Conduits were gauged soon after completion and in general these measurements of flow have been made annually since 1894. Tables are published showing the date of gauging, the duration, the character of the conduit, its length, the loss of head, the velocity, the discharge in cubic feet per second, and also gallons per day and the coefficient in the formula $c = V \div \sqrt{Rs}$.

History of the Water Supply

First Period—1834-1872

The history of water supply in this City since its incorporation in 1834 may be divided into five periods. The first period may be characterized as the period when efforts of the City authorities were centered upon getting a water supply from private corporations. This period may also be subdivided into two divisions, the first from 1834 to 1852. A private water company was incorporated under the name of the Rochester Water Works Company in 1835. Nothing was accomplished by this company and its charter expired in 1852.

Mention may be made of the efforts of Elisha Johnson, a former Mayor, who submitted a report by resolution of the Council in 1838, in which he urged the great importance of the construction of water works and recommended the taking of water from the Genesee River a short distance south of the City, etc. Nothing was done with this report.

The second division of the first period, a period of 20 years from 1852 to 1872, was chiefly occupied by the City authorities in an endeavor to obtain a water supply through a private company or-

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ganized in 1852.[1] During this period several contracts were executed, upon the recommendation of special committees of the Council, between the Council and the private water company. All of them failed by reason of the private company not carrying out its part of the contract.

In the valedictory message of Mayor Scrantom in March 29, 1861, he said: "The contract for a supply of pure water, executed under the sanction of this Board, and to which validity has been given by the Legislature of the State, affords me the highest gratification, and the completion of the works contemplated by that contract, will give me a satisfaction equal to any that I have experienced in connection with matters of public import." This contract was never carried out.

The several committees making the investigations and reports lacked any definite engineering information relative to a suitable plan for a water supply. The only action by the Council with reference to an engineering report was first in March 22, 1853, where the City Surveyor was directed to make necessary surveys and investigations for a feasible plan for obtaining water and constructing works at an expense not exceeding $300. This resolution was modified so that the report should be made by a special committee; and nothing was done under it. The only other engineering report was by Daniel Marsh, who was at one time Engineer for the private company. This report was made under a resolution adopted by the Council requesting the Water Works Company to report the expense of a survey from Hemlock Lake to the City.

The Committee on March 20, 1860, submitted a report that they had received three propositions; first Mr. Silas Cornell proposed to survey one route with maps for $250; Mr. Penny one route with

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[1] The Common Council in 1859 adopted, after considerable discussion, an ordinance for laying cast iron water pipes six inches in diameter connecting Childs basin of the Erie Canal with reservoirs in some of the city streets for increasing fire protection. These reservoirs were generally 10 feet wide by 20 feet long and the bottom 16 feet below the surface of the streets.

The ordinance also provided for repairing three old reservoirs which will be supplied by said pipe.

The estimated cost of constructing three new reservoirs 8 x 16 feet in the clear and 14 feet below the level of the street, laying an iron water pipe from Childs basin to Mumford Street and repairing those in Ann Street, was $2,384.

In February 15, 1859, George B. Harris, Chief Engineer of the Fire Department, reported that the covering of the reservoir in front of the City Hall was unsafe, liable at any time to fall in, and also reported that the reservoir leaked at the rate of one inch in depth per hour.

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maps, etc., for $150; and Mr. Marsh proposed to furnish a complete system of surveys, etc., for a sum not exceeding $500. The Committee recommended that the work be given to Mr. Marsh, which report was approved by the Council at the same meeting.

The report of Mr. Marsh provided plans and estimates for five distinct plans, one, Lake Ontario; two, the Genesee River at the Rapids; three, Little Black Creek; four, Outlet of Honeoye Lake near Smithtown; and five, by taking water directly from Hemlock Lake in a 16″ pipe to a distributing reservoir. Three kinds of pipe were presented for consideration, namely, one, iron pipe; two, cement pipe with a frame of sheet iron; and three, banded wood pipe laid in cement, and the comparative cost of each was presented. No action leading to a public water supply was taken on this report.

On December 26, 1865, Mr. D. D. T. Moore, Mayor, called attention of the Council to the fact that the contract of the City with the Rochester Water Works Company for a supply of water, etc., expires with the current year and suggested the propriety of renewing the contract for a limited period; and if the Company failed to commence their works the coming season that it might be advisable for the City to undertake the important enterprise. The Committee reported on January 9, 1866, against granting a renewal, and said in conclusion of their report, "your Committee is of the opinion that if this contract was not given to this Company five years ago, Rochester would be supplied to-day with water works."

On June 2, 1869, a resolution was introduced "That the Board of Common Council of the City of Rochester will heartily co-operate with the Rochester Water Works Company in the construction and completion of said works." Prior to this, however, on January 8, 1867, Ald. Kelley introduced a resolution which was adopted, in which he stated, for the purpose of setting at rest all anxiety and uneasiness on the part of the taxpayers of the City with reference thereto, "Be it resolved that it is the firm and unaltered purpose of this Board that under no circumstances and upon no consideration whatever will the Board of Common Council at any time entertain favorably a proposition to issue the bonds of the City for any amount for the purpose of taking stock in the said Water Works Company." After considerable discussion the resolution was adopted, 21 to 4.

In this connection it might be interesting to include a remonstrance by a large number of citizens against taking stock or loan-

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ing moneys to the Rochester Water Works Company. A large public meeting was held at the City Hall on Monday evening, October 8, 1855, in which it was resolved among other things, "that we regard with anxiety and alarm the proposal of a scheme which will so largely increase the enormous burden of taxation, by which the enterprise and prosperity of our city are already depressed." The present funded debt of the City is $446,000. The proposed measure will add now $350,000, making the whole debt $796,000. The population at this time was about 42,000.

The Charter of the Water Works Company provided that the Company might issue bonds to the amount of $800,000 and the same amount in stock. The City was also authorized to take $150,000 of stock in the Company and also to loan the Company the proceeds of an issue of $200,000 in bonds.

Construction Work of the "Water Works Company"—Mr. Tubbs in an article in Peck's History of Rochester gives a report made to the Water Company's stockholders December 2, 1871, by McRee Swift, a Civil Engineer, from which the following extracts are taken:

"The works, so far as completed, consist of:

First—a canal eighteen hundred feet long by twenty feet wide, by seven deep at the lake with the weir partially constructed, as above referred to.

Second—a wooden conduit twenty-four inches in diameter by sixteen and one fourth miles.

Third—a reservoir about two thirds completed near East Henrietta. This reservoir measures, at the middle of the embankment, seven hundred by eight hundred feet and is twenty-one feet deep, and, when completed and filled to within three feet of top, will contain 70,000,000 gallons, a supply for twenty days at a full estimate for consumption.

Fourth—a small distributing reservoir on the outskirts of the city, too small for purposes of a reservoir. . . .

Fifth—seven and one-half miles of cast iron distributing pipe in the city, and six miles of wrought iron (lined with and laid in hydraulic cement) distributing pipe, all with partial appendages of gates, hydrants, etc.

Sixth—a farm of one hundred and ten acres near the lake, with mill and houses upon it, and which cost $21,000, upon which $10,500 is paid.

Seventh—a plat of fifty acres near East Henrietta, upon which the large distributing reservoir is located, and lastly the right of way across private property, at the upper end of conduit for a distance of about four and one-half miles."

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"From the examination I was enabled to make, I am forced to conclude that the wooden pipe cannot be relied upon." [2]

Mr. Swift's estimate of the total value of work done was $222,738. His estimate for completing the work ready for use was $410,067.

The bondholders evidently came to the conclusion that they had been badly swindled, and proceedings were commenced to foreclose the mortgage on the water-works property, given to secure payment of the bonds. It appears that a sale had been fully consummated early in 1872, as on the 28th day of May, 1872, Thomas B. Rand and Associates presented a memorial to the Common Council, representing that they had become the owners of the lands, property, estate, reservoirs, pipes, rights of land and water, water works, fixtures and appurtenances and the rights and franchises of the Rochester Water Works. They stated that they have become satisfied that the wooden conduit pipe laid from Smithtown to the city is not sufficient and needs to be relaid of iron. They offered to complete the works during the year 1872 and 1873 to the amount of 40 miles of distribution and to connect hydrants thereto each four hundred feet, etc.

A contract was finally drawn and presented to the Common Council, which provided that the compensation to be paid by the City for such use of water should be $70,000 per annum for four hundred hydrants and $100 per annum for each fire hydrant exceeding that number.

Mr. Thomas B. Rand and Associates, soon after their purchase of the assets of the old company, organized a new company under the title of the Rochester Water Company. It made strenuous attempts to dispose of its property to the Water Commissioners at prices ranging from $250,000 to $90,000, and finally on the 18th day of August 1882, the City made a purchase of all the property of the Rochester Water Company for the sum of $26,000, a falling off in value, even from the $223,000 estimated by McRee Swift in 1871.

The ruins of the projected reservoir are indicated on the Rochester topographic sheet, one and one-half miles east of north of the existing Rush Reservoir. And another relic is a 24-inch cast iron gate, for the wooden conduit, figure 1.

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[2] Some of the farmers along the line said that the wooden pipe wouldn't hold white beans, let alone water.

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SECOND PERIOD—1872-1890

Public Water Supply. This period covers construction, maintenance and operation of the original public supply. The works were constructed by and maintained under the charge of J. Nelson Tubbs, who was appointed Chief Engineer on May 7, 1872.

In 1872, Chapter 387, entitled "An act to supply the City of Rochester with pure and wholesome water," was passed by the Legislature. Mayor A. Carter Wilder appointed five citizens as

Figure 1. IRON GATE
Intended for use in the wooden conduit. 24-inch

commissioners, Roswell Hart, Edward M. Smith, William H. Bowman, Charles C. Morse and Gilman H. Perkins. Soon after the organization of the Board at a meeting held May 7, 1872, Isaac F. Quimby was appointed Consulting Engineer for the Commission.

The plan proposed by the Commissioners may be summarized as follows: To furnish from Hemlock Lake a supply of 4,500,000 gallons of water per day through an iron conduit, or one of iron for the greater part of the distance and the balance of brick, with a storage reservoir in Rush and a distributing reservoir on the Mt.

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Hope range of hills near the City; also to furnish a supply of water from the Genesee River by direct pressure on the Holly direct pressure plan, for the furnishing of light, power and for suppression of fires on the compactly built portions of the City, the water to be distributed through 40 miles of cast iron pipes in the streets of the City. The estimated cost of the combined system was $2,-184,000.

The Mayor promptly approved of the plan proposed by the Water Commissioners and directed the Chief Engineer to prepare plans, etc., for a public letting of the whole work. Mr. Tubbs said:

"Soon thereafter Emil Kuichling, who had just completed an engineering course of study in the Polytechnic School at Carlsruhe, in Germany, was appointed Principal Assistant Engineer, a position which he has retained to this date, giving evidence during the whole period of service of most excellent training and a remarkable aptitude for his profession and great ability in the practical working out of the ever-varying problems of water-works construction and management."

A contract for the construction of the Hemlock Lake System was awarded on the 12th day of April 1873, to James McDonald of Willsborough Falls. A contract for the construction and setting in place of the pumping machinery in connection with the Holly system had been previously executed February 27, 1873, with the Holly Manufacturing Company of Lockport, N. Y.

The work of laying the mains in the streets was commenced early in the summer of 1873, and continued up to about January 1, 1874. In cases where both Holly and Hemlock mains were laid in the same street they were laid in the same trench. The Holly System was so far completed that on and after January 1, 1874, it was brought into use for the extinguishment of fires.

Official Test of the Holly System. The official test of the Holly System is described by Mr. Tubbs in a supplementary report dated February 20, 1874. A test occurred on February 18 the same year.

"The hydrants used for throwing fire streams were located on East and West Main streets, between the Erie Canal and North Street. The first test consisted in throwing 14 fire streams at once, alternately by the pumps operated by water power and by steam, the change from one to the other set of machinery not being observable by those watching the streams. The height of these streams, determined by instrumental observation, varied from 131 to 152

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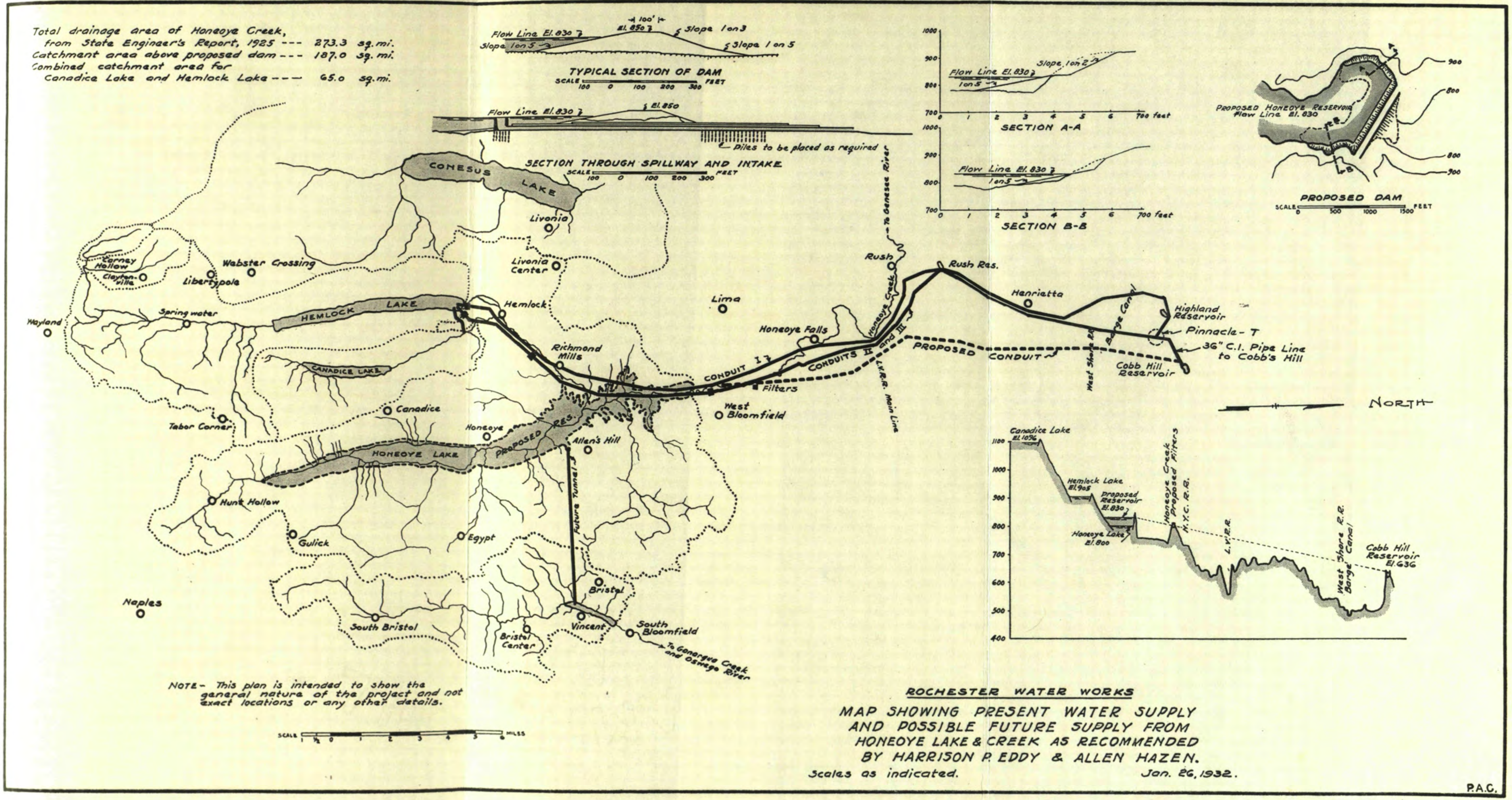

ROCHESTER WATER WORKS

MAP SHOWING PRESENT WATER SUPPLY AND POSSIBLE FUTURE SUPPLY FROM HONEOYE LAKE & CREEK AS RECOMMENDED BY HARRISON P. EDDY & ALLEN HAZEN.

Scales as indicated. Jan. 26, 1932.

P.A.C.

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feet. During this test the pressure at the pumps was maintained at 120 pounds per square inch. The second test of fire streams consisted in throwing thirty streams at once. . . . The height of the streams was about the same as in the previous test and the pressure maintained at the pumps was 135 pounds per square inch. Water was discharged at the rate of 8,220 gallons per minute. The third test consisted in throwing a two-inch stream in front of the court house. Although at no time fully vertical, yet, when it most nearly approached that condition, the observations showed an elevation of 210.34 feet. The pressure maintained at the pumps was 165 pounds per square inch and the discharge was at the rate of 1,215 gallons per minute. The fourth test was a three-inch vertical stream, thrown from a point near the corner of State and West Main streets, during which a pressure of 175 pounds per square inch was maintained at the pumps. The discharge was at the rate of 2,778 gallons per minute and the elevation reached by the stream was 285.98 feet."

"Another test consisted in throwing a four-inch vertical stream to an elevation of 294.4 feet. The rate of discharge was 4,938 gallons per minute and the pressure at the pumps was 175 and at the stand pipe 165 pounds per square inch. A second test of the four-inch stream consisted in throwing the same horizontally a distance of 465 feet, only the solid jets of water being measured. The final test consisted of throwing a five-inch vertical stream to an elevation of 256.8 feet, discharging at the rate of 6,463 gallons per minute. As this stream was intended to show volume and not height the pressure at the pumps was only raised to 140 pounds. . . . It is believed that this was the most remarkable exhibition of large streams ever made in any country, and as such it attracted widespread attention from hydraulic engineers, compelling the introduction of larger factors in the hydraulic formulas used to determine the results to be obtained from large streams, with liberal-sized pumping mains."

Mr. Tubbs gives the total cost of the works to April 1, 1884:

Proceeds of water bonds issued for constructing	$3,182,000
Paid for two additional water rights on Brown's race	7,500
Raised by taxation for pipe extension and other miscellaneous expenses	466,549
Total	$3,656,049

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Water Famine. Mr. Tubbs in his report dated April 1, 1889, under the heading "Existing conditions which render an additional water supply necessary," said "During the extreme cold of January and February, 1885, the draft upon the water mains and the reserve water in the two reservoirs became so great, that I felt compelled to call the attention of the Executive Board to the imminence of a water famine unless stern repressive measures were at once adopted to check the waste. A vigorous house to house inspection was at once instituted. . . . During the extreme heat of each succeeding summer and the coldest part of each winter up to 1887, there were periods when the uses of water were greater than any possible supply through the conduit, . . ."

Under another heading "The remedy for existing conditions," he said: "Two plans have been suggested, one of which proposes a reduction in the amount of water used and wasted from the present system by the immediate and universal application of meters to all water services. The other is the construction of another conduit for conveying additional water from either Hemlock Lake or some other source of supply."

Mr. Tubbs then proceeds to discuss the different sources of an additional supply, and estimates and recommends a daily supply of 10,000,000 gallons of water from Hemlock Lake by means of a combined pumping and gravity plan.

The plans of Mr. Tubbs for a pumping and gravity system did not appear to be generally accepted and the matter was submitted on February 16, 1889, to the well known engineers, Messrs. A. Fteley of New York, and J. T. Fanning of Minneapolis, for investigation. Several new surveys were made under their direction and on May 14, 1889, they reported in favor of either Hemlock Lake or Conesus Lake as a proper source, and that the new conduit should have a capacity of 15,000,000 gallons per day. While their plans differed in detail from those of Mr. Tubbs, they agreed with the latter as to the source and required quantity.

No definite action upon these reports was taken by the municipal authorities, and the agitation of the subject was briskly continued by the promoters of other plans. Meanwhile it became evident that temporary relief would be needed, even if the construction of a new conduit to Hemlock Lake were authorized. The only remedy to prevent the depletion of the reservoirs was to restrict the consumption in the city to the delivery of the conduit, by suitably throttling

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for a portion of the day a few of the stop-valves in the principal mains at the foot of the hill on which the distributing reservoir is situated. This plan was accordingly adopted in June 1890, and was retained with some modifications until August 1894.

In June 1890 a close gauging of the flow of the conduit into Rush Reservoir was made, which revealed the fact that its actual delivery was then only about 6,730,000 gallons per day. The facts are well stated in quotation from two reports by Mr. Kuichling in later years. In his report to the Executive Board, published in 1901, he says:

"Water from Hemlock Lake was first delivered into Rush Reservoir on January 22, 1876, and into Mt. Hope on the day following. Gaugings of the capacity of the conduit were undertaken soon afterward by L. L. Nichols, C.E., one of the Assistant Engineers employed for construction of the works. The result of several gaugings indicated that the conduit was delivering from Hemlock Lake into Rush Reservoir 9,000,000 gallons per day."

And from his report in 1894 and 1895, on the same subject:

"It should be remarked that up to June 1890 it had been taken for granted that no appreciable diminution in the discharging capacity of the old conduit had occurred, and that it was still continuing to deliver about 9,000,000 gallons per day. At that time, however, a close gauging of its flow into Rush Reservoir was made which revealed the fact that its actual delivery was then only about 6,730,000 gallons per day. The discrepancy between these two discharges could not be accounted for by leakage or abstraction of water from any portion of the conduit, and hence it was evident that its efficiency had become impaired."

On July 18, 1890, Mr. Tubbs resigned his position as Chief Engineer and from that date to September 6, 1890, Mr. George W. Rafter was Acting Chief Engineer. On September 6 Mr. Emil Kuichling was appointed Chief Engineer. At that time a very heated discussion was going on as to the reasons for the loss of delivery in the conduit, with propositions, plans and projects for increasing the supply. Various explanations were given by numerous correspondents in the local press for months after the fact was announced. The public discussion and agitation is indicated in an article in the Post Express of August 9, 1890. Referring to the position of Chief Engineer it said:

"If Emil Kuichling ever comes to Rochester to accept the position of Chief Engineer of the Water Works it will be on conditions named by him; and one of the conditions will be that every architect, the Chamber of Commerce, and every crank in town shall not be his superior officer, and that his opinion

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on strictly engineering subjects shall go and not be modified to suit the ideas of every newspaper correspondent."

Third Period

September 6, 1890 to December 31, 1899

Additional Supply. The third period includes the construction of the second conduit from Hemlock Lake to the City. During this period work was under the charge of an Executive Board of three members. Mr. Emil Kuichling was the Chief Engineer during this period. Mr. Kuichling, as stated, was appointed Chief Engineer on September 6, 1890. Early in October 1890 he was requested to investigate the various general plans for a permanent additional water supply which had previously been submitted by other engineers heretofore mentioned, and to make such further examinations as he might deem necessary.

After a careful investigation of various sources of supply the preference was finally given to Hemlock Lake by all the municipal authorities on June 16, 1891. A bill was introduced in the Legislature early in 1891 allowing the City to take an additional water supply from Hemlock Lake or Conesus Lake, and to bond itself for the necessary cost in the sum of $1,750,000. This bill failed of passage. A new bill similar to the one above mentioned was introduced early in 1892 and became a law on April 20, 1892.

Mr. A. Fteley, Chief Engineer of the Croton Aqueduct Commission was retained as Consulting Engineer by the Executive Board.

Description of Plans. The plans for the new conduit contemplated the construction of a brick conduit of horseshoe shape construction about six feet in diameter on a grade of one in 4,000 from Hemlock Lake northerly for a distance of about 12,000 feet. Seventy-five hundred feet of this was in tunnel. A screenhouse was to be built at the shore from which a steel intake pipe five feet in diameter and 1,600 feet long was to be extended into the lake to where the water was about 35 feet deep. The invert of the brick conduit in the gate house was to be about 17 feet below the low water level of the lake. From an overflow chamber at the end of the brick conduit the water was to be conducted either in a 36" cast iron or a 38" steel pipe conduit laid on a continuous hydraulic grade of about 1 in 570 for the total distance of nearly 26½ miles to its terminus in the city reservoir.

Bids were requested from contractors for the masonry conduit and the pipe work separately, the letting to take place on December

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23, 1892. Contract for the brick conduit and tunnel was let to William H. Jones & Sons of Rochester at an aggregate amount based on estimated quantities of $292,518.11. The contract for the pipe was awarded by the Executive Board on January 12 to the firm of Moffett, Hodgkins & Clark Company for $857,552.50, based on estimated quantities. The Company refused to accept the award and immediately secured an injunction preventing the Executive Board from declaring them in default and proceeding with the collection of the money on a bond of $90,000. The Company claimed that it had made an error in its bid due to too short a time to figure the contract.[3]

The Executive Board on January 20, 1893, awarded the contract to the next lowest bidder, Whitmore, Rauber & Vicinus of this city at the amount of the proposal computed from the prices and estimated quantities $1,123,920.

The work of manufacturing the steel pipes was divided equally between the East Jersey Pipe Works of Paterson, N. J., and the Rochester Bridge & Iron Works of this City. For the first named works the plates were made by the Carnegie Steel Company and for the second by the Paxton Rolling Mill at Harrisburg, Pa. Four classes of pipe formed of three different thickness of plate were manufactured and arranged according to the water pressure to which they would be subjected in the line of the conduit. The thicknesses of the plate used were $\frac{1}{4}''$, $\frac{5}{16}''$ and $\frac{3}{8}''$. Pipes were generally furnished in lengths of $27\frac{1}{3}$ feet.

Coating of Steel Pipe. Mr. Kuichling gave much study to the matter of preparing and applying a coating mixture to the smooth surface of the steel plates which would be durable, hard, tough and adhesive at all ordinary temperatures. Every effort was made to obtain materials of the best quality and also to apply the coating in the most approved manner.

The first half of the work done by the East Jersey Pipe Company

[3] The case entitled Moffett, Hodgkins & Clarke Company, Petitioners, vs. City of Rochester, George W. Aldridge, William W. W. Barnard and John U. Schroth, composing the Executive Board of the City of Rochester.

The case went first to the United States Circuit Court in which the decision was against the City. An appeal was taken to the Circuit Court of Appeals, which reversed the decision of the Circuit Court and decided in favor of the City. The Contractors appealed from the Circuit Court of Appeals to the United States Supreme Court, which Court on May 20, 1900, reversed the decree of the Circuit Court of Appeals and affirmed that of the Circuit Court, which was in favor of the Contractor. The opinion was delivered by Justice McKenna.

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was coated with California asphalt. That not proving satisfactory the second half was coated with a mixture of refined Trinidad asphalt and the best grade of coal tar, producing the same coating as had been applied to the old conduit laid in 1873. The remaining half of the pipe, constructed and laid by the Rochester Bridge & Iron Works, was coated under the direction of Prof. A. H. Sabin, by a process devised by him which was expected would be superior to any existing coating.

The new gate house and intake pipe at the lake was constructed by Chambers & Casey of this City. The total cost of the work up to January 1, 1896, was $1,776,911.86.

Temporary Additional Water Supply from Brighton Wells. A contract between the City and a private corporation known as the Rochester Water Supply Company was executed, and on July 12, 1893 the said Company commenced delivering about 500,000 gallons per day into Mt. Hope Reservoir from six artesian wells in the Town of Brighton. This supply continued until October 4, 1894.

Completion of the Second Conduit. On August 24, 1894, the water by the second conduit was first let into Rush Reservoir, and on October 9, 1894, into Mt. Hope Reservoir.

Reinforcement of Distributing Mains. Mr. Kuichling early in 1894 made plans for a new system of large distributing mains that had reference to the anticipated future growth of the city. The new mains were mostly 36″ and 30″ in diameter. The estimated cost of the work proposed for immediate construction was about $500,000. The diameters of the new mains were computed on the basis that with 150,000 persons using water at the rate of 150 gallons per head per day during the hours of greatest consumption, together with the discharge of 25 fire streams, each of 225 gallons per minute, the loss of head in said mains will be such as to leave a pressure from 18 to 25 pounds per square inch at the highest point in the city except in the immediate vicinity of the reservoir. Plans for the enlargement of the domestic mains in the city in addition to distributing mains were also prepared.

Fourth Period

January 1900 to January 1926

Administration. During this period the City was under the provisions of what is known as the Uniform Charter of cities of the

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second class. The former Executive Board was abolished. The general care and management of the Water Works came under the Commissioner of Public Works, the maintenance and operation under a Superintendent of Water Works and the engineering and construction under the City Engineer. Mr. Emil Kuichling, Chief Engineer and Superintendent of the Water Works prior to 1900, not desiring to continue longer in the service of the City retired and opened an office as Consulting Engineer in New York City.

Special Studies and Activities of the City Engineer. The work in the Water Works field during this period was:

First, a study of electrolysis in the water pipe system. Prior to this time the matter had been taken up to some extent by Mr. Kuichling. In 1900 the City Engineer made the most extensive study of the subject that had been made by any city. In his report was included a summary of what had been done in the way of investigations of proposed remedies in some 25 other cities. The policy then adopted was to carry on these investigations with the cooperation of the Street Railway, the Gas & Electric Company and the Telephone & Telegraph companies.

Mr. Joseph E. Putnam, Electrical Engineer for the City, was in charge of the electrical features of the investigation. Mr. Beekman C. Little, Superintendent of Water Works, also cooperated. Studies and investigations were continued for several years, and Albert B. Herrick, a Specialist on this subject, was employed to continue the studies and to suggest remedies. It should be stated that so far as known none of the water mains were affected, the only damage being to comparatively few of the services. The remedy applied in this City, as elsewhere, *was to see to it that sufficient unbroken capacity for the electric return current was provided.*

Second. Another extensive study was made of the corrosion of the steel pipe laid in 1893 and 1894. The steel plate of these pipes was from $\frac{1}{4}''$ to $\frac{3}{8}''$ in thickness. The corrosion consisted in small perforations from the outside at places where the coating had failed to protect the pipe. The pitting of the plate was first discovered in 1900. A very thorough examination of all portions of the conduit where these pittings had occurred was made under the supervision of the Principal Assistant Engineer, Mr. John F. Skinner. The late Prof. F. L. Kortright of the Department of Chemistry, of the West Virginia University, a Chemist of 15 years practical experience,

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trained in this country and in the schools of Carlsruhe and Zurich, was employed in this investigation.

Up to January 1, 1914, a total of 727 of these perforations were discovered and between 6 and 7 miles of the total of 26 miles of steel pipe had been recoated with a coating recommended by Mr. Kortright. The result of these investigations, and the remedies applied, were described in the reports of the City Engineer from 1900 up to the year 1914, and also published in a special report in 1913. This investigation was one of the most extensive that had been carried on on this subject. The effect of the pipe coating recommended by Mr. Kortright in preventing corrosion is shown by the fact that in this recoated portion, which was in that part of the line most susceptible to corrosion, only 198 perforations had occurred in 18 years, from 1914 to 1932, or an average of less than one per month.

In 1918 the steel portion of a third conduit 17¾ miles in length was completed on which the coating recommended by Prof. Kortright was used.

Third. The construction of a distributing reservoir on Cobb's Hill, as recommended by Mr. Kuichling for many years, was completed in 1908. This reservoir, when full at the same elevation as Mt. Hope Reservoir, has a capacity of 144,000,000 gallons. The area of water surface when the reservoir is full to the crest of the overflow is 18.2 acres. The plans for this work containing some novel features were described in the City Engineer's reports. The design and construction were under the general charge of John F. Skinner, Principal Assistant Engineer. The late Frederick P. Stearns was employed as Consulting Engineer with reference to special conditions of the lining. The accompanying sketch, plate 24, shows interesting features of the work.

Fourth. The extension of the distributing water mains and enlargement of the street system. In 1905 the National Board of Fire Underwriters' Committee of Twenty submitted a report on the fire conditions in Rochester. The City Engineer, at the request of Mayor Cutler, prepared a concise discussion of the report to show to what extent these recommendations had already been anticipated by the City. This report dated April 1, 1905, was printed in pamphlet form for distribution and discussed the requirements of the National Board of Fire Underwriters and gave in detail the improvements made in the domestic and Holly systems up to that time, and also the plans for future construction. The report re-

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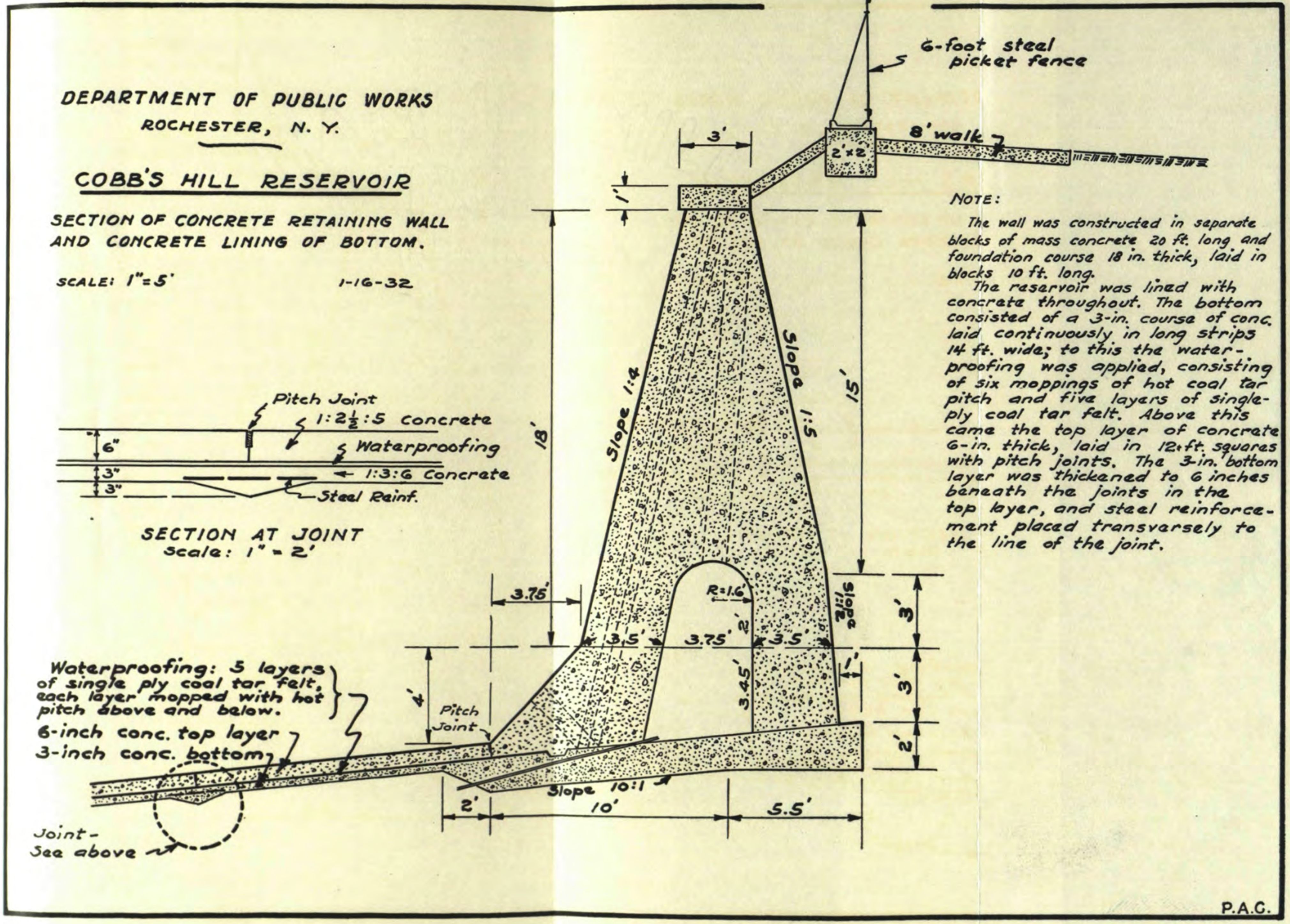

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ferred also to betterments of the Holly system which included doubling the actual capacity.

The Committee of Twenty carefully considered the report and in conclusion said with reference to the Water Supply, that "the statements of improvements already made, together with improvements in progress and contemplated, show that the Water Works and Fire Department were being maintained and developed in keeping with the increase in population and business of the City, and as far as practicable, substantially along the lines recommended by the Committee of the National Board."

Fifth. This study related to sanitation of the Hemlock Lake water.

Chapter 1018 of the Laws of 1895 provided for the "sanitary protection of the sources of water supply of the City of Rochester by the acquisition by said City of real property and interests therein necessary for that purpose and the abatement and removal of sources of pollution."

Commissioners were appointed by the Supreme Court to carry out the provisions of this act. The first Commission was composed of Ira L. Otis, Chairman, Sol Wile, Secretary, and Charles T. Chapin. H. N. Schlick later succeeded Mr. Otis. The Commission entered upon its duties in 1895 and on June 30, 1902, submitted its final report to J. Y. McClintock, Commissioner of Public Works.

The Commission purchased 187 parcels of land having a frontage on the lake of 73,572 feet, 94.4% of the total frontage on both sides of the lake. The purchase also included five hotels, 107 cottages, 121 barns and other buildings. The total cost of this purchase was $336,634.94.

The Commission also reported the amount of property unbought fronting on the lake, a total of 20 parcels having a frontage of 4,347 feet. Also included in these parcels were 14 cottages, 24 barns and other buildings.

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Report of This Commission

Henry N. Schlick,
Charles T. Chapin,
Sol Wile,
Commissioners.

HEMLOCK LAKE COMMISSION
241 Powers Block
Rochester, N. Y., June 30, 1902.

To the Honorable J. Y. McClintock
Commissioner of Public Works of the
City of Rochester

Dear Sir:

The Hemlock Lake Commission herewith submits its report as follows:

There has been placed to the credit of this Commission with the City Treasurer, viz.:

From the sale of bonds	$200,000.00
Premium on sale of bonds	11,650.00
Appropriation from Common Council	165,000.00
From the sale of buildings	1,245.44
Making a total of	$377,895.44

Our disbursements in full have been orders drawn on the City Treasurer, viz.:

Boat account	519.20
Expense account	3,453.74
Furniture account	105.00
Highway account	3,978.10
Land account	336,634.94
Rent account	1,504.36
Salaries, Clerk	750.00
Salaries, Commissioners	18,895.00
Search account	8,454.13
Stationery account	147.75
Survey account	2,026.63
Total	$376,468.85
Balance	1,426.59

Statement "A" hereto annexed is a detailed itemized statement of the several accounts representing our disbursements in full, showing to whom and amount paid; the lands account showing in addition the number of feet frontage and buildings included in purchases.

The balance of $1,426.59
to our credit is covered by our order on City Treasurer accompanying this report.

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CANADICE LAKE
View at foot of lake, looking south

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Herewith attached is certificate from City Treasurer of this date, showing total amount placed to the credit of the Commission and balance on hand.

There are no unpaid bills of the Commission.

Statement "B," hereto annexed, is a list of the properties fronting on Lake unpurchased, with number of buildings.

All our vouchers, books, deeds, searches and other properties belonging to the city are subject to your order, and we request a full and complete examination of the same.

Respectfully submitted,
Henry N. Schlick,
Sol Wile,
Chas. T. Chapin.

Sixth. The dike at the north end of Hemlock Lake was raised five feet providing additional capacity in the lake and avoiding the necessity of drawing the lake down as was previously contemplated.

Seventh. Canadice Lake (plate 25) from the time of construction of the original works had been considered as a part of Rochester's water supply. The outlet discharged into the Hemlock Lake outlet below the lake. No use of the water of Canadice Lake could be made in the City's supply until a connection between the two lakes was constructed.

In 1912, owing to the increase in population and use of water, a contract was awarded for the construction of a concrete dam and basin in the outlet of Canadice Lake near the main highway to Hemlock Lake and a 5-foot reinforced concrete pipe from this basin for a distance of about 4000 feet into Hemlock Lake. Extensive purchases of land bordering on Canadice Lake and its outlet were made prior to taking the water into Hemlock Lake. The water from Canadice Lake was also chlorinated before discharging into Hemlock Lake.

The water from Canadice Lake was turned into Hemlock Lake February 6, 1919.

It was also observed that the City was rapidly approaching the capacity of Conduits I and II and that immediate steps should be taken for the construction of the third conduit as originally contemplated. It may be noted here that the capacity of Conduits I and II corresponded substantially with the safe yield of Hemlock Lake alone.

The additional water supply of 1892 to 1894 provided for a brick conduit six feet in diameter, mostly in tunnel, from the lake to a point about 12,000 feet northerly. This conduit was of sufficient

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capacity to take the entire yield of the catchment area of both Hemlock and Canadice lakes. At the end of this brick conduit an overflow structure was erected. The second conduit of 38″ steel pipe began at this overflow and extended to Highland Reservoir in the City. At the time of the construction of this second conduit it was realized that an additional conduit would be required later and the right of way necessary for both conduits was secured for the entire distance.

Eighth. The third conduit was constructed in three general contracts.

Contract No. 1, extending from the overflow at the end of the brick conduit known as Overflow No. 1, to Factory Hollow, a distance of about 7.755 miles, was awarded on March 18, 1914, to the R. T. Ford Company for a 37″ cast iron pipe laid parallel to and 10 feet west of Conduit II, being cross-connected at four points. The work was started early in April 1914 and completed the following November.

Contract No. 2, extending from the north end of the cast iron pipe at Factory Hollow to Rush Reservoir, a distance of about 9.603 miles, was awarded on May 10, 1916, to the T. A. Gillespie Company for a 37″ Lock-bar steel pipe having plates ¼″ and 5/16″ thick, laid parallel to and 10 feet west of Conduit II. The work was completed in December 1916.

The contract price for the 37″ steel Lock-bar pipe was $44,235 less than the bid for cast iron pipe, or about $4,600 per mile. The average operating head on this part of the line is more than double that of the section south of Factory Hollow, which was constructed in 1914 of cast iron. The lock-bar pipe avoids the longitudinal rivets and develops the full strength of the plate.

Contract No. 3, extending from Rush Reservoir to the Pinnacle T on Clinton Avenue South, was awarded on March 15, 1917, to the T. A. Gillespie Company and consisted of about 8.143 miles of 37″ Lock-bar steel pipe laid parallel to and 10 feet west of Conduit II outside of the public roads and on the west side of the Henrietta Road and Clinton Avenue South. Owing to the difficulty of procuring steel on account of the War the work was delayed and completed late in 1918.

The plans and specifications for this conduit and its appurtenances, including the coating, were prepared by the Principal Assistant Engineer, Mr. John F. Skinner. Mr. Skinner also supervised

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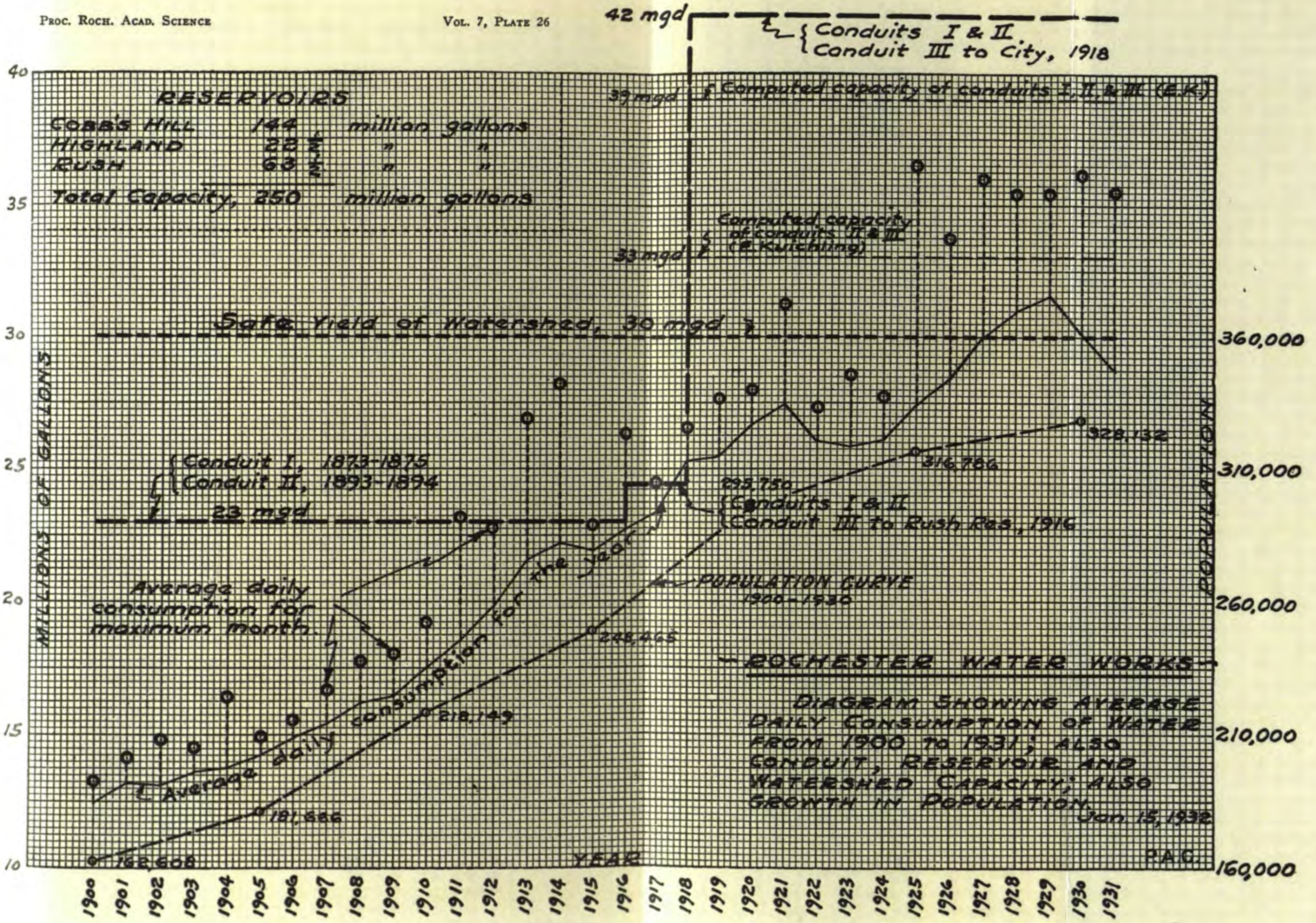

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the construction until the 15th of September 1918, when he entered the United States War Service as Sanitary Engineer. From this time until its completion the work was under the supervision of Irving E. Matthews, Second Deputy City Engineer. The estimated cost of this line, including the three contracts, is approximately $1,550,000.

The Pinnacle T in Clinton Avenue referred to is where the second conduit branches off to Highland Reservoir, and where a cast iron main was laid in 1908, which now connects both the second and third conduits directly with Cobb's Hill Reservoir. The length of this cast iron pipe was 1.57 miles.

It will be noted that after completing the third conduit the next consideration should be toward increasing the capacity of the watershed and studies by the Engineering Deparment under the general direction of Mr. Skinner were made with a view of using Conesus Lake as an additional supply. Also studies relating to the use of Honeoye Lake were made.

Ninth. The capacity of the watershed is shown in the diagram, plate 26.

This diagram shows the average daily consumption for the years from 1900 to 1931; also the maximum daily average for any month during the same period. The diagram also shows that the total actual capacity of the three completed conduits is 42,000,000 gallons per day. This amount is 3,000,000 gallons more than the estimated capacity by Mr. Kuichling. The diagram also gives the capacity of the three reservoirs, also the population curve from 1900 to 1930.

The safe yield of the watershed of Hemlock and Canadice lakes, as estimated by Hazen, Eddy and Fisher is also shown on the diagram at 30,000,000 gallons per day. It will be noted that the actual use exceeded this yield for the years 1928 and 1929.

It may also be stated that in a report of a survey of the Rochester Water Works submitted to the Board of Trustees of the Rochester Bureau of Municipal Research in April 1921, it was said that an addition to the water supply was then imperative. The report stated "The conditions which the City now faces will become more acute as time goes on and the Water Works can ill afford to postpone the day upon which additional supply will be available. Gambling with conditions and trusting to chance cannot be done with the lives of citizens at stake. Preliminary work for additional

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supply is under way and the work should be pushed to a conclusion without delay."

In 1926 the late Allen Hazen and Harrison P. Eddy were employed to investigate additional sources of supply. The writer, as Consulting Engineer, was associated in this work. A brief extract from the report on this subject is included in the Fifth Period.

Fifth Period

January 1926 to January 1932

The present condition of the City's water supply and the necessity for an increase, also recommendations for the additional work, is summarized in the following extracts from the Report of the Consulting Engineers, Allen Hazen, Harrison P. Eddy, and Edwin A. Fisher, made to the City Engineer.

Engineers' Report on Additional Supply

"March 7, 1927

Mr. C. Arthur Poole,
City Engineer,
Rochester, N. Y.

Dear Sir:

On February 23, 1926, you asked us to advise you with reference to the water supply of Rochester, and particularly to aid in determining the most advantageous additional source of supply and the method of its development.

* * * * *

Conclusions

After investigation we find that the present water consumption has reached the safe capacity of the present sources and that steps should be taken at once to provide additional supply.

Of the several sources which are available, we believe that the development of a large storage reservoir on Honeoye Creek near West Bloomfield will be the best and in the long run the most economical and satisfactory. With the present supply it will be adequate to serve the city until it approaches a population of 1,000,000.

That part of the total plant required for early construction will cost about $12,000,000 and a moderate increase in water rates will be necessary.

Present Supply Conditions

* * * * *

The present population of the city is 320,000 within the city limits, and there is a further population of 23,000 in villages and suburban communities not far beyond those limits."

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Uses of Water

Works	Total-Output Millions of Gallons Daily	Industrial Uses Millions of Gallons Daily
City of Rochester	28	7
Rochester and Lake Ontario Water Company	7	5
Eastman Kodak Works	6	6
	41	18

Rochester and Lake Ontario Water Company

"The present population of the city is 320,000 within the city limits, and there is a further population of 23,000 in villages and suburban communities not far beyond those limits."

"The city works does not supply the entire population of the City of Rochester and for a complete statement the Rochester and Lake Ontario Water Company must be included. This company supplies most of the previously mentioned population of 23,000 beyond the city limits and some population that is farther away to the Eastward. It also supplies a substantial population in parts of the city that have been recently annexed and to which the city pipes do not reach.

This company takes water from Lake Ontario and filters it. The present output of roughly 7 mgd is all that can be handled comfortably by the present works. It sells some water to the city and it has been necessary for the City to sell water to the Company from time to time to meet peak loads. Of the total output of the Company's plant about three fourths goes to industrial takers and railroads. A little more than half its output is sold within the city limits.

The City of Rochester may some day take over the plant of the Water Company. If that plant was all within the city limits there would be every reason why this should be done at once.

If the City does take this plant, it should take it all and not split it on artificial lines leaving a smaller plant in the possession of the Company.

If the Company's plant should be absorbed before a new water supply is obtained, it would continue to operate as at present and there would be no reduction in supply and no considerable added load at the moment for the gravity works.

On the other hand, if the Company's plant should be taken over when a large addition to the gravity supply is available, it would furnish additional market for the new water and its revenues would help to pay for it.

The program presented must be elastic enough, as we believe it is, to fit with any contingency likely to arise in this regard.

Eastman Kodak Supply

It is also to be mentioned that the Eastman Kodak Company has a plant taking water from Lake Ontario, with filtration and with an average output of 6 or 7 mgd, used mainly for process water in manufacturing film. The Eastman Kodak Company has special and unusual requirements in regard to

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quality, which are met by its supply. It may therefore be assumed that this service will be continued and also that various other industries will continue to get process water independently from the Genesee River, and no provision for these uses need be made in plans for future water supply."

Future Requirements

The estimated quantities to be provided in million gallons per day will be as follows:

Year	Population supplied by present city plant	Entire population, urban district
1926	28	35
1930	31	39
1940	42	53
1950	57	72
1960	76	95

Capacity of the Present Works

* * * * *

For the present purposes we may consider these improvements as effective and the capacity of the present system to be 31,000,000 gallons.

The improvements referred to were the raising of the dike five feet, such construction as would permit of lowering the lake three feet lower than it had been in the past; also a diversion of the Carney Hollow water of about 1,000,000 gallons per day. This diversion has not been completed and the effective capacity of the present system is then 30,000,000 gallons per day instead of 31,000,000.

Other Sources of Supply

"Conesus Lake is directly west of Hemlock Lake and for more than a generation it has been accepted by the people of Rochester as the next probable addition to the Rochester water supply. . . .

Conesus Lake is larger than Hemlock Lake, and it has a greater catchment area, namely 67.0 square miles. . . .

If the storage is limited to about 6 feet, i. e., to a range of six feet between high and low water in the lake, the yield to be counted on is estimated at 20,000,000 gallons. Twice as much storage, i. e., 12 feet, would be needed to get a full development up to a possible maximum of about 25,000,000 gallons.

* * * * *

From the standpoint of quantity Conesus Lake does not provide adequately for future growth. When cities build new works it is desirable to get sources that will maintain service for longer periods.

* * * * *

Considering the matter from a standpoint of what we consider to be the inevitable future development, we are not willing to recommend the use of Conesus Lake with the cottages remaining, even with filtration.

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The estimated cost of acquiring all the cottages and moving them and developing the lake so that it would be comparable in its occupation and purity with Hemlock and Canadice Lakes, is clearly greater than is warranted by the amount of water that can be obtained from it."

The estimated cost of development of Conesus Lake project for 25,000,000 gallons per day is $11,662,800.

Genesee River

"A reservoir above Portage has been proposed for water power purposes and it may be built some day. . . . If it should be built at some time for power purposes, the City of Rochester, on proper arrangements being made, might become a partner in the enterprise and take such quantities of additional water as needed from this source.

* * * * *

For the present, this source is too large and too distant and the first installment would cost too much money to permit its serious consideration at this time, but looking to a remote future it is not at all impossible that it may be part of Rochester's ultimate supply."

Canandaigua Lake

"This lake is much larger than Hemlock Lake and has a catchment area of 186 square miles.

* * * * *

A supply from Canandaigua Lake would not be satisfactory unless strong measures were taken to control both the quality and quantity of the water, and the present uses of the lake for other purposes are such that full control would be very difficult.

A rough preliminary study indicated that works would cost much more than for other possible sources."

Lake Ontario

"Lake Ontario is an obvious source of future water supply.

* * * * *

One great handicap in the use of Lake Ontario water is the pumping. The cost of pumping will be much greater in this case because of the unusual elevation of the city above the lake. Most of the cities that use lake water are elevated but little above the lakes and it is necessary to pump only against the pressures actually required for ordinary service."

The first installment of works would cost $8,400,000. The heavy pumping cost is a great handicap to this project.

Honeoye Creek

"Honeoye Lake has been considered as a possible source of supply and has attractive features, but by itself is not large enough. Honeoye Lake is

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a comparatively small lake but in a valley that is as large as that which holds Canandaigua Lake.

*   *   *   *   *

The plan that we propose is to build a reservoir, or in reality, a lake that would include and raise Honeoye Lake. The dam would be a short distance above Factory Hollow on a site that has been surveyed and bored by your assistants.

This dam will control a catchment area of 187 square miles which includes all the catchment area now used for water supply by the City of Rochester and also Honeoye Lake and a very considerable area downstream from it.

*   *   *   *   *

The population per square mile on the added area is 26, which is practically the same as it is upon the present catchment area and there would thus be no lowering of present standards with respect to freedom from pollution."

Reservoirs

"The reservoir to be formed by this dam will have an area of 12.5 square miles, being 15 miles long and averaging ¾ of a mile wide. The average depth of water, not including the water now in Honeoye Lake, which cannot be drawn, will be 26 feet, and the capacity 68 billion gallons, of which 45 billions are in the upper 20 feet, and considered available.

*   *   *   *   *

The areas and capacities shown in the following table have been calculated from this map: (Plate 26. This map had been compiled from several maps of the district.)

TABLE No. 4—AREA AND CAPACITY OF PROPOSED RESERVOIR

Elevation Above Sea level	Elevation Rochester Water Works datum	Area in square miles	Capacity in billions of gallons excluding water now in Honeoye Lake which cannot be drawn	Average depth in feet
785	277	0.7	0.4	3
790	282	1.4	1.5	5
795	287	2.3	3.4	7
800 (a)	292	3.3–6.6	6.3	8
805	297	8.0	13.9	9
810	302	9.0	22.8	12
815	307	10.1	32.8	15
820	312	11.0	43.8	19
825	317	11.5	55.5	23
830 (b)	322	12.5	68.0	26
835	327	13.7	81.7	29
840 (c)	332	14.7	96.5	33

(a) Present level of Honeoye Lake.
(b) Proposed flow line of reservoir.
(c) Proposed extreme possible flood height.

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	Billion Gallons
The proposed range to be used for water supply, 810–830, holds	45.2
Add storage in Hemlock and Canadice lakes when present proposed arrangements are complete	11.5
Total net storage in proposed system	56.7

This amounts to more than one year run-off from the tributary area of 187 (or 219) square miles.

Quality of Water

"Water from Hemlock and Canadice lakes will be delivered as at present to the limit of the capacity of the source and of the present pipes. For some years most of the required supply will come from them. Additional water will be taken from the new reservoir as needed.

The water entering the proposed reservoir will be in every respect equal to the water entering Hemlock and Canadice lakes, . . ."

Quantity of Water to Be Obtained

". . . With Honeoye Reservoir built as proposed, the safe capacity of the combined system is estimated at 85 mgd, sufficient to last at the assumed rate of growth for the entire city, including the area in and outside the city now supplied by the Water Company, until 1957.

The addition of the headwaters of Ganargua Creek above South Bloomfield would add a further 15 mgd, bringing the total to 100 mgd."

Filters

* * * * *

"We do not propose to discuss the advantages of filters, but merely to point out that there is an adequate site for the construction of filters for the entire proposed supply including the present supply, located so that water will flow to them from present and proposed reservoirs by gravity, and, in turn, from the filters to the present service reservoirs through existing pipe lines which pass close to the proposed filter site, and also through additional pipe lines laid in future as they may be required."

The estimated cost of this supply and the first instalment for early construction is $12,000,000 and the cost of the whole project, including future construction is $23,000,000.

"The exigencies of the situation require that the construction program of new works be carried forward rapidly. We have not attempted to work the matter out in detail, but a moderate increase in present water rates will apparently be necessary under these conditions."

Recommendation

"Taking all the conditions into consideration, we recommend that the City

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adopt the development of a gravity supply on Honeoye Creek substantially as outlined in this report.

Respectfully submitted,
Harrison P. Eddy,
Allen Hazen,
Edwin A. Fisher."

ACTION BY THE CITY ON THE HONEOYE VALLEY WATER PROJECT

The foregoing report of Hazen, Eddy and Fisher was transmitted by the City Engineer, C. Arthur Poole, to His Honor the Mayor, Martin B. O'Neil, and by him transmitted to the Common Council on April 1, 1927.

On April 26, 1927, the Common Council adopted Ordinance No. 388, Authorizing Additional Water Supply and Authorizing the Mayor to Make a Petition to the Water Supply Commission of the State of New York for Approval of Said Additional Water Supply Project.

"Be it ordained by the Common Council of the City of Rochester, as follows:

Section 1. This Council hereby authorizes the construction and erection for municipal purposes of the necessary works for an addition to the present water supply of this city in accordance with the general plan or project recommended in a report dated March 7, 1927, submitted by Allen Hazen, Harrison P. Eddy and Edwin A. Fisher, to the City Engineer of Rochester, and the accompanying general plans on file in the office of the City Engineer, when said plans are approved by the New York State Water Supply Commission, or any extension or modification thereof that may be approved by said Water Supply Commission. Such works include all construction of any name or nature necessary to provide an abundant supply of wholesome water for public and private use and its protection against contamination, including treatment by filtration or otherwise which may be deemed necessary or desirable; also the acquisition of real estate, easements and water rights necessary or proper in carrying out said works, including any lands or easements required for the sanitary protection of said water supply; also the payment of all legal damages.

Sec. 2. The Mayor is hereby authorized to prepare and submit to the Water Supply Commission of the State of New York, a petition for the approval of the said Water Supply Commission to the project for additional water supply for the City of Rochester, authorized by section 1 of this ordinance.

Sec. 3. This ordinance shall take effect immediately."

Adopted unanimously.

PETITION TO THE WATER POWER AND SUPPLY COMMISSION

On April 29, 1927, a petition under authority of the foregoing ordinance was presented to the New York State Water Power and

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Control Commission. In this petition the conclusions of the Consulting Engineers heretofore stated were given, together with other information relating to the matter and accompanied by four exhibits. The petition was signed by Martin B. O'Neil as Mayor, Harold W. Baker, Commissioner of Public Works, and C. Arthur Poole, City Engineer.

The New York State Water Power and Control Commission gave extended hearings on the project during the year 1927, and on December 14 gave a conditional approval. The main condition was that final decision on this application should be held in abeyance and the City of Rochester be given a reasonable time in which to apply to the Legislature for relief, and thereafter to submit a modified scheme for the determination and payment of direct and indirect damages.

On April 17, 1928, a supplemental petition was presented to the New York State Water Power and Control Commission. This petition was amendatory and supplemental to the petition heretofore presented to and filed in the office of the Commission on the 30th day of April 1927 and thereafter designated as Application No. 439.

The Supplemental Petition was signed by the City Manager and the Commissioner of Public Works.

Attention was called to a recent enactment of the Legislature which was signed by the Governor of the State of New York on the 6th day of April, 1920, and immediately thereafter became a law, being Chapter 862 of the Laws of 1928. The petitioner further represented that the said Legislative action complies completely with the suggestion heretofore made by the Commission, and asks that the Commission grant the petition.

APPLICATION GRANTED BY THE COMMISSION

Hearings were held on the supplemental petition by the Commission during the early part of 1928, and on June 22, 1928, the Water Power and Control Commission made a final decision granting the application of the City which should be modified to conform to the following conditions:

1. Mud or Ganargua Creek as a source of an additional water supply for the City of Rochester, is eliminated entirely from this project.

2. Detailed plans and specifications for any structure to be built under authority of this decision must be submitted to this Commission for approval before work is started.

3. The City must have procured the enactment by the State Department of

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Health of rules and regulations for the sanitary protection of the additional watershed, etc.

4. Water drawn from the Honeoye reservoir shall be filtered. The Commission will, in the future, consider applications from the City for modifications of this condition, etc.

5. All the water shall be sterilized.

6. On order of the Commission the applicant shall install and operate approved apparatus for the future purification of the water, etc.

7. Nothing in this decision and approval contained shall be held to bar any community on the watershed of Honeoye Creek above the proposed dam from obtaining a supply of water from sources on said watershed, etc.

8. Nothing in this decision contained shall be held to authorize the City of Rochester to supply or distribute water outside of or for use outside of the limits of that city except with the further consent and approval of this Commission.

9. Damages shall be determined and paid in accordance with the provisions of Section 527 of the Conservation Law.

10. Within two years of the date of this decision the City must submit to this Commission for its approval maps showing the outside boundaries of the lands proposed to be acquired about Honeoye Lake, etc.

11. Where any highway, or part of a highway, which is to be submerged is to be relocated, such relocation must be completed before water may be impounded, etc.

12. After the dam on Honeoye Creek is completed the City of Rochester shall allow water to escape over or through the outlet works of this structure in amount such that the flow of Honeoye Creek at Honeoye Falls shall not be less than seven cubic feet per second for each thousand persons dwelling in that village. The City may conserve a part of this water for its own use if it shall construct, maintain and operate at its own expense sewage disposal and waste treatment works, etc.

The Commission further determines and decides as follows:

1. That the application, maps and plans submitted are modified as set forth above and, as so modified, are the plans hereinafter mentioned.

2. That the plans proposed are justified by public necessity.

3. That said plans provide for the proper and safe construction of all work connected therewith.

4. That said plans provide for the proper protection of the supply, etc.

5. That said plans are just and equitable to the other municipalities, etc.

6. That said plans make fair and equitable provisions for the determination and payment of any and all legal damages to persons and property, both direct and indirect, which will result from the execution of said plans or the acquiring of said lands.

WHEREFORE, The Water Power and Control Commission does hereby approve the said application, maps and plans of the City of Rochester as thus modified. Dated at Albany this 22nd day of June 1928, and signed by the Water Power and Control Commission, Alexander Macdonald, Conservation Commissioner-Chairman, F. S. Greene, Superintendent of Public Works; Albert J. Danaher, Assistant Attorney General.

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Appeal by Ontario County. The Board of Supervisors of Ontario County appealed to the Appellate Division from the decision of the Water Power and Control Commission and the Appellate Division unanimously confirmed the determinations of the Water Power and Control Commission on January 1930.

From this decision the Board of Supervisors of Ontario County appealed to the Court of Appeals, which appeal was argued on the 14th day of October 1930 by Earle S. Warner, Esq., Counsel for the Petitioner and George B. Draper, Esq., Deputy Corporation Counsel of the City of Rochester and by Frederick D. Colson, Esq., Assistant Attorney of Counsel for the Water Power and Control Commission to the Court of Appeals on the 18th day of November 1930.

Decision of the Court of Appeals. Ordered and adjudged that the judgment and order so appealed from be affirmed with costs.

Judgment was filed and entered in the office of the County Clerk of Albany County on the 29th day of September 1930.

The Water Supply and Power Control Commission extended the date for filing maps and land required for the reservoir to November 29, 1932, and for the complete taking of lands to November 29, 1938.

Personnel

References and Acknowledgements

In addition to the personal recollections of the writer from his relations in some measure to the water supply of the City of Rochester for the past 40 years, the following publications and papers are referred to:

Current Proceedings of the Common Council as far as available from 1834 to date.

Public Works and City Engineers' Reports.

Peck's History of Rochester, 1884.

Papers and reports of J. Nelson Tubbs.

Papers and reports of Emil Kuichling.

Papers and reports of John F. Skinner, including a Report on the Steel Plate Pipe Conduit No. II, published in book form in 1913.

Paper by Irving E. Matthews, published in the Proceedings of the New York Section of the American Water Works Association, March, 1928.

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Reports of Edwin A. Fisher, City Engineer, to Hon. James G. Cutler, Mayor, 1904 to 1908.

Reports of Hazen, Eddy and Fisher on Additional Water Supply, March 7, 1927.

Report of the Rochester Bureau of Municipal Research.

Message of Mayor Rodenbeck, November 28, 1903.

Mention should also be made of the suggestions relative to matter to be included in this paper and its arrangement by Dr. Herman L. Fairchild, Professor Emeritus of the University of Rochester.

PARTIAL LIST OF ENGINEERS CONNECTED WITH THE WATER SUPPLY

Daniel Marsh, at one time Chief Engineer of the Rochester Water Company.

J. Nelson Tubbs, Chief Engineer and Superintendent of the Rochester Water Works, 1872 to July 18, 1889.

I. F. Quimby, Consulting Engineer, construction of original works.

George W. Rafter, Assistant Engineer and Acting Chief Engineer, July 18, 1889 to September 6, 1889.

Emil Kuichling, Principal Assistant to Mr. Tubbs in the original water works construction, and Chief Engineer and Superintendent from September 6, 1889 to January 1, 1900.

Edwin A. Fisher, Principal Assistant Engineer in construction of additional water supply, 1893 to 1896, City Engineer 1896 to 1914, Consulting Engineer 1914 to 1927, retired.

Frederick T. Elwood, City Engineer, 1914 to May 8, 1917.

C. Arthur Poole, City Engineer, 1918 to January 1928, Consulting Engineer 1928 to January 1, 1932, City Manager 1932.

H. L. Howe, City Engineer, 1928 to 1932, Mechanical and Electrical Engineer 1932.

I. E. Matthews, Superintendent of Water Works, 1926 to 1932, City Engineer, 1932.

John F. Skinner, Assistant to Chief Engineer, 1891 to 1900, Special W. W. Assistant Engineer, 1900 to 1903, Special Assistant Engineer, 1903 to 1905, Principal Assistant Engineer, 1905 to 1923, Deputy City Engineer, 1923 to 1928, Sanitary Engineer, 1928 to 1932.

Frederick P. Stearns, Consulting Engineer on Cobb's Hill Reservoir.

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LeGrand Brown, Assistant Engineer, Additional Water Supply, part time, 1891 to 1895, Deputy City Engineer, July 1, 1919 to February 8, 1923.

Gaylord Thompson, Assistant Engineer in Charge of Contract No. 1, Additional Water Supply Construction, 1893 to 1895.

Walter H. Sears, Principal Assistant Engineer, 1892 to 1893.

Alphonse Fteley, Consulting Engineer, 1892 to 1895.

Commissioners of Public Works

J. Herbert Grant, 1900 to 1902.
J. Y. McClintock, 1902 to 1903.
Thomas J. Neville, 1903 to 1906.
Frederick T. Elwood, 1906 to 1912.
Herbert W. Pierce, 1912 to 1924.
Harold W. Baker, 1924 to 1932.
John G. Ellendt, 1932.

Superintendents of Water Works

George A. Hotchkin, 1900 to 1902.
Beekman C. Little, 1902 to 1926.
Irving E. Matthews, 1926 to 1932.

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PROCEEDINGS OF THE ROCHESTER ACADEMY OF SCIENCE
VOL. 7, PP. 97-135 PLATES 27-29 OCTOBER, 1932

NEW YORK PHYSIOGRAPHY AND GLACIOLOGY WEST OF THE GENESEE VALLEY

By Herman L. Fairchild

CONTENTS

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General Statement

This district, the extreme western portion of the State, includes a variety of singular and highly interesting features, physiographic and geologic, many of which have their first notice in this writing. In the paper number 5 of the attached list of writings Dr. Frank Leverett, in 1892, described the morainal belts; and a quarter of a century ago the writer mapped the inscriptions of the widespread glacial waters in a set of colored charts in paper 10. The features to be specially noted in the present writing include the remarkable Cattaraugus Valley and the series of parallel valleys on the north, with their romantic glacial lakes.

The unusual assemblege of striking features in this district, with their origin and glacial history, deserved detailed description long ago by the local scientific interests. In the lack of such publication the Rochester Academy of Science presents this outline of the physical characters of the neighboring province.

When the paper number 10 was published the topographic mapping by the United States Geological Survey had not covered all of the area and a number of the topographic sheets were lacking. Plate 4 in that Bulletin 106, covering a stretch from Gowanda north to Hamburg and Orchard Park, was based on imperfect county maps, and the glacial lake shores and the stream channels could not be precisely shown in either location or form, and the topography not at all. That district is now shown, in reduced scale, in the accompanying plate 29. However that former paper, State Museum Bulletin 106, is yet requisite for the general glacial history as introduction to the present paper. Unfortunately it has long been "out of print," but copies should be found in the libraries of the larger High Schools and certainly in the city libraries.

The geographic divisions of the district as based on the river systems or hydrographic areas are shown in plate 27. The present disposition of the drainage dates from the close of the Glacial Period. Previous to the "Ice Age" and the invasion of the Quebec glacier all of the major streams flowed northward, as indicated in figure 2.

The continental ice sheet in its relentless overriding of the land piled heavy fillings of rock rubbish, the glacial "drift," in many valleys, thereby interfering with the ancient stream flow. The present divide between the Allegheny River and Lake Erie was created by the drift blockade, and also the divides north and south of the

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Cattaraugus Valley. This anomalous valley, which is out of harmony with the topography and stream flow of the large district, was developed at the front of the waning ice sheet by glacial and drift damming and the forced glacial drainage. This remarkable valley is entirely due to glacial interference, and will be briefly described, with the aid of the map, plate 28.

Plate 29, emphasizes the series of eight parallel north-leading valleys, with the forced, or ice-border, drainage during the recession of the ice front. The map, with its great reduction in scale, is mainly suggestive. The glacial stream channels are much exaggerated in width. Students, in and out of the schools, may find satisfaction and instruction in correcting possible errors and in the discovery of unmapped features and interesting details.

This writing does not attempt a complete, detailed description of the district, with its wealth of very instructive physiographic and glacial characters. Such treatment would require, and deserves, a large monograph. Its aim is to direct attention to the salient characters of the region as records of dramatic geologic activities; and also to encourage people with interest in nature to explore their home surroundings. The topographic maps should be utilized by the schools for recognition and study of their local features. Exploration in the field with intelligent study of the geologic phenomena is the highest intellectual exercise, and may well replace much study of books.

Map Illustrations

Plate 27 distinguishes the several drainage districts or stream system. Three of these are entire, the Cattaraugus, Erie-Niagara and the Ontario west of the Genesee Valley. For New York the Genesee Valley is also complete. The Allegheny headwaters is widely shown.

This map should be compared with figure 2. It will be seen that the Genesee River is the only large stream which has retained its general northward course across the State, in spite of the interference and opposition of the continental glacier.

Plates 28 and 29 have utilized as base maps the topographic sheets by the United State Geological Survey. Great reduction in size has been necessary. The sheets are easily available for study.

Plate 28 shows the central portion of the singular Cattaraugus Valley, using the Cattaraugus, Ellicottville and Franklinville sheets.

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The three rock ravines may be located. On the southern divide the low passes which were the outlets of the high-upheld glacial waters are indicated, with some exaggeration. This map adjoins, with the same scale, the bottom of the map in plate 29. The two maps cover all of the Cattaraugus drainage except the few miles west of Versailles Village.

Plate 29 emphasizes the series of north-leading parallel valleys. Comparison of drainage should be made with figure 2. The many passes which provided outlets for the ice-impounded waters are interesting features and conspicuous in the mapping, but are not complete for the northern part of the area.

The moraines and the outwash plains, with their kettles and kettle lakes, are not specially designated. They may be recognized by the topography, and are noted in later chapters.

The shore lines and deltas of the widespread glacial lakes on the lower ground are heavily indicated. The Whittlesey features are incomplete, being mapped only where seen in the field. Some enterprising student should map them with refinement.

For areas north and south of plate 29 the lake features are mapped in paper 10.

The figures, 1, 2, 3, are described in the text.

Physiography

One of the physical characters of which western New York may properly boast is its singular physiography. Its land surface is recognized as the type example of "Cuesta" topography, a titanic stairway with insloping treads.

The production of this singular structure required an unusual combination of geologic elements, and is the record of especially interesting history. When the area of western New York and Ontario was permanently raised out of oceanic waters, the interior or epicontinental sea, the newly created land, a vast coastal plain, had a general slope toward the south and southwest. But to-day the land surface rises southward, from the level of Lake Ontario, 246 feet above tide, and Lake Erie 573 feet, to much over 2,000 feet in the southern tier of counties.

During unnumbered millions of years exposure to the destructive agencies of the atmosphere, along with high uplifting and deep erosion of the rock strata, the land has been carved into a series of plains with sharp upslopes or escarpments. The three plains,

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Ontario Lowland, Huron and Erie, with three escarpments, Niagara, Onondaga and Portage, rise to the elevated Allegheny Plateau. These interesting physiographic elements are clearly shown in figure 1, reproduced from Professor A. K. Lobeck's figure 9 in his Handbook for the Allegany State Park, paper 21 of the appended list of writings.

The succession, rising southward, of plain and scarp, is an expression of three conditions; (1), the varying resistance of the different

Courtesy of the New York State Museum

Figure 1. WESTERN NEW YORK PHYSIOGRAPHY

rock strata to the atmospheric erosion; (2), the high-uplifted attitude permitting deep erosion; and (3), the northward upslant, or southward "dip" of the strata of perhaps fifty feet to the mile.

The extended succession of rocks, in all variety of the sedimentary class, may not be described here, being noted in all text-books and treatises on the New York stratigraphy, and given in detail in paper

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16. The succession of less resistant rocks constitute the plains, the "treads" in the physiographic stairway; while the more resistant beds make the scarps or "risers." The wide outcrop of thick and weak Ordovician strata, the beds beneath the Medina sandstone, were eroded in Tertiary time to produce the deep and wide Ontario basin, with its eastern extension as the Mohawk Valley. This great depression reversed the direction of river flow, described below.

In the western part of the State the Ontario Lowland is faced by the Niagara escarpment, which is capped by the Niagara or Lockport limestone. The outcrop of the thick and weak Salina shales, containing the rock salt of New York and Michigan, has been excavated to produce the east and west depression through western and central New York, named in figure 1 the Huron plain. The Onondaga limestone forms the scarp at the south border. This Salina depression had gathered, by the end of Tertiary time, a large part of the regional drainage into east and west courses, as shown in figure 2; and that control of drainage is yet exercised in spite of the glacial interference.

Overlying the Onondaga limestone the thick shales and sandstones of the middle Devonian strata constitute the Erie plain of figure 1. The heavy strata of the Portage and the Chemung build the high scarp that forms the north-facing front of the Allegheny Plateau.

The minor physiography, especially the preglacial and the present river valleys, will be described below.

Tertiary, Preglacial, Stream Flow

The ancient river flow, as noted above and as mapped in figure 2, was northward or northwestward and tributary to the Mississippi through the master rivers in the Ontario and Erie basins. However, this northward drainage was not the earliest stream flow. Far back, in the Devonian Period of Paleozoic time, the earliest or primitive streams were created when the area was permanently raised out of the interior or continental sea, and their direction of flow was southward or southwestward. With further uplift of the continent the Ontario-Mohawk and Erie valleys were carved out of weak strata. And these east and west depressions captured the drainage and reversed the direction of flow. With the northeastern

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part of the continent standing perhaps several thousand feet higher than at present the north-flowing streams were vigorous and rapidly cut deep, steep-sided valleys. This drainage history is described in papers 14–16.

As noted in the preceding chapter the present land surface with its striking topography is the final effect of the removal of great thickness of rock strata, producing the deep valleys and the basins

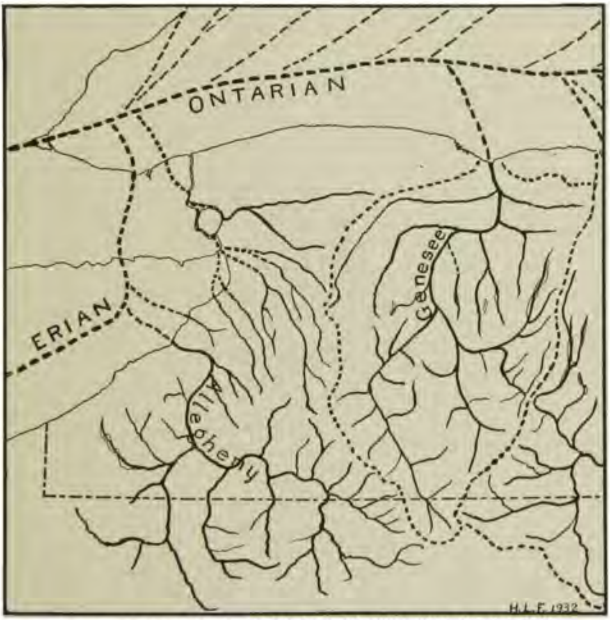

Figure 2. PREGLACIAL DRAINAGE IN WESTERN NEW YORK

now holding lakes Erie and Ontario. The strata which constitute the highland, the Allegheny Plateau, once extended far north into Canada. The detritus derived through millions of years of destructive processes has been largely contributed to the Mississippi River deposits in lower Louisiana.

In the lowering by erosion of the land surface, with the shifting

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of river flow, the paths or valleys of the primitive, south-flowing rivers are obliterated or quite obscured in all the area under description, and any doubtful relics are not here considered. North of the Cattaraugus Valley the many valleys declining northward (plate 29) are relics or survivors of the preglacial, Tertiary drainage. And an interesting fact which has not been recognized is that they are the western members of the remarkable series of parallel valleys lying eastward through central New York.

South of the Cattaraugus basin, where all of the present stream flow is southward, to the Allegheny River, the preglacial, north-leading valleys are deeply filled with detritus, from glacier, lake and river, and are now holding wide plains and swamps. These wide valleys with deep filling and slack drainage are abnormal features, being an indirect effect of the invading and overriding ice sheet. The deep, north-declining valleys were blocked in places by glacial drift fillings. South of the drift dams the valleys have been filled by detrital outwash from the ice sheet, and subsequently, in some cases, by glacial lake deposits and finally to the present level by the stream detritus of the reversed, or south-leading drainage. The conspicuous example is the wide, capacious valley now slowly drained by the Conewango Creek. Along with the lower stretch of the Cattaraugus the Conewango valley was the path of the preglacial Allegheny River.

Deep drillings in the line of the larger preglacial valleys go below sea level before reaching "bed rock," which is one proof of the high elevation of the region before glacial time.

The rock bottoms of these filled valleys were graded to the rock bottom of the Erie Valley. Drillings, for gas or water, down to bed rock will prove that the valley bottoms have a uniform slope northward. The amount of that slope has been slightly reduced, one or two feet per mile, depending on direction, by the northward uptilting of the land since the weight of the ice sheet was removed (papers 13, 14).

The diverting effect, direct and indirect, of the ice sheet invasion may be seen by comparison of the Tertiary drainage shown in figure 2 with the map of the present stream flow, plate 27.

The map of Tertiary drainage, figure 2, indicates by broken lines the stream flow which is chiefly hypothetic. Those north of the axis of Lake Ontario retain the primitive southerly direction of Paleozoic time. The drainage relation of the Erie basin to the

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Ontario basin in preglacial time, with the ultimate outflow, is a difficult problem. In this map the Erian and Niagaran flow is tributary to the Ontarian. It must be understood that today the bottom of the shallow Lake Erie is over 600 feet above the bottom of Lake Ontario.

Glaciation

The high elevation of northeastern America in later Tertiary time was one cause, if not the principal cause, of the formation of an ice cap, or continental glacier, in Canada which expanded so as to cover most of New York. Students in the western states and in Europe find that the Glacial Period covered epochs of glaciation with intervening mild climate epochs of deglaciation. And the duration of the Glacial Period has been greatly extended, to cover 500,000 years, or more.

As applied to western New York our knowledge is limited to the closing stage of the Ice Age, the Wisconsin Epoch, and the operation and effects of the Quebec (Labradorian) ice sheet. The glacial phenomena are so well known that general description is here unnecessary, but some particular phases of the glacial behavior and interesting records will be considered in the following chapters.

The direction of movement of the overriding ice sheet, at least in the later phase, was southwestward from the Ontario basin, as shown by the orientation of the drumlins in Orleans and Genesee counties. The spreading flow from the Erie basin was to the southeast, as shown by the attitude of the drumlins in Chautauqua County and the trend of the terminal drift or moraines.

Ice-Front Recession

The geologic effects by the invasion (or invasions) of the ice sheet in western New York are a matter of conjecture or inference. The recessional records are conspicuous as the will and testament of the recently departed visitor.

The moraines in figure 3 mark the succession of ice-front positions as the glacier was reluctantly departing. South of Lake Ontario the trend of the ice margin was quite parallel to the lake shore. In the Erie basin the spreading movement of the ice body caused the ice front to lie slantingly or obliquely on the New York wall of the valley. And in consequence of this oblique relation the ice was not removed at once along the whole length of the wall or

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scarp, from State Line to Buffalo, but receded progressively from the southwest to northeast.

The glacial waters which produced the beaches mapped in plates 2–5, paper 10, and in plate 29, crept in from the west between the ice and the land slope, slowly extending northeastward. For example, the site of Dunkirk was yet beneath the ice sheet while Westfield was submerged in Lake Whittlesey.

The Lake Warren beaches were not formed until after the ice front had receded to the district of Marilla, fifteen miles east of Buffalo. At that time the far-west ice margin in the State of Michigan released an outlet lower than that of Whittlesey, and the imprisoned waters fell, some 45 to 50 feet, to the Warren level. The history is given in paper 10, pages 41–74, and in paper 17.

The moraines and outwash plains along the north side of the Cattaraugus Valley were under construction about the time, perhaps, when the Whittlesey waters were entering the State.

The glacier front in its recession over the areas mapped in plates 28, 29, probably had a general direction northeast by southwest. In its backward movement the drainage outlets for the glacial waters were probably opened sucessively westward.

Moraines and Valley Fillings

The slow melting of the ice sheet, with the backward recession (to northwestward) of the margin of the ice, left, normally, a thin mantle of ice-laid material, the "till," on the deserted land. But the waning of the glacier was far from steady or uniform. Climatic and other factors made the ice-front recession somewhat spasmodic. Along some stretches the ice margin hesitated and lingered, producing masses of the drift, as moraines. Occasionally the ice front readvanced after it had receded less or greater distance. Such pauses at readvanced positions produced the heavier moraines on the uplands and the massive blockades in the valleys.

These drift deposits are responsible for the changes in the drainage and for some of the anomalous features noted above with others to be described.

Figure 3 gives the location of the more extended and massive accumulations of frontal or morainal drift. The matter is discussed in paper 18.

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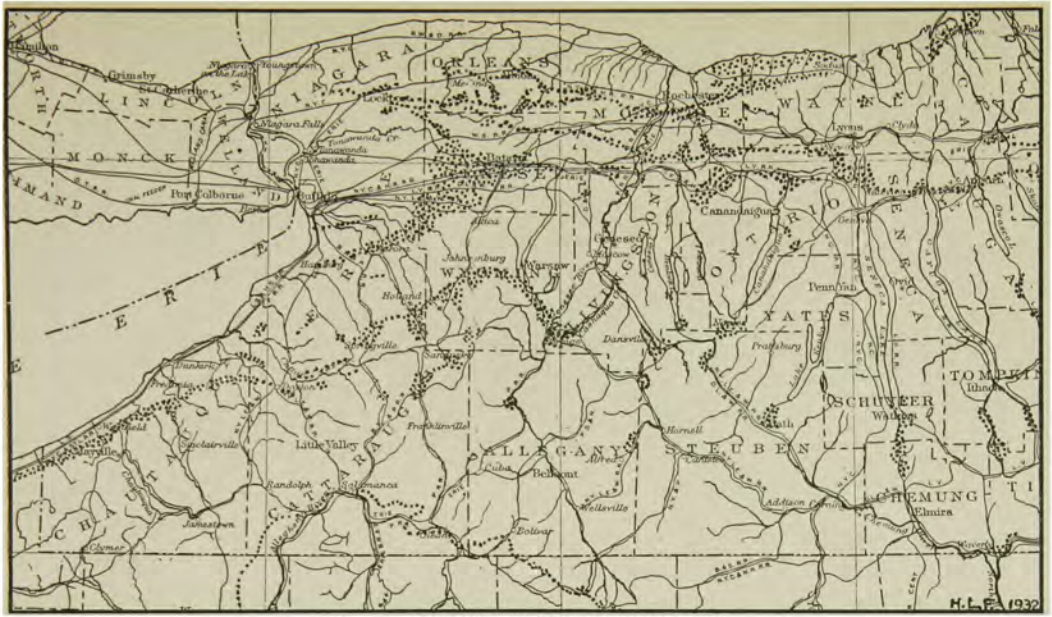

Figure 3. MORAINES IN WESTERN NEW YORK

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The most continuous and extended moraine in the area is the one which forms the crest of the steep slope, or scarp, facing Lake Erie. This was described and mapped in paper 5, and named by Leverett the Lake Escarpment moraine. It appears on the Westfield and Dunkirk sheets of the topographic map, in plates 1–3 of paper 10, and in figure 1 of paper 18.

Distinct and definite moraine ridges, marking precise positions of an ice front, are rare and seldom will be found above the Terminal Moraine or on territory with high relief.

On plate 28 the irregular topography east of Dayton indicates a morainal tract. Also along the Cattaraugus Creek north and south of Zoar Bridge. A conspicuous moraine field lies south of Delevan and north of Machias; and another one at Sandusky, on Clear Creek in town of Freedom (Arcade and Franklinville sheets).

On plate 29 a series of heavy moraines and valley fillings are seen at the heads of all the north-leading valleys except that of Hunter Creek. They lie on the Eden, Springville and Arcade sheets. These fillings helped to produce the northern divide of the Cattaraugus basin, and they apparently correlate with the Escarpment moraine and its eastward continuation as the Valley Heads moraine in central New York. This moraine is mapped in papers 5, 10, 18.

The long standstill of the ice margin in the production of these fillings and the blockade of the ancient valleys forced the westward flow of the proglacial, or ice-border, drainage which developed the Cattaraugus Creek.

Outwash and Valley Plains

Interesting features connected with the valley moraines are the plains of "glacial outwash." These water-smoothed plains lie in front of the moraine fillings and were built of the detritus, gravel, sand and silt washed out of the glacier by the subglacial streams that drained the melting ice sheet. The detritus filled the incipient lakelets which were held in the heads of the valleys by the ice dam, the fillings being smoothed by the lake waters, and later channeled by the streams of the outflow.

These plains are recognized on the topographic sheets by their many basins, the "kettles," and the kettle lakes and lakelets, which features are characteristic of frontal moraine deposits.

The outwash plains in this area have no superiors, and lying on

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the north border of the high Allegheny Plateau they are remarkable for their altitude.

On plate 28 a good example is seen at Machias, which includes Lime Lake. Another is seen at and south of Freedom village, which includes Crystal Lake, with elevation 1,761 feet.

On plate 29 are the larger outwash plains. Extensive plains appear at East Concord and Springville, 1,400 feet elevation; at Chaffee-Yorkshire–Sardinia, 1,400 to 1,450 feet. The most elevated is at Eagle village (Arcade sheet), four miles southwest of Bliss, at the head of Wiscoy Creek in the Genesee drainage. Its altitude is 1,900 feet, which probably distinguishes it as the most elevated outwash plain in America if not in the entire world.

Valley Plains lead away, southward, from the heavy moraines on the divides, the detritus filling the valleys being derived at first from the glacier and supplied later by the lakes and the land drainage.

Good examples of these features are seen in the two valley plains which head in the moraine south of Dunkirk. One is the Bear Lake Valley, which holds the village of Stockton. The other is the upper part of the Cassadaga Valley, headed by the Cassadaga lakes. These two valleys unite to make the greater Cassadaga Valley, with a breadth at the junction of over three miles (Dunkirk sheet). The full display of the handsome valley is mapped on the Dunkirk, Chautauqua and Jamestown sheets.

Passing eastward we find definite outwash plains, connected with moraines, at Mud Lake, the head of the West Branch Conewango Creek; at East Mud Lake, the head of the North Branch Conewango; and at the village of Cottage on Slab City Creek. The plains of glacial outwash are shown on the Cherry Creek sheet.

Another excellent example, and with large kettle lakes similar to the Cassadaga lakes, is at Machias, at the head of the Ischua Valley, as shown on the Franklinvile sheet, and on plate 28.

The valley plains which are headed by the outwash deposits noted above are very conspicuous geographic features on the topographic sheets, and require particular notice.

The elevation of Bear Lake is a litle over 1,300 feet; and the upper Cassadaga Lake is 1,306 feet. In the distance of twenty miles to the junction of the Cassadaga Valley with the Conewango Valley the decline in elevation is only forty feet. This remarkable

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flatness is because the ancient valley declined northward and has been deeply filled by glacial, lake and stream detritus. Such peculiar valley forms are produced by morainal blockade and deep filling in valleys of reversed stream flow. These valley features are mapped in plate 2, paper 10, and also in paper 9, plate 38.

Twelve miles east of the Cassadaga Valley lies the very broad valley of the Conewango Creek. The creek heads in six branches, and their very interesting directions and relations are clearly shown on the Cherry Creek and Cattaraugus sheets. They all unite in the district of South Dayton and Markham villages. The recognized source of the creek is far east, by the hamlet of New Albion, three miles south of Cattaraugus village.

The Conewango Valley is remarkable in its size, form and history. It begins in a great basin at Markham, Dayton and Persia, four miles in width, and extends as a swamp, two or more miles in width, for twelve miles to the village of Conewango Valley. With similar width the ancient valley continues southeast fourteen miles, through Randolph and Steamburg, to the Allegheny River. It was the course of the preglacial Allegheny River.

In singular and unexpected manner the Conewango Creek deserts the broad ancient valley three miles northwest of Randolph and enters a narrow, steep-walled valley leading southwest, through Kennedy village, for six miles to Poland Center, where it joins the Cassadaga Creek in another very wide ancient valley, east of Jamestown. The geography is all mapped on the Cherry Creek, Cattaraugus, Jamestown and Randolph sheets.

These valley plains should be distinguished from the smooth areas filled and leveled by standing waters or lakes. Examples of the latter are seen on plate 28 in the towns of East Otto (Cattaraugus sheet); and Ashford (Ellicottville sheet). Also in the terraces along Ischua Creek (Franklinville sheet).

On plate 29 lake plains are seen in the town of Collins (Eden sheet), and north of Cattaraugus Creek in Sardinia (Springville sheet). As in the last example the lake plains may adjoin or blend into the outwash plains.

Recognizing water as the agent in eastern America producing fluid levels we must discriminate at least three classes of plains, according to their manner of origin or their genesis; the outwash plains, lake plains, and valley plains.

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Existing Lakes

Lakes are ephemeral features and cannot occur in normal drainage. They are an effect of drainage blockade, and must be young, speaking geologically, as they face ultimate extinction. The myriads of lakes and lakelets in northern lands are an indirect effect of recent glaciation (paper 16, pages 185–194).

Lake Chautauqua is a "morainal" lake, due to drift damming, with elevation 1,308 feet. It occupies a shallow basin, a partially filled valley, which before glacial interference drained northward; as did all of the streams of the region. The glacial flow, forced southward from the escarpment moraine, produced the swampy tracts north of the present lake (Westfield and Dunkirk sheets).

Except Chautauqua the ponded waters are small in size and relatively few for the large area. Most, if not all, of them belong in the singular category of "kettle-basin" lakes. These basins were primarily occupied by blocks of ice, detached from the ragged front of the ice sheet, and were buried or enclosed in the gravel and sand swept out of the glacier. The eventual melting of the buried ice, and the consequent slumping of the detrital cover and enclosing walls, produced the "kettles." Multitudes of the kettles hold no water.

Kettles and kettle lakes are characteristic features of morainal tracts, occurring especially in outwash plains. They are well represented in the plains at Machias; between Yorkshire and Protection; and at Springville and East Concord.

The Cassadaga Lakes (Dunkirk sheet) are good examples of kettle lakes in wide outwash plains. Bear Lake has the same origin and character (paper 9, plate 38).

Eastward, on the Cherry Creek sheet, is Mud Lake, 1,380 feet elevation; and East Mud Lake, 1,330 feet, both in the headwaters of the western branches of Conewango Creek.

A group of lakes lie near Sandusky (Franklinville sheet), and Crystal Lake, three miles from the village, has elevation of 1,761 feet. Two lie in Elton Creek drainage. Lime Lake at Machias, probably the largest kettle lake in the area, has elevation 1,631 feet.

Java Lake, on the Arcade quadrangle, 1,651 feet altitude, is the head of Cattaraugus Creek. In the moraine, five miles southwest of Bliss, the Arcade sheet depicts a multitude of kettles, both dry and watered, having elevations up to 1,900 feet.

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Lake Erie Plain

WIDESPREAD GLACIAL WATERS

The New York records of the extended glacial lakes which occupied the Erie and Huron basins were described in paper 10 (year 1907) and the beaches mapped in six colored sheets. It is deemed undesirable to rehearse the facts and data given in that publication, but a change is made in the interpretation of the lake records as regards their succession and history. The more detailed description and discussion is published in paper 17.

The succession of glacial lakes in the former paper was given as lakes Whittlesey, Warren and Dana. Further study through the years of the glacial records, with some change in their interpretation, make demand for two lakes at the Warren level, and between them a long stage of deglaciation and free drainage eastward to the Mohawk-Hudson valleys. The glacial features which are concerned in this reinterpretation lie in the Ontario drainage area, and are discussed in paper 17.

Under the new view the lake succession in the Erie basin is as follows:

1. Lake Whittlesey; with westward outflow.

2. Lake Warren, the first; with westward outflow.

3. Downdraining of Lake Warren, eastward, with the outflow control on the salient, the Onondaga scarp, north of Batavia, followed by a long stage with no ice-impounded waters in the Great Lakes area.

4. Lake Warren, the second. Readvance of the ice barrier in central New York slowly lifted the imprisoned waters until they rediscovered the western outlet across Michigan, at the Warren level.

5. The second downdraining, eastward, but with the outflow controlled on the high ground in the Syracuse-Utica district.

6. Lake Dana; due to a long pause in the downdraining, with outlet at Marcellus.

7. Lake Erie. The incipient lake was very small, but has been lengthened and deepened by the deformative land uplift.

The shore inscriptions of Lake Warren, with spacing of the bars in their northern reach had been recognized, and was discussed in paper 10, pages 64–79. The present theory appears to explain

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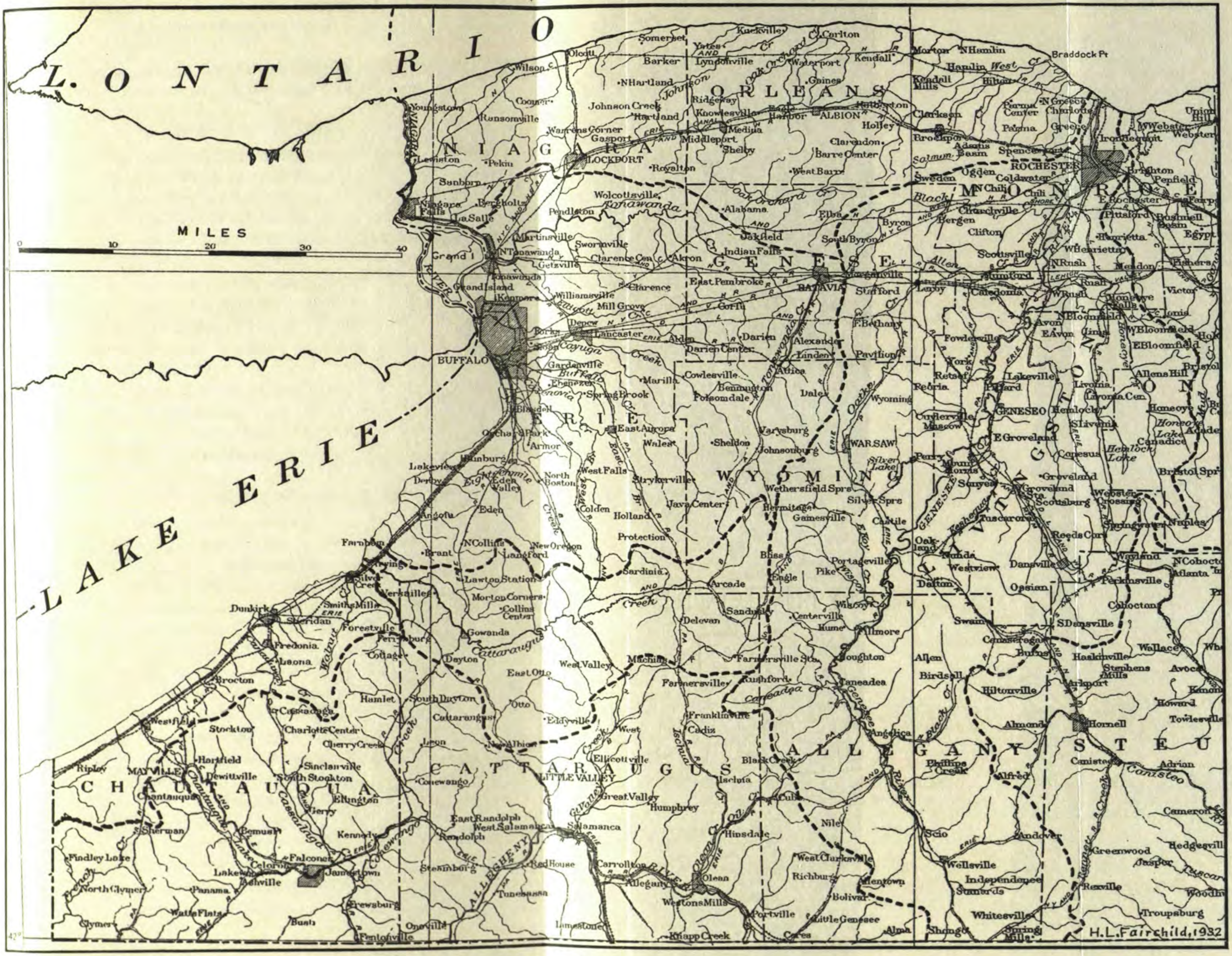

RIVER SYSTEMS AND DRAINAGE DISTRICTS IN WESTERN NEW YORK

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the discrepancy in the water planes by attributing the lower wave work, at least in part, to the second Lake Warren.

STREAM CHANNELS AND DELTAS

The multitudinous stream channels, remarkable in their relations and succession, which carried the outflow of the glacial lakes described above, are depicted on plates 2, 3, paper 10. They were initiated at the edge of the ice sheet, but many of them became land streams as the ice front withdrew. Some of the later channels in the district are shown in plate 29.

As far northeast as the village of Marilla, six miles northeast of East Aurora, the stream channels carried the flow and detritus into Lake Whittlesey. But at and beyond Marilla the streams contributed to Lake Warren. A few of the larger delta tracts are indicated on plate 29.

The drainage into the second Lake Warren, and the succeeding Lake Dana, was derived wholly from the land. This later stream flow was not so heavily loaded with detritus, and the delta deposits are not readily discriminated from the earlier ones.

Lake Ontario Plain

This stretch of plain, bordering Lake Ontario for seventy miles, between the Genesee and Niagara rivers, and with a width of twenty or more miles, is in striking contrast with the Erie lowland; with which it merges in the area east of Buffalo.

This plain carries one conspicuous glacial lake feature, the strong embankment beach of Lake Iroquois, from Lewiston to Rochester. The plain rises from 246 feet, the Lake Ontario level, to 385 at Lewiston, 420 at Ridgeway and 435 at Rochester.

The beach of Lake Warren (papers 8, 11), with elevation of 880 feet, may be regarded as the southern limit of the Ontario plain.

During the downdraining of the first Lake Warren (paper 17) the plain was mostly buried under the glacier. A portion on the south and west was covered by the second Lake Warren; and a larger area by lakes Dana and Dawson. A few drumlins in the district north of Batavia rise high enough to carry the wave work of the Dana waters, at about 700 feet, as partly mapped on plate 2, paper 11. The northern belt was covered by the shortlived Lake Dawson, but the shore features are weak and have not been traced.

The Ontario plain is not traversed by any preglacial river chan-

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nels. As shown in figure 2 the Tertiary drainage in this province was held to east and west directions in the depression caused by the thick and nonresistent Salina shales; the same as east of the Genesee Valley. Today this depression is occupied by the Tonawanda and Black creeks. The only trenching of the Niagara formation (Lockport limestone and Medina sandstone) is by the Irondequoit and Sodus valleys (figure 2).

This Ontario plain was smoothed by the friction of the ice sheet, with flow southwestward. In its latest flow it rubbed the till mantle into great ribs, or flutings, producing a drumlinized surface. This is described in two papers on drumlins, *N. Y. State Museum Bulletin* No. 127, and *Proceedings of the Rochester Academy of Science,* volume 7, 1929, pages 1–37.

Allegheny Drainage Area

The portion of this area which is included in the Allegany State Park is described in paper 21.

The southward stream flow of this area is due to glacial interference, which has wholly reversed the preglacial direction, as shown in figure 2. The rivers in Tertiary time were tributary to the Erie Valley. The new divides are morainal valley fillings.

The boundary of the area is roughly semicircular; the divide on the west lies over against Lake Erie; on the north against the Cattaraugus Valley; and on the east against the Genesee Valley.

When the ice front receded from the terminal moraine, figure 3, it was very deliberately, by pauses and readvances. The more effective standstills produced the valley fillings, thereby establishing the present water partings.

Three classes of the glacial features are conspicuous and important. These are, the existing lakes; the outwash plains and valley plains; and the records of the vanished lakes.

GLACIAL LAKES

The term "glacial lakes" denotes the water bodies, small or large, that were held up or impounded by the glacier, which served as a movable dam. Except the Marjelen See, in Switzerland, none are recognized today. The innumerable existing lakes and tarns due indirectly to the ice sheet are properly classed as morainal or drift-barrier, kettle and plunge-basin.

While the glacier was lingering in the Allegheny area the front of

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the ice sheet during its slow rescession, and especially in its standstills, held lakes in the valleys which declined northward, or toward the ice. The more definite and extended glacial waters were in the Conewango Valley; the South Branch of the Cattaraugus; and the valley of Ischua Creek.

Probably the earliest of the glacial valley lakes was in the Ischua Valley. The Franklinville sheet shows level areas, mostly the deltas of side streams, at Fitch, 1,680 feet; at Cadiz, 1,600; north of Franklinville, 1,620; at mouth of Johnson Creek, 1,680; at mouth of Bear Creek and north to Gulf Creek good terraces at 1,680 to 1,720. Similar levels occur about Machias village, at East Machias School, and in the Elton Valley.

The standing water which produced these level stretches may be named the Franklinville glacial lake. The blockade, either drift or rock, or both, or perhaps drift-buried ice, must have been in the very narrow valley at Ischua Village, with present elevation of about 1,530 feet; and also on the west in the constricted valleys at Devereaux and Ashford, some six miles northeast of Ellicottville.

The valley of Elton Creek, holding the villages of Elton and Farmersville Station, appears to have been flooded by the Franklinville lake through the valleys southwest of Elton Station.

Eventually the river flow across the barrier at Ischua Village eroded and lowered that outlet sufficiently to drain the Franklinville Lake. Evidence of this event in the history is found in a definite stream channel cut by glacial flow along the east side of the valley at Machias Junction. This channel is described by Mr. H. W. Clough,[1] in a letter, as heading at Lime Lake and extending along the east wall of the valley over three miles, and blending into the open valley a mile southeast of School No. 1. The Franklinville sheet gives the elevation of the channel on the divide, in a "swamp col," as 1,640 feet. The lake terraces on the west side of the valley below School No. 1 are 1,720 feet, and over, in elevation.

This Machias outlet channel implies a lake on the north. The geographic relations suggest that the upper portion of the Catta-

[1] The writer is indebted for valuable data relating to the Cattaraugus region to Mr. Clough, a student of the writer in far-gone days, with a life-work as meteorologist in the United States Weather Bureau, now retired, with summer residence at Arcade.

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raugus Valley was, for a time, drained through the Machias outlet. In this view we may name the lake the Arcade glacial lake. It belongs in the glacial lake succession of the Cattaraugus Valley, recounted below.

The two swamp divides, five miles north and northeast of Ashford, on the Ellicottville sheet, and called "Beaver Meadows," indicate ponding of water in the valleys on the north.

Going west to the Conewango drainage area we find evidence of ice-impounded waters. When in the waning of the glacier the ice front had receded north of Randolph a lake was held in the valley of Little Conewango Creek, which we will call the Randolph lake. The barrier and outlet was at Steamburg, with the present elevation 1,420 feet. With further recession of the ice front the Randolph waters found lower escape through the narrow side valley in which rest the villages of Waterboro and Kennedy (Jamestown sheet).

As the ice front backed away the Randolph lake became the extended Conewango glacial lake. Eventually this lake received the overflow of the Cattaraugus glacial lake, by the outflow channel at Persia station on the Erie Railroad, three miles southeast of Dayton. This channel was described in paper 10, page 17.

The heavy outwash of rock-rubbish from the ice sheet, and the copious inflow of the many creeks draining large territory and sweeping in detritus for many thousands of years, accounts for the valley filling and the swampy condition. The creek is now a sluggish, serpentine flow, hundreds of feet above the bed of its preglacial ancestor. State drainage ditches now help to reduce the watery condition of the great valley.

The later glacial waters are described in the chapter on the Cattaraugus Valley.

The above account of the Allegheny area is only an outline. The varied and complex features have much of geologic and geographic interest and will well repay careful, detailed study.

Cattaraugus Valley

CREATION OF THE RIVER AND VALLEY

This valley is remarkable in its complex origin, its singular physiographic relations, its rock ravines and its glacial lake history. The area is covered by eight topographic sheets; Silver Creek, Eden,

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Springville, Arcade, Cherry Creek, Cattaraugus, Ellicottville and Franklinville. The features and relations which can be shown in black and white are seen on plates 27–29.

Plate 29 joins directly on plate 28 and the two cover all of the Cattaraugus drainage area except the seven miles below Versailles, which is shown on the Silver Creek sheet. The central and more critical part of the valley and river is shown on plate 28. The head-water part of the valley, from east of Springville to Java Lake, a stretch of twenty miles, is shown on plate 29. The lower stretch of the valley, below Gowanda, which was in the course of the pre-glacial Allegheny River, is partly displayed on the two plates.

The topography of the upper valley suggests that in preglacial time a water parting existed at East Arcade. North of this divide the flow was, probably, to the Tonawanda valley. Below East Arcade to Arcade and Yorkshire the tributaries appear to lie in their preglacial courses. But below Yorkshire the river is postglacial.

In its westward course the new river lies across the deep pre-glacial valleys that led northward, as shown in figure 2. During the removal of the ice sheet those ancient north-leading valleys were blocked, at first by the receding front of the ice sheet and then permanently by the morainal fillings. The escaping waters were forced to westward flow along the ice margin and took possession of some east and west valleys which had been tributary to the north-flowing rivers. In three stretches the glacial flow was compelled to cut across intervalley highlands, thus producing the deep rock canyons (plate 28).

The wider, more open, portions of the valley represent preglacial stream work, while the narrow, steep-walled rock ravines register the new, postglacial erosion by the newly-created river. The canyon section of the South Branch also represents diversion of stream flow. Careful study of deep borings may determine the old lines of drainage.

One of the two intersections of the preglacial, north-leading valleys is seen in the wide plain of water-leveled moraine and glacial outwash at Chaffee, Sardinia and Yorkshire (plate 29). This area is part of the great valley which headed at Ischua (plate 28) and passed northward as the East Branch Cazenovia. At Springville and Cascade Park is another great drift filling and pitted-plain, evidently related to the valleys of Buttermilk and Eighteen mile creeks. These extensive water-smoothed plains, with their kettles

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and lakelets, are the most unusual and interesting of the glacial features.

The courses in direct line of the Connoisarauley and Derby creeks with the South Branch Eighteenmile Creek is suggestive of a preglacial north-leading valley deserving of study. In this relation the valley of Spooner Creek must be considered.

The rock ravines will be described in a later chapter.

The quite direct course of the Cattaraugus Creek from East Arcade to the junction of the South Branch, a right-line distance of thirty miles, is a striking feature, but probably fortuitous.

The windings of the river in the rock ravines are "intrenched meanders" that were acquired when the stream was lazily swinging on detrital plains overlying the rock strata.

GLACIAL LAKES

The Cattaraugus Valley declines toward the southwest. The front of the waning ice sheet receded westward, and consequently the valley held ice-impounded waters, glacial lakes, in the main valley and its tributaries.

The lake history is complicated and not easily translated. In the production of the new valley the north boundary, created as described above by ice and stream deposition in the preglacial north-leading valleys, so blocked the valleys that even today there is no northward flow from the Cattaraugus basin. Except during the latest presence of the ice front all of the outflow was across the southern divide into Allegheny drainage (plate 28). That divide was uncovered by the ice removal from east to west, and the low passes permitting outflow of the ice dammed waters were opened successively westward. The height or elevation of the lakes and their extent were determined by the elevations of the points of outflow. The several outlets are indicated on plate 28.

Passing westward along the crooked line of water parting between north and south flow no pass with elevation lower than the Machias outlet, of 1,636 feet, is found until we travel fourteen miles in direct line and reach the head of Mansfield Creek, two miles northwest of Ellicottville. Here a pass leads southeast to Great Valley Creek, with elevation 1,620 feet and with form and relation indicating copious flow of water.

Further westward, seven miles in direct line, another pass ten feet lower is found two miles northwest of Little Valley (Cat-

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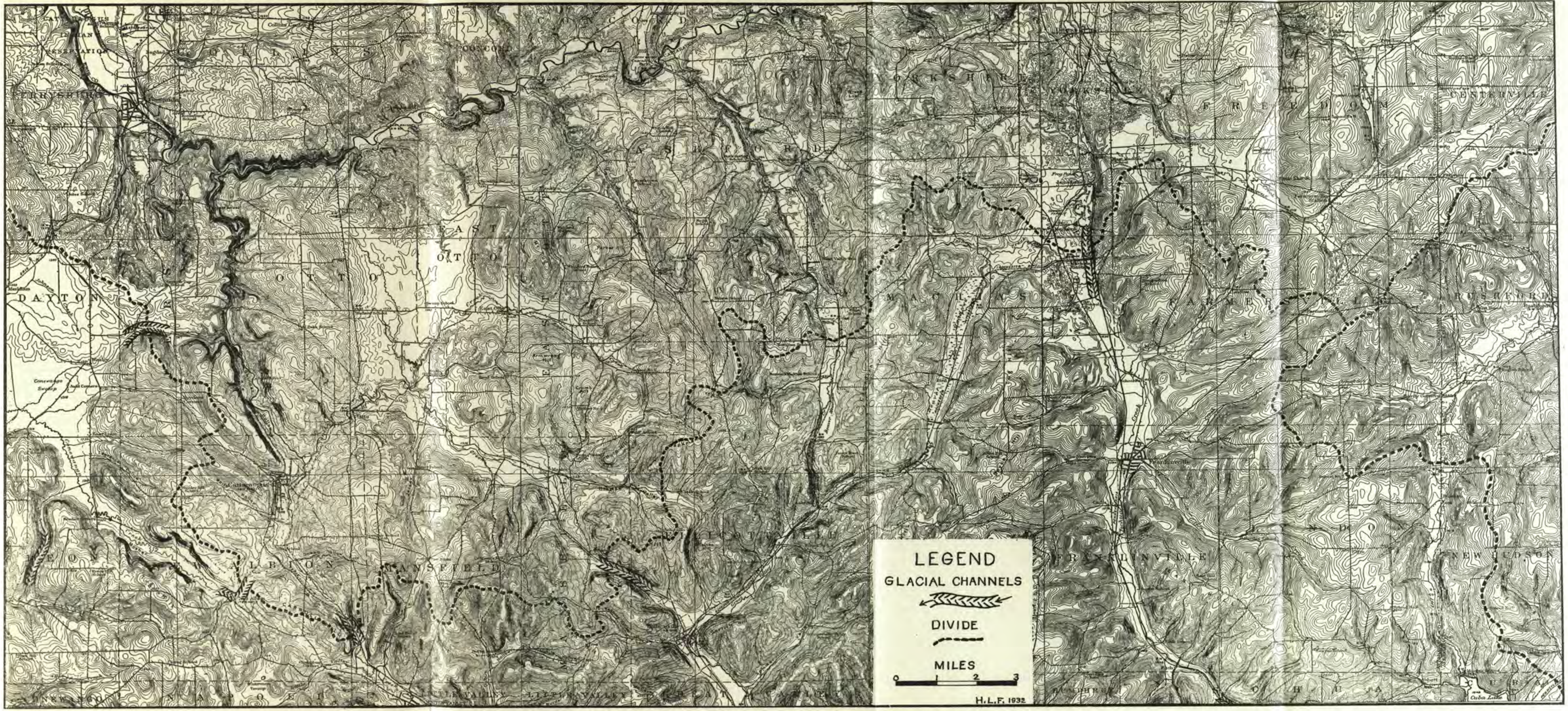

CATTARAUGUS VALLEY GLACIAL WATERS AND THEIR OUTFLOW CHANNELS

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taraugus sheet), but with the form less favorable. The Erie railroad found this pass available in passing from the Allegheny basin over to the Cattaraugus.

Five miles northwest of Little Valley, and three miles south of Cattaraugus village, a much lower pass occurs at the village of New Albion. This outlet has elevation of 1,440 feet and opens to the head of Conewango Creek. But the outflow by this pass was forced through the deep canyon west of Kendall Corners to the Mud Creek, tributary to the Conewango, until the ice front had moved away from the Wells Hill, six miles south of Dayton. The features are shown on the Cattaraugus sheet.

The westernmost and lowest pass is found at Persia flag station on the Erie railroad, with elevation 1,320 feet. This outlet, the latest across the southern divide, is three miles southeast of Dayton, leading to the wide Conewango Valley.

The next and the final escape for the Cattaraugus glacial waters was five miles west of Gowanda and northwest and north from Perrysburg, appearing on the Cherry Creek sheet and in plate 3 of paper 10. The outflow began at 1,300 feet, in the channel followed west of Perrysburg by the Erie railroad, while lower channels permitted outflow down to the level of Lake Whittlesey, 850 feet. Three interesting channels south of West Perysburg have elevation of 1,200 feet.

In review, these several outlets of the glacial waters are:

Machias,	elevation	1,640	feet.
Ellicottville,	"	1,620	"
Little Valley,	"	1,610	"
New Albion,	"	1,440	"
Persia,	"	1,320	"
Perrysburg,	"	1,300–850	feet.

The several outlets with the falling levels gives us the following theoretic lake succession, all of which, with exception of the last one, contributed their overflow to the Allegheny River.

1. Arcade-Yorkshire-Delevan lake. The outlet was at Machias village, with elevation about 1,640 feet, leading to Ischua Creek. The water in this stage filled the upper stretch of the valley nearly to the river's head in Java Lake, and the lower portions of the tributary creeks. The Arcade and Franklinville sheets depict the features.

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2. Springville Lake. This occupied the middle stretch of the main valley, and the tributary Buttermilk and Connoisarauley creek valleys. Apparently the lake had outlets at Ellicottville, 1,620 feet, and at Little Valley, 1,610 feet.

3. South Branch Cattaraugus Lake. This three-branched water body had its central point at Cattaraugus Village. Perhaps its early outflow was at Little Valley but its chief outlet was at New Albion, elevation 1,440 feet, over to the Conewango Valley (Ellicottville and Cattaraugus sheets).

During this stage a pass at Brooklyn School, three miles north of East Otto Village and three miles southeast of Zoar Bridge, at 1,360 feet, appears to have given connection with the water in the main valley above Cascade Park. The intrenching of the rock canyon below Zoar Bridge had not begun in this stage of the history; but the lake deposits which completed the fillings in the intersections at Yorkshire and at Springville probably began during this stage.

4. Main Cattaraugus Lake. The outflow was by the Persia channel, elevation 1,320 feet, over to the wide Conewango Valley. This was probably the longest in life of the several lake stages, with larger area, and more copious outflow. The higher lake plains and the deltas by tributary streams were completed during this stage. Some of the features are described below.

5. Gowanda Lake. This was the closing stage of the glacial waters. It existed while the ice front weakened and slowly receded on the north-facing slope at Perrysburg and West Perrysburg, from elevation of 1,300 feet down to 850 feet, when the water blended with Lake Whittlesey.

This falling level did not occupy the Cattaraugus Valley above the district of Gowanda because the canyon above Gowanda had not been cut. But all the water of the basin passed through the Gowanda lake, reaching the latter by cascades or cataracts.

The first and highest of the Perrysburg scourways, produced by the escape of the Cattaraugus waters along the ice front, is followed by the railroad that used Persia channel, five miles on the southeast. The elevation should be less than the bottom of the Persia channel, and is shown by the Cherry Creek sheet as about 1,300 feet. Plate 3 in paper 10 shows the succession of downdraining channels from

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1,300 feet down toward 900 feet, where the Cattaraugus waters blended with the great glacial Lake Whittlesey in the Erie basin. The wide plain of the Cattaraugus Indian Reservation and of the State Asylum are records of the lower lake waters, from 900 to 800 feet (plate 28).

6. Land-locked Cattaraugus Lake. When the glacial water in the Gowanda stage had lowered to about 1,200 feet, by the channels near Perrysburg, the water above Zoar Bridge was held in by the rock barrier. This lake was not, like its predecessors, a glacial or ice-barrier lake, but a rock-barrier lake.

This lake has long since been drained by the downcutting of the rock dam and the production of the great gorge or canyon above Gowanda. The lake was initiated while the ice margin lay on the ground northwest of Perrysburg, but its life, of tens of thousands of years, was mostly in postglacial time. Although the lake disappeared long ago the canyon erosion is yet in progress. The other rock gorges up stream, and the one in the South Branch, have similar and contemporaneous life history.

The curvatures or meanders in the rock sections were established before erosion of the rock began. They were formed on detrital plains when the new valley was filled with glacial and stream deposition to perhaps 1,300 feet elevation, at the close of the glacial history in the fourth stage, while the water was held up to the Persia outlet and the highest of the Perrysburg scourways.

ROCK RAVINES

The three ravines or canyons in the course of the Cattaraugus Creek (plate 28) mark the stretches where the stream was compelled to carve entirely new paths. In the intermediate open stretches of its course the stream, under control by the glacier front, discovered old valleys that had been tributary to the north-flowing rivers.

The surface of the ancient rock plain, of upper Devonian strata, appears to have been quite uniform in the district, as the ravines are similar in elevation and depth. The dimensions are approximately as follows:

Upper ravine, Cascade Park, two miles long.

Elevation of top of rock section	1,280 feet.
Elevation of the stream	1,080 feet.
Depth of ravine	200 feet.

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Middle ravine, below Frye Bridge, four miles long.

Elevation of top of rock section	1,200 feet.
Elevation of stream	1,000 feet.
Depth of ravine	200 feet.

Lower ravine, below Zoar Bridge, five miles long.

Elevation of top of rock section	1,200 feet.
Elevation of stream	900 feet.
Depth of ravine	300 feet.

The carving of the ravines by stream erosion is in postglacial time, for the district, and is a measure of the uncounted years since the ice sheet melted from that locality. The cutting of the rock did not begin until the ice-impounded water in the Cattaraugus basin and the newly-created river valley had fallen to the level of the shale and sandstone. As that level is today about 1,200 feet while the Persia outlet (plate 28) is 1,320 feet it is apparent that the ravine cutting is subsequent to the lake outflow at Persia flag station. The lake water was lowered, and the river encountered the rock obstructions when the outflow was held against the north-facing slope west of Perrysburg. At that time, as noted above, the water held in the Cattaraugus Valley had become a land-locked lake.

A striking feature is the winding course of each ravine. They are excellent illustration of "intrenched meanders." The meanders antedate the initiation of the rock cutting, having been established on the detrital plains which overlay the rock surfaces. The drop in the lake surface with the desertion of the Persia outlet caused the river to rapidly deepen its winding channel. The curvatures in the rock ravines are an inheritance from the meanders in the superimposed detritus.

Of course the deepening of the middle and upper ravines was dependent on the downcutting in the lower ravine, above Gowanda. And the erosion is yet in slow progress.

LAKE PLAINS

Without much careful exploration and study, with precise measurements, the history and records of the earlier lake stages in the basin of the Cattaraugus cannot be described in detail. An interesting task for some enterprising geologist is the examination of the outlet passes on the southern divide, with determination of the correlating features and of the history in detail.

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Beginning with stage 4, control by the Persia outlet, there is more of certainty and much of interest. The present elevation of the Persia outlet after its downcutting is 1,320 feet. The surface of the river in this channel determined the elevation of the impounded waters in the basin. The Cattaraugus topographic sheet shows extended smooth plains at 1,320 to 1,360 feet in the towns of Otto and East Otto. The valley plain at the village of Cattaraugus is 1,320 to 1,340 feet.

Examination of the topographic sheets will show that the plains, indicated by the white spaces, rise in elevation to the northeast, attaining 1,400 feet at Sardinia and Yorkshire. This increase in altitude is due in part to the postglacial uplift of the land, upslanting toward two feet per mile in the northeast direction. In the twenty-five miles of rightline distance from Persia to Sardinia the deformation may be toward fifty feet. If the outlet river at Persia had in its summer floods a depth of ten feet that alone carries the lake plane to 1,380 feet.

The wide plains at Sardinia-Yorkshire-Chaffee were built by the glacial outwash from the Cazenovia and Buffalo valleys into the Cattaraugus waters, and the abundant detritus was probably spread out, at Chaffee, above the lake level. At Arcade the delta filling, to 1,500 feet, was by the detritus of the upper stretch of the Cattaraugus Creek, and also by Clear Creek.

Another great outwash plain extends from Cascade Park through Springville to East Concord, first by glacial outwash and later by the outflow from the valleys of Cazenovia and the two Eighteenmile creeks. The elevations are 1,300 feet at Cascade Park, rising to 1,400 feet at East Concord (Ellicottville and Springville sheets).

The tributary valleys were also filled with detritus at the Persia level. A very handsome display is seen in Ashford Town (Ellicottville sheet) extending up the wide valley of Buttermilk Creek, and west to the Connoisarauley Creek, with elevations 1,300 to 1,360 feet.

During the thousands of years that the Cattaraugus river has been cutting the rock canyons detrital plains and deltas were forming in the land-locked lake by inwash by the tributaries, with slowly falling levels, from 1,200 feet down to the present creek.

The South Branch Valley has a similar history, produced by the rock barrier at Forty Bridge, with corresponding altitudes.

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In the slow deepening of the ravines the open-valley stretches above the ravines were always filled with stream detritus at the level of the rock channel downstream. With the deepening of each rock channel the stream was correspondingly lowered in the up-stream open-valley stretch, producing terraces and benches at various levels in the abandoned floodplains. These are abundant and conspicuous above Cascade Park in the fourteen miles to Arcade, with elevations from about 1,460 feet down to 1,100 feet, the present elevation of the river at the Park. An excellent example is found on the north side of the Creek, northwest of The Forks and south of Sardinia (southeast corner of the Springville sheet).

Below Gowanda, and beyond the control by the rock dam up-stream, the wide old valley and adjacent land were yet under the glacial waters, controlled by the Perrysburg scourways. An excellent evidence of the slowly falling waters is seen in the drainage area of both branches of Clear Creek, in the town of Collins and North Collins (Cattaraugus and Eden sheets). Marshfield is on a plain at 1,320 feet. Westward, down stream, the beautiful plains and terraces decline to 850 feet, the level of Lake Whittlesey; while lower plains represent glacial Lake Warren, 780, and down to Lake Erie, 573 feet. The interesting succession of plains and terraces in the Gowanda region are described in paper 9, pages 137–139 and in paper 10, page 38.

North-Leading Parallel Valleys

ORIGIN AND CHARACTER

The remarkable series of parallel valleys in central New York, tributary to the Ontario Valley, have long been famous. The westward representatives of the great sisterhood of preglacial valleys, the ones leading to Lake Erie, have been given small attention, although of much physiographic and geologic interest. The neglect has been due partly to the absence of lakes, partly because the valleys are deep and narrow with less advantage for occupation and agriculture. Also the area has high relief and few important villages.

The Erie basin series include eight valleys with general decline northwestward. From west to east they are: the lower portion of the Cattaraugus, which was the course of the Tertiary Allegheny; South Branch Eighteenmile; main Eighteenmile; West Branch

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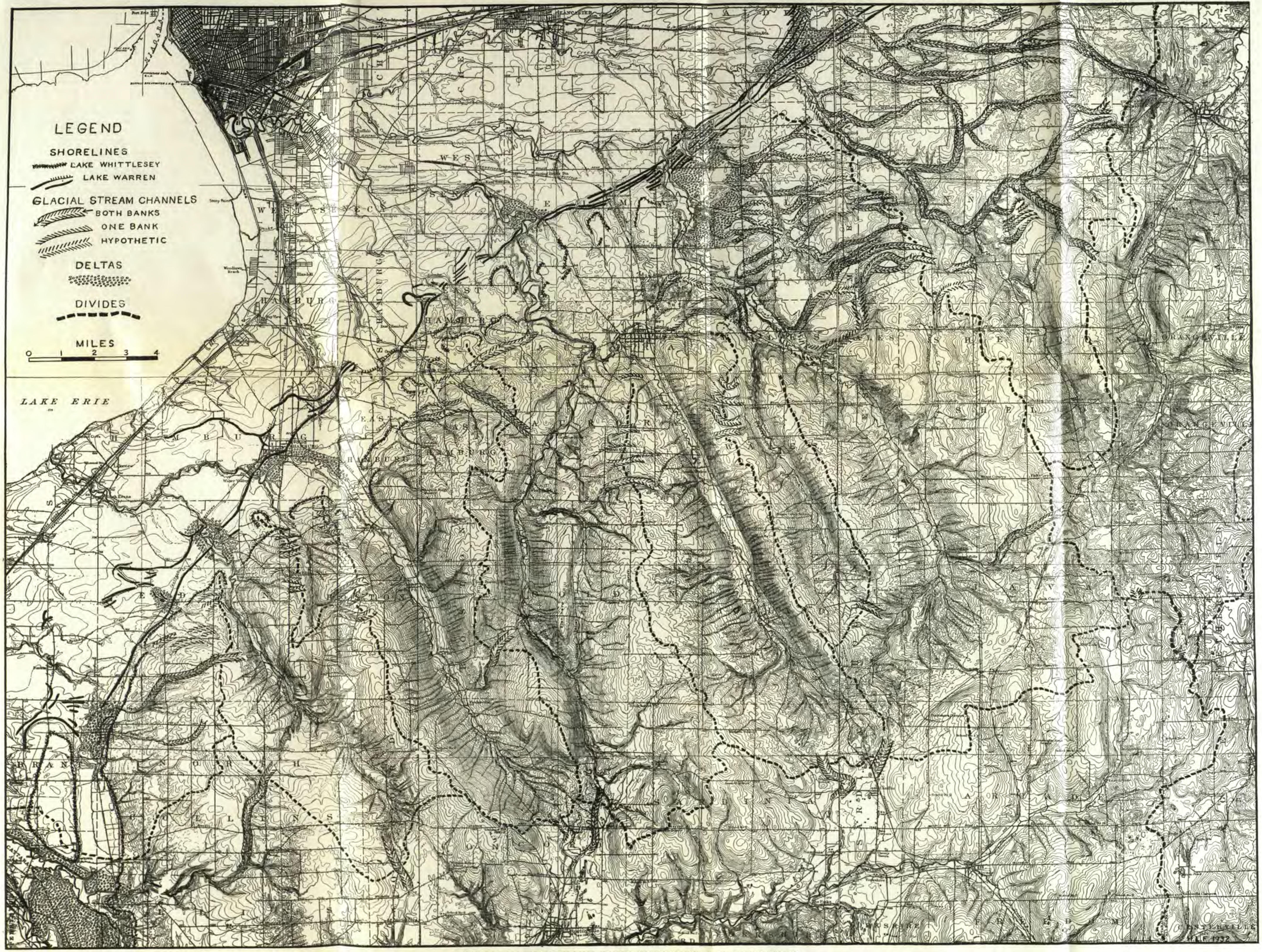

PARALLEL VALLEYS AND GLACIAL WATERS NORTH OF THE CATTARAUGUS VALLEY

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Cazenovia; East Branch Cazenovia; Hunter; Buffalo; Cayuga. East of these the Tonawanda is a connecting link between the Erian and Ontarian groups, the creek having a course east of north and then west into Niagara River.

These open valleys are remnants and relics of much more extended valleys of Tertiary drainage. As with the valleys of central New York the former southern or headward portions and the northern, terminal portions of most of them have been obscured or even buried by the work of the ice sheet and the glacial lakes. West of the Cattaraugus the heavy moraine deposits on the scarp of the plateau have buried the channels of northward flow.

This group of valleys is an inheritance from Tertiary time, when all of the drainage of central and western New York, including the Allegheny River, passed northward (figure 2). The streams which carved these valleys performed the same function, and at the same time, as the Ontarian tributaries, namely, the removal of the precipitation from the northern scarp of the Allegheny Plateau. And, like the Ontarian group, they have been dissected or beheaded by moraine filling.

As these deep parallel valleys decline to the northwest, and as the blockading ice front lay across them transversely, the outflow from each valley was into the adjacent valley on the west. In the case of two valleys, Hunter and Cayuga, the water was held up to confluence with its neighboring lake, or lakes.

In the precise study of the elevations of the outflow channels and the planes of the lake surfaces it is necessary to take into account the postglacial land uplift, with the northward uptilt of about two feet per mile; and the lowering of outlets by the stream erosion.

MORAINES AND VALLEY BLOCKADE

The moraines in this area were mapped by Frank Leverett in paper 5, plates 19, 25, and described in pages 651–684. In a general way they are shown in figure 3, but require further study.

The ice front acting as a barrier, along with the moraine fillings which it piled in the valleys, produced the Cattaraugus Creek, which cuts across and has beheaded the longer preglacial valleys.

The outwash plains facing the valley fillings are extensive, and pitted with kettles and ornamented with lakelets. They are shown on the Eden, Springville and Arcade sheets. They are unequalled in New York; but kettled plains in comparison are the delta plains

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along the east side of the Black River Valley, described in the State Museum Bulletin 160.

The valley fillings along the north side of the Cattaraugus Valley are part of Leverett's "Escarpment Moraine System," described in pages 651–672 in paper 5, and partly mapped in the plate 19. It will be seen in the new moraine map, figure 3, that this moraine correlates with the "Valley Heads" moraine in the central part of the State, and has similar relations. In both areas the drift belt is poorly developed between the valleys, across the intervalley ridges.

The moraine deposits, the wide and smooth outwash plains blending with the Cattaraugus Lake plains, and the valley lakes and their outlets, described below, make a very interesting geographic and geologic complex.

BURIED VALLEYS

An interesting element in the study relates to the buried or obscured lines of the preglacial drainage, especially the southern or headward portions. With even the present limited data and information it is possible to locate and trace some of the drift-filled valleys, having in mind that the northern divide of the Cattaraugus basin is wholly of post-glacial origin, but that the southern divide mostly dates from preglacial time.

Excepting the valley of Hunter Creek it appears probable that all of the deep north-leading valleys north of the Cattaraugus had their original headings south of the present divide; and some of the old drainage lines may be confidently inferred.

It appears quite certain that the stretches of the Cattaraugus with wide fillings of lake deposits, as at Zoar, at Cascade Park and Springville and at Yorkshire-Sardinia are filled sections of ancient north-leading valleys. The directions and relations of the unfilled portions of valleys north and south of those filled areas clearly indicate the paths of some of the Tertiary rivers. Detaching, temporarily, from its binding the map, plate 28, and placing it in proper juxtaposition with that of plate 29 the above features appear in their true relationship.

Perhaps the clearest of the old valleys is that which had its head in the constricted notch or col at Ischua Village (Franklinville and Olean sheets). Its northward course is well marked past Franklinville, Machias, Delevan, Yorkshire, Chaffee, and the now-open stretch from Protection to East Aurora; a distance of forty miles. North of East Aurora the old valley is obliterated, as are all of

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the old drainage lines on the Erie lowland. As a name for the Tertiary valley we may favor that of the deep, open stretch and call the stream the Preglacial Cazenovia River.

Passing westward we find that Buttermilk Valley, heading near Ashford, is in line, through the valley filling at Springville, with, probably, the Eighteenmile Valley; a length to Hamburg of about thirty miles. The close relation of the West Branch Cazenovia requires study of the rock exposures and of any deep borings.

Apparently the valley of the east Beaver Meadows also headed near Ashford, and was tributary, at Machias, to the ancient Cazenovia.

The Connoisarauley Valley, heading near the hamlet of Plato, appears to connect with the South Branch Eighteenmile Creek. The length to Eden Valley is about twenty-five miles.

The Conewango Valley was long ago (paper 1) shown to connect with the lower Cattaraugus as the Tertiary path of the Allegheny.

The lines of the ancient, preglacial stream flow can be positively and fully determined only by systematic deep drilling, and study of the well records along with the observable rock outcrops. Perhaps there may now be considerable available data for the use of some enthusiastic student of the local geology.

On plate 28 the headings of some minor lines of the old drainage may be noted. The site of the outlet channel northwest of Ellicottville was originally a divide between a tributary of the Allegheny and the present valley of Mansfield Creek. This suggests continuation through the towns of Otto, crossing of the Cattaraugus at Zoar, with probable continuation northwestward to the old Allegheny.

The channel three miles northwest of Little Valley was the location of a col which headed the valley holding Cattaraugus Village. Apparently this drainage line passed northwest toward Gowanda as an Allegheny tributary.

On plate 29, an ancient col at East Arcade was doubtless the head of a north-leading valley which was tributary to the Tonawanda Creek, and was the actual head of that drainage system. Only the stretch at and south of Java Lake remains unfilled.

GLACIAL LAKES IN VALLEYS NORTH OF THE CATTARAUGUS

The territory including these valleys is mapped on the Buffalo, Depew, Attica, Eden, Springville and Arcade sheets. The first three

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of the sheets, in part, and the last three are combined to form plate 29, with reduction in size.

All of these valleys decline northwestward, and consequently were effectively dammed by the receding ice front. The earliest impounded waters, the primitive lakes, had outflow southward, across the moraine fillings, into the newly-created Cattaraugus Lake. Later outflow was westward, across the intervalley ridges, with the ultimate escape into lakes Whittlesey and First Warren. The abandoned, cross-ridge channels are evident on the topographic sheets and conspicuous and fascinating in the field. They are fairly indicated on plate 29. The latest and complex outflow channels were long ago mapped in plates 3, 5 of paper 10.

These glacial lakes will be described in order passing from west to east.

New Oregon-Clarksburg Lake

In the South Branch Eighteenmile Creek

The area is wholly shown on the Eden sheet, and in plate 29. The primitive outflow at the valley head was apparently across the outwash, at 1,420 feet, into the Cattaraugus waters by Derby Brook. The outwash plain lies between Concord and Morton Corners.

The earliest well-defined lateral outflow was a mile south of Langford corners, at 1,240 feet, over into the North Branch of Clear Creek. This flow contributed to the plains and terraces along Clear Creek.

Another main outlet of the lake was five miles farther north and only a mile from the present stream, at the head of Franklin Gulf, 1,120 feet. The canyon form of the channel attests a copious and erosional outflow, which contributed to the Whittlesey beach and delta at North Collins.

Close study on the ground in this district will doubtless locate several scourways across the divide at intermediate elevations between the three outlets here described. Some of the unmapped outlets may correlate with the fragmentary stream channels shown in plate 4, paper 10.

The final downdraining was east of Eden Village; first by a channel at 1,000 feet, and later on a north-facing slope into Lake Whittlesey. See plate 4, paper 10.

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Boston Lake

In the West Branch Cazenovia Valley

The earliest waters were probably confluent with the highest Cattaraugus waters, producing the extensive kettle-pitted plain north of Springville and west of East Concord. This level, 1,400 feet, must have existed until the ice front receded on the western divide some nine miles. Southwest and west of Boston Center escape was found at 1,400 down to 1,300 feet. Below this the control was west of the Hampton Valley, at East Eden. Here a set of channels begin one half mile south of the corners, at 1,140 feet and continue north and northwest of the village down to 1,000 feet. At this lowest level control was also held a mile west of North Boston. These channels were mapped on plate 4, paper 10.

TRANSPOSE

Two miles north of North Boston the lake waters blended with those of Lake Whittlesey at or just under 900 feet.

Glenwood-Colden Lake

In the Main Valley of Eighteenmile Creek

This is shown on the Springville sheet. The valley heads, like the former one, in the outwash plain at East Concord; and the primitive outflow appears to have been along the path followed by the Buffalo, Rochester & Pittsburg Railroad, at 1,420 feet.

The water in this valley was confluent with that of the Boston Lake, on the west, through the cross-valley pass two miles southwest of Colden, now occupied in part by Landon Brook. But when the Boston Lake was lowered about 200 feet this pass became the outflow channel. The swamp col has elevation of 1,170 feet.

This valley, like the others of the series, has walls too steep to hold large and conspicuous delta plains on its slopes. But some of the inflowing brooks should have built deltas that can be recognized in the field, and the altitudes definitely measured. Such small deltas are the very best criteria for determining the water planes and elevations.

The next lowest escape for the Colden waters was far northward, no pass below 1,080 feet being found until we reach Loveland, northwest of Jewettville and Griffins Mills. Here is a complex of channels, and one followed by the B. R. & P. RR. leading northwest curves around to southwest as a scourway opening to Lake Whittlesey.

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The intake of the Loveland channel is 1,020 feet. Three miles north, and three miles west of East Aurora, a channel at 900 feet elevation leads west and joins the Loveland channel.

Holland Lake

In the East Branch Cazenovia Valley

The creek heads in several twigs in the moraine and outwash plain at Protection Station and Chaffee Village. The channel of primitive outflow is a capacious scourway across the divide, one half mile east of the Briggs School and two miles northwest of Chaffee, leading over to Hosmer Brook. The elevation is 1,440 feet. The features appear on the Springville and Arcade sheets.

The lake existed at the level of its early outflow until the ice dam had backed away on the high western ridge, a distance of eleven miles, to near the latitude of South Wales (Springville sheet). Two miles west by south from South Wales is a channel entered by the Darling Road and curving around to Pipe Creek. The elevation of the channel bottom at the intake on the divide is about 1,310 feet. The form of the pass and channel and the Pipe Creek canyon indicate a heavy stream flow. Indeed it appears that the channel carried not only the outflow of the Cazenovia Valley but also the later outflow of the Hunter and Buffalo valleys on the east.

On the dividing ridge, declining northward, scourways occur at successively lower levels, four of which are indicated on the map, plate 29, before this East Branch Valley joins the West Branch at East Aurora, at the level of Lake Whittlesey, about 900 feet.

Colegrove Lake

Hunter Creek Valley

This deep valley lies between the East Branch Cazenovia and Buffalo valleys, on the Springville and Arcade sheets. It does not head in a moraine and outwash plain like the other valleys. When the head of the valley was released from the ice sheet it was flooded by water from the Buffalo valley through a pass two miles north of Dutchtown, with elevation of 1,370 feet. During that phase the water in the Hunter Valley was a branch of the Wales Hollow Lake, described below.

The first outflow from the valley was southwest of Colegrove and two miles northeast of South Wales, by a channel at 1,300 feet.

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This channel and the succeeding ones also served for the final escape of the Buffalo Valley waters.

West and northwest of Colegrove are three more passes which lowered the waters from 1,300 down to 1,200 feet. East and northeast of East Aurora the lower channels belong to the next lake, and are on the Depew quadrangle.

Wales Hollow-Java Village Lake

Buffalo Creek Valley

As shown on the Arcade sheet and on plate 29 the Buffalo Creek heads in many branches in the towns of Holland, Arcade and Java in an extensive moraine. The longest branch, through Dutchtown, heads close to the longest branch of the East Branch Cazenovia Creek.

Mr. H. W. Clough has drawn attention to an interesting path of glacial drainage which appears on the Arcade sheet but is not indicated on plate 29. This is a smooth and level stretch extending northeast from Chaffee past Punkshers Corners and Java to near Java Center, a distance of seven miles, which carried the earliest drainage of the Buffalo Creek basin.

This belt is quite level, with elevation 1,500–1,520 feet, and apparently was smoothed as a scourway of glacial flow along the margin of the waning ice sheet. It carried the overflow of the glacial waters on the northeast, especially those of the Tonawanda Valley. This ice-border drainage immediately preceded the flow through the Gallagher Swamp channel, three miles northeast of Java Village, and it carried the earlier contribution of detritus to the great outwash plain at Chaffee.

The early flow in the Java Center—Chaffee scourway was pressed against the northwest faces of two hills, one southeast of Curriers and the other northeast of Punkshers Corners, and produced undercutting and oversteepening of the eroded slopes. This is shown by the close-set contours, 1,540 up to 1,700 feet.

A later escape of the glacial waters appears to have been through the moraine by a pass across the divide a mile north of Chaffee, at 1,480 feet elevation, leading to the outwash plain at Chaffee and Sardinia. This pass exhibits no channel features. It is the north portion of the outwash plain and carries many and deep kettles (Arcade sheet). The kettles were produced by the

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melting of blocks of ice which had been buried in the drift, and the melting did not occur until the ground was exposed to the atmosphere and leaching rains.

The history, the succession of events and lake conditions, is not evident and positive. An important, and uncertain, factor is the position of the ice margin in this area in its time relation to the ice-front position on the southern divide of the Cattaraugus Valley having control of the glacial lake waters. The Chaffee-Sardinia outwash plain was built in the higher glacial Cattaraugus waters; and the question now arises, how long in time and how far in northward distance did the Cattaraugus waters occupy the Buffalo Creek basin.

Evidently the Buffalo Valley waters flooded the Tonawanda Valley, on the east, by the pass at Gallagher swamp, 1,420 feet elevation, some four miles east of Java Village. And the Tonawanda waters flooded the valley of Cayuga Creek through a pass one mile northeast of North Java Station. Thus it appears that one water body occupied portions of four distinct stream systems, the Buffalo, Hunter, Tonawanda and Cayuga; to which perhaps we may add the Cattaraugus as a fifth drainage area. The relations geographic are shown on plate 29.

Apparently the only ultimate escape for the Buffalo Valley and its confluent waters was by the Chaffee pass until the ice front had receded eleven miles so as to uncover the Hunter Valley outlet, one mile southwest of Colegrove, the outlet of the Colegrove Lake, at 1,300 feet. With the fall of the Colegrove Lake (Hunter Valley) the Buffalo Valley waters became tributary to the Hunter Valley, Colegrove Lake, by northward outflow through the pass two miles north of Dutchtown, described above as the strait which had been the connection of the earlier waters of the Hunter and Buffalo valleys.

The northward outflow of the Wales Hollow Lake persisted until the two lakes blended together south of Sales Center (plate 29). The final flow was by a network of channels northeast and north of East Aurora, from 1,000 down to 900 feet. This latest flow appears to have been forced by the ice front around to the Holland Lake, just before their lowering into Lake Whittlesey. The features lie on the Depew sheet, and are mapped on plate 5, paper 10, and plate 29 of this writing.

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In Valley of Cayuga Creek

This is the most easterly of the larger valleys tributary to Lake Erie. The slender creek heads in a swamp with elevation 1,376 feet, one mile north of North Java Station on the Arcade & Attica Railroad; and very close to the west fork of the Tonawanda Creek. The glacial history is tied in with that of the Tonawanda, the waters of which flooded the valley through the swamp noted above. The early waters, also the earliest glacial water of the Tonawanda, had elevation of 1,420 feet.

The first lateral outflow of the combined waters was one mile southeast of Bennington Corners (Attica sheet), at what is now 1,400 feet. A remarkable network of channels carried the later outflow, covering seven miles northwest. These are mapped on plate 5, paper 10, and partially on plate 29.

Johnsonburg-Varysburg-Attica Lake

Tonawanda Valley

Here is the most easterly of the parallel valleys with the streams having escape to the Erie basin. Today it contributes to the Niagara River. The next important valley on the east, the Oatka, contributes to the Genesee River and Lake Ontario, and belongs with the central New York series, described in papers 11 and 17.

The Tonawanda Creek has two sprawling forks in the towns of Java and Weathersfield, shown on the Arcade sheet. The west fork lies close to the Java Lake branch of Cattaraugus Creek. It runs only one half mile south of the head of Cayuga Creek, as noted above. The single deep valley begins two miles south of Johnsonburg.

The primitive glacial lake appears to have had outlet through Gallagher swamp and a pass one mile southwest, with elevation 1,420 feet. This led to the Beaver Meadow Creek, a fork of the Buffalo Creek. This level carried 44 feet over the head of Cayuga Creek, described above, and consequently flooded the Cayuga Valley.

The first westward outflow of the Tonawanda glacial waters was on the northwest-facing hill slope, less than two miles south of Bennington Village. Allowing for the tilting land uplift the first flow between the ice front and the sloping ground was at elevation over 1,400 feet. The series of successive channels below about 1,380 feet are mapped on plate 5, paper 10.

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That flow past the ice front, south of Bennington, acquired drift from the ice and constructed a very interesting set of deltas, along the east slope of French Brook. Their elevation of 1,240 feet determines the elevation of the water surface, at that time, in the Cayuga Valley; under control of the outlets near Bennington Corners.

The next lower escape of the Tonawanda Valley waters was by the Konawaugus Valley, Gillett Creek and French Brook, passing close to the corners at Bennington.

Eventually a lower outlet was found four miles north, at East Bennington, at elevation 1,300 and down to 1,240. And two miles yet further north a low pass northwest of Attica, at 1,080 feet, which is utilized by the Erie Railroad. Yet later escape was by channels two miles north of Alexander, at 1,040 and down to 940 feet.

All of this northern territory is covered with moraine, and the Attica glacial waters found a plexus of low channels which carried the flow westward into Lake Warren at Alden and Crittenden.

The mapping of the glacial stream channels on plate 29 is not intended to be complete, only some of the principal channels being indicated. A keen observer, with a trained eye, may find many other minor scourways; and perhaps some errors in this mapping. The topographic sheets are the "guide, counselor and friend" in the field study.

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THE RICHMOND MASTODON

By John T. Sanford

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ILLUSTRATIONS

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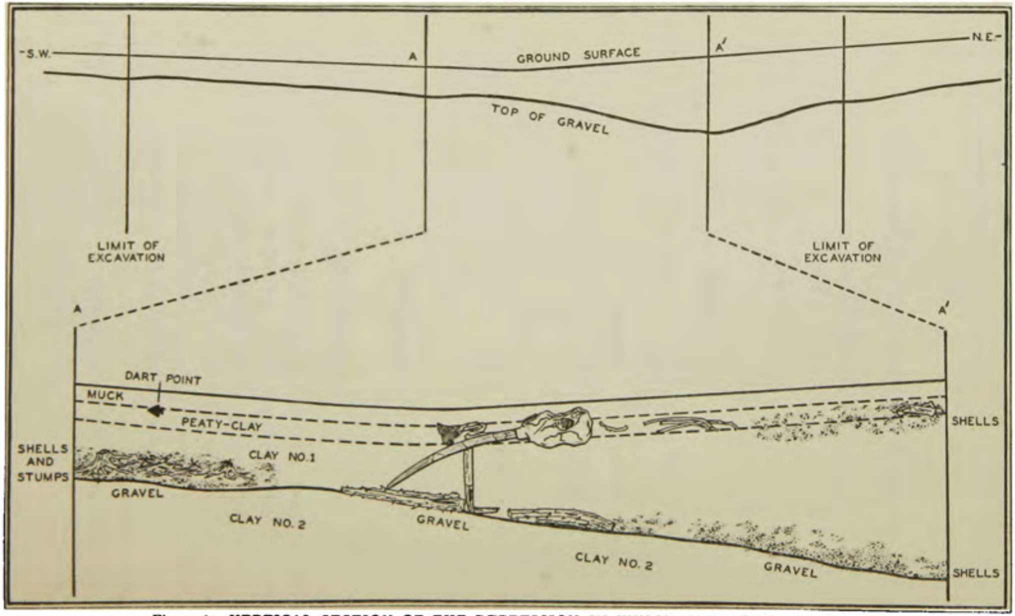

Figure 1. **VERTICAL SECTION OF THE DEPRESSION IN WHICH THE BONES OCCURRED**
The diagram A–A' below, corresponds to the portion A–A' in the profile above

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Explanation and Credits

The finding of human artifacts associated with the remains of the Richmond mastodon has aroused much interest in the scientific world as well as among the general public. The paleontology of the find has not as yet been studied but a wealth of information is at hand concerning the occurrence of the mastodon and is herewith presented, together with suggestions regarding the creature's age.

Detailed field studies and adequate time and facilities for the collection of the specimen were made possible by the interest and generosity of Mr. Watts S. Richmond of Buffalo, New York, who secured the specimen for the Buffalo Museum of Science. It is therefore most appropriate that the huge fossil be named in his honor the Richmond mastodon. To Mr. Everett R. Burmaster, of Irving, New York, who co-operated in the work, the writer is under deep obligation, both for assistance in the field and for many valuable suggestions regarding the preparation of this account. Without his aid much of the present paper might never have been written. Dr. Ira Edwards, of the Milwaukee Public Museum, spent several weeks in the field and was most helpful. The staff of the Buffalo Museum of Science have assisted in many ways as have also the Museum of Natural History and the Department of Geology at the University of Rochester. Dr. William D. Merrell, Professor of Botany at the University of Rochester, has identified the plant remains. Dr. A. C. Parker, Director of the Municipal Museum at Rochester, and Dr. J. E. Hoffmeister, Professor of Geology at the University of Rochester, have made helpful suggestions regarding the manuscript. Mrs. Sanford has aided constantly, both in the field and in the writing of this report.

History of the Find

The Richmond mastodon was found in the fall of 1930 on the farm of Charles Feldheiser, situated about two and a half miles southeast of the town of Cromwell, in Noble County, Indiana. The original find was a tooth, discovered by a boy, Donovan Harper, who was living on the farm at the time. Several weeks later a search was being made for a tile ditch which had been laid a number of years before. An iron rod was thrust into the ground here and there. It finally struck something hard which digging revealed to be the skull and tusk of a mastodon associated with a few miscellaneous bones from the same beast.

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Fortunately Mr. Feldheiser did not attempt to further unearth his find but communicated with several museums, among them the Buffalo Museum of Science.

Excavation and Preservation of Material

The mastodon remains were buried at a depth ranging from less than a foot up to five feet, although most of them were found at a depth of about two feet, in a clay rich in plant remains and overlain by muck. Before proceeding with a more detailed account of the occurrence and condition of the fossil a few paragraphs will be devoted to the methods used in excavating and in preparing the bones for shipment.

Inasmuch as the specimen had been partly uncovered by the finders it was thought best to begin excavation at once in spite of the winter season. The portions of the skull and tusks originally unearthed had been covered with straw. These were brushed clean and covered with burlap over which was spread straw to prevent freezing.

Excavation was started at from ten to fifteen feet from the skull and carried toward it. As soon as a bone was found digging was stopped at that particular place and it was covered with newspaper and straw. This procedure was followed until the find had been outlined. The muck was then removed from the surface and the whole banked with straw. For this preliminary work, where large quantities of material were handled, spading forks were found to be the best and safest tools to use. Before this work was completed inclement weather made a canvas cover necessary and as soon as the material had been outlined a shed 30 by 22 feet was erected over it. This shed was equipped with a stove which was tended night and day to eliminate any chance of radical temperature changes, as frost might easily have damaged the water-soaked bones. Meanwhile trenches had been started from opposite sides of the excavation to give a cross-section of the depression.

Uncovering and cleaning the matrix from the bones required infinite care and patience as there was constant danger of losing some of the smaller bones and other material. There was also danger of breaking some of the more fragile pieces. The work was done with trowels, brushes, and small wooden tools which could be whittled out on the spot to suit the needs of the user.

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All of the material with the exception of the lower parts of the tusks was uncovered and photographed before any of it was removed. During this uncovering pieces of the bones began to dry out somewhat so from time to time the exposed portions were given a coat of ambroid, thinned with an almost equal part of acetone. When ambroid is applied to a damp surface it later peels off or loosens and can be brushed away, but although it does not stick, it has the advantage of causing the bone to dry more slowly. The first coat did stick to most of the material. After being photographed, the skeleton, with the exception of the tusks and skull, was removed from the clay and placed on shelves built around the shanty and on burlap spread out on the clay floor. As soon as the outside had dried the bones were given a coat of thin ambroid, the smaller ones being dipped in a dishpan of it and the excess brushed off. Ambroid was applied to the larger bones with paint brushes. This process was repeated almost daily until the material was packed.

Figure 2. MODEL, SHOWING POSITIONS OF SOME OF THE BONES
(By E. R. Burmaster)

A, Muck. B, Peaty clay. C, Clay. D, Gravel. E, Skull. F, Broken tip of left tusk. G, Logs, lying under tip of right tusk. H, Stump, in place. I, Dart points. J, Charred log.

One end of the only humerus found was badly cracked. Very thin ambroid was poured into this broken portion several times at

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intervals of a day or two. As a result this humerus came out in good condition.

Most of the vertebrae, toe bones and other small bones were packed in barrels of sawdust. The ribs, the leg bones, atlas, etc., were covered with excelsior and then wrapped in burlap which had been soaked in thin plaster of paris. This was covered by an outer coat of plaster of paris. In the case of the largest of these bones, leg bones, etc., another cover of burlap and plaster was added which in turn was followed by a second coat of plaster. Numbers could be written on the outside of each package while the plaster was still wet.

The large tusk was a problem in itself. It still retained its original shape but was badly cracked in several places. Tusks have frequently been broken in the process of recovery. The clay was carefully removed from this tusk until it was possible to jacket it for nearly two-thirds of the circumference except for the tip. Before jacketing it was covered with a coating of clay mixed with water until of the proper consistency to be applied with the hands or a brush. This would permit the jacket to be removed easily. The jacket was built of thin plaster into which was worked excelsior previously soaked in water. The procedure was to take a handful of wet excelsior, work the plaster well into it with plenty of excess and then apply it to the tusk. Short pieces of board were built into this jacket to strengthen it. After the exposed portion of the tusk was jacketed it was entirely undercut in two places and jacks were placed under it. The tusk was slowly raised until it colled be rolled over and onto blocking placed ready to receive it. The jacket was continued to the tip and a clay joint made between it and the remainder of the jacket so that the smaller part could be removed easily. The two parts of the jacket were sealed together with plaster reinforced with burlap.

The basal portion of the smaller tusk was badly shattered. It was jacketed before removal. The remainder of the tusk was removed before being packed. The skull was reinforced with plaster before it was jacketed. Two small pieces of timber were built into the under side of this jacket so that it could be carried more easily.

Excavation, cleaning, and preparing the bones required approximately six weeks. Warm weather near the end of that period caused water to pour into the excavation but fortunately the work was so

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nearly completed that but slight damage was done. It was necessary to employ a power pump that the work might be finished.

It was not definitely known at that time whether or not more bones might be found outside the excavated area or below the horizon al-

Figure 3. STUMPS, STANDING ON THE GLACIOFLUVIAL GRAVEL

ready explored, so work was resumed in June, 1931, and six more weeks were spent in hunting for more of the fossil and collecting data on the deposit in which it occurred. One broken vertebra was

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all that was found of the specimen but the time was well spent, as an abundance of other data having a bearing on the age and occurrence of the creature was obtained.

During this time the excavation was extended to cover an area roughly rectangular and approximately 110 feet long and 80 feet wide. Sections showing the thickness of the various beds to the top of the gravel outside this area were obtained with the aid of a well augur. A section of the strata from the surface to the gravel was taken in tin trays and treated with glycerine in much the same way that varved clays are handled. Specimens of the trees found on the gravel were coated with clay and jacketed with plaster and excelsior in the same way that the tusks had been treated.

Description of the Deposit

The shallow depression, a partially filled kettle, in which the mastodon occurred was approximately eight hundred and fifty feet above sea level, two hundred feet in diameter and roughly circular. The east and north sides rose somewhat more steeply than the south and west sides. It had been occupied by a pond within the memory of some of the older inhabitants of Cromwell and is situated about one hundred feet west of low ground that may have been a drainage line in times of high water. At present this lower ground is occupied by a ditch.

The surface deposit in the depression was a mucky soil varying in thickness between six inches and one foot. (See figures 1 and 2.) The upper part had been disturbed by cultivation for a number of years. A dart point was found in the lower part beneath the disturbed portion. This mucky soil graded downward in most parts of the excavation into a clay which contained a large percentage of plant material, so much, in fact, that the workmen termed it "peat." This material was approximately one foot in thickness and was missing in places. It will be referred to here as a peaty clay. Below it was a clay (Clay No. 1), the upper part very rich in plant remains which became less plentiful downward until near its base, but were to be found throughout the stratum. This clay varied greatly in thickness, being eight and one half feet thick in one place and pinching out entirely around the rim of the depression. Throughout a part of the excavation numbers of the shells of pond molluscs were to be found in the upper part of the clay and in the

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Figure 4. BONES, AS THEY LAY AFTER REMOVAL OF THE COVER

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peaty clay. Most of the mastodon bones were found near the contact of the peaty clay with Clay No. 1. Bits of charcoal were also found at this horizon and a dart point which will be considered later.

Below Clay No. 1 was a gravel containing a strong admixture of clay. This graded rapidly downward within one to one and a half feet into a clay with an admixture of sand and gravel or a purer clay. This clay is designated as Clay No. 2; it was exceedingly plastic.

In the base of Clay No. 1, and resting on the gravel were a number of tree trunks, most of them rather small with the stubs of numerous branches still showing which gave the impression that they had not been transported. The butt of one of these was charred. In addition to these were found in place the stumps of trees which had once grown on the surface of the gravel. (See figure 3.) The larger roots of these stumps all extended toward the margin of the depression, away from the water. One of these stumps was the remnant of a tree with a trunk about one foot in diameter. Others were smaller.

Associated with the roots of these stumps and near some of the tree trunks were cones and needles of black spruce. Similar cones were found throughout Clay No. 1. Pond shells were also found associated with these stumps and trunks and at other places throughout the base of Clay No. 1.

A microscopic study of Clay No. 1 shows that in addition to the very minute fragments composing the major part of the material there are somewhat coarser fragments of quartz which are very angular. Samples taken at both the top and bottom of the stratum were similar in this respect. The clay was tested for calcite with hydrochloric acid in the field but no reaction was obtained except at or near the base of the stratum.

On the north side of the excavation two thin beds of sand were encountered. These were about 0.1 of a foot thick and 0.3 of a foot apart. The top of the upper bed was 5.3 feet from the surface. The clay above the sands gave no reaction when tested with acid but the sands reacted strongly. Calcite is present in the gravel and in Clay No. 2.

Occurrence of the Bones

The mastodon bones were all found at practically the same horizon at the point where the clay graded upward into the peaty clay and

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at this horizon fragments of charcoal occurred. Extending below this was the broken left tusk which reached to the gravel approximately three feet beneath the skull and five feet beneath the surface at this point. The end of the right tusk also extended down into the clay, almost to the gravel, and rested on the fallen trunks of some trees. As the skull was lying bottom side up and was larger than some of the other bones, the upper teeth were within a short

Figure 5. PORTION OF FEMUR, UNDER SIDE, WITH CLINGING SHELLS

distance of the surface, so that the first discovery, a tooth which was found some feet from the skull, was in all probability knocked loose by a plow.

The position in which the bones occurred is shown in figure 4, which is a composite of several photographs taken from directly above. Practically all the material found is seen here. Although concentrated in an area about twenty by thirty feet, the skeleton taken as a whole had no semblance of order, but some of the ankle bones and the vertebrae seen near the skull were perfectly articulated.

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As has been noted the skull was lying on its top. The stump of the left tusk remained in the skull but was broken off a short distance from it. The next two feet of the tusk were badly shattered and another break separated this portion from the remainder which stood vertically in the clay with the tip broken off against the gravel. (See figures 1 and 2.) As previously mentioned the right tusk lay intact although cracked in several places. The attachment to the skull was not perfect, the relative position of tusk and skull being slightly shifted, but the shift was small and the tusk had approximately the same position in relation to the skull as during life. In life the tusks of this specimen pointed outward and upward. There is a remarkable discrepancy in the size of the tusks, the left tusk being five feet shorter than the right one. Both tusks although broken were complete and had not been broken during the life of the animal. The lower jaw was broken in one place but lay right side up on the left tusk with the anterior facing the anterior of the skull.

The pelvis was in excellent condition and was found in front of and a little to the side of the skull. Near it was a femur, its position indicating that it had moved but little since becoming disjointed. Beneath this femur were found numerous small shells which clung to it when it was raised. (See figure 5.)

Several pieces of ribs were found beneath the side of the skull. One of them had been broken during the life of the animal, the ends had slipped by each other and it had mended in that position. This can be seen in figure 6. A floating rib was found near the pelvis. Most of the other ribs which were recovered were found lying back of the skull although two may be seen lying between the pelvis and the lower jaw. Many of the ribs were broken. The single humerus which was found lay on the opposite side of the skull from the femur. The radius and ulna from both forelegs lay back of the skull and on the same side as the humerus.

From among the data presented regarding the occurrence of the bones there are several facts selected for special emphasis.

(1) The skull was lying on its top and there were several ribs under it.
(2) The pelvis was in front of the skull.
(3) The smaller (left) tusk was broken and both tusks were sticking into the clay.
(4) Although the bones were scattered some of the smaller ones (as ankle bones) were still articulated.

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Flint Dart Points

Two dart points were found. (See figure 8.) The first of these, the butt of which was broken, was discovered about fifteen feet south and a little west of the skeleton. It lay at the contact of the clay with the overlying peaty clay, the same horizon at which the mastodon was entombed.

The second dart point, the tip of which was missing, was found about twenty feet north of the skeleton and was not as deeply buried. It lay in the muck beneath the disturbed soil, too deep to have been

Figure 6. RIB, BROKEN AND MENDED DURING LIFE OF THE ANIMAL

plowed under. Both of these dart points had the same flaking quality as freshly mined flint indicating that they had been buried long enough to regain this property.

Photographs of these dart points were examined by M. R. Harrington, Curator in Charge, The Southwest Museum, California. The following is a quotation from a letter written by him to Everett R. Burmaster.

"If the points had been found out here, especially in Nevada, Arizona, or New Mexico, I should have called them dart points probably made by the Basketmaker people, who seem to have been at their height about 1500 B. C.

"I should also say that the points represent a later type than those we found in Gypsum Cave associated with ground sloth, horses and camels or the points found with the extinct bison at Folsom, New Mexico."

In the opinion of Burmaster, "The dart points are similar to those

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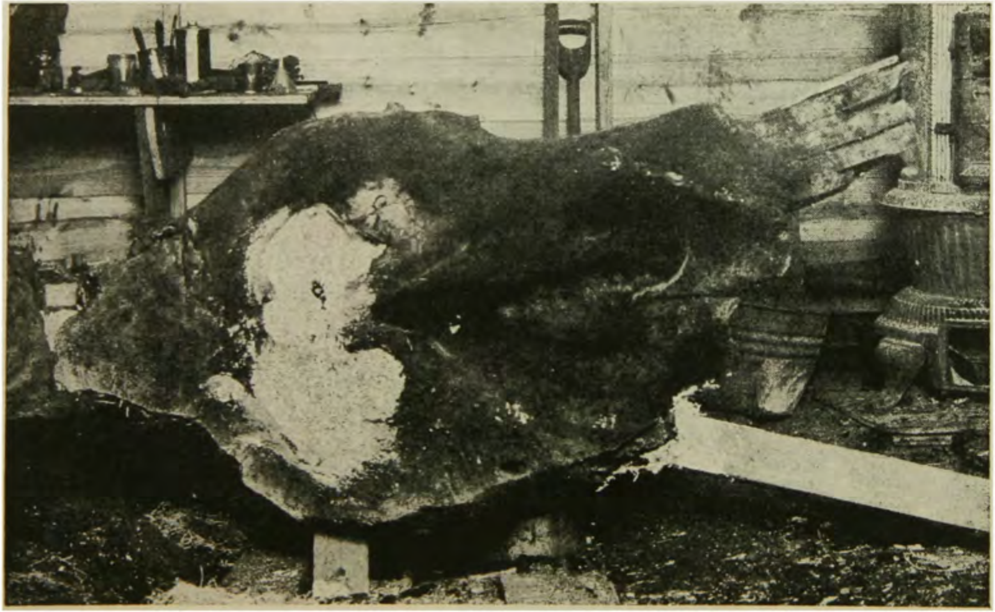

Figure 7. THE SKULL

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found in Western New York at the sites of some of the oldest Indian occupations."

Masses of twigs and small branches were found overlying and associated with some of the bones. The character of this material did not indicate that it had been the contents of the stomach.

Interpretation of the History

It will never be known just how the Richmond mastodon died or what happened to the missing parts of his skeleton. However in the light of the data presented above, the writer wishes to point out possible interpretations and to make some suggestions regarding those which seem to him most probable.

It has been noted that within the memory of some of the inhabitants of the region the little depression from which the mastodon was removed contained a pond. This pond, somewhat deeper, undoubtedly, existed at the time of the introduction of the creature. That the mastodon was not brought in by glacial ice is evident. It does not seem probable that he floated in for there is no evidence of a body of water large enough to have accomplished this, although it is not impossible that such a body did exist during times of spring freshets. Moreover, had the carcass floated in it should have grounded on high land rather than in a depression. Breaking up of the carcass and differential flotation could hardly account for the absence of many of the ribs. Neither could it explain why the ankle bones are present while tibia and fibula are missing, nor why both scapulae are missing while one humerus and the radius and ulna of each foreleg are preserved. Lastly, grounding of the carcass could not have caused the left tusk to become embedded in the clay in the manner in which it was found.

Just how the various parts of the skeleton came to be in the positions in which they were found is open to question. They may have been moved somewhat by carnivorous beasts, man, or by ice action, but it does not seem probable that the skull or pelvis was moved to the positions which they occupied, at least not by ice. At the time of his death the mastodon sat back on his haunches, his head falling backward and to the right. The heavier right tusk caused that side of the skull to tip downward and the smaller left tusk was therefore lifted upward. Pond ice freezing on this tusk broke it

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off and pointed it into the clay, later causing the tip to break against the gravel and another break near the butt.

Muscle and cartilage held some of the angle bones and six of the vertebrae together until deposited on the pond bottom so that when found they were articulated. There is no indication that the beast was mired. The situation was quite different from that in which the bones of the Temple Hill mastodon which died in this way were found. Regarding this find, Hartnagel and Bishop[1] say: "The position in which the bones were found gives support to the theory that the mastodon mired while foraging along the boggy margin of the pond, for the head and tusks were nearest the present surface of the ground, as if thrown back in an effort to keep them above water."

Granted that the animal walked in, what were the circumstances attending his entrance to the pond? It has been said that modern elephants when old frequently wander off by themselves to a swampy spot to die. There is no reason for believing that mastodons did not do the same thing. It is entirely possible that the Richmond mastodon did just this and that subsequent to his death parts of the remains were dragged from the shallow water or from the frogen surface of the pond by carnivorous beasts, the flesh gnawed off and the bones left exposed to destructive atmospheric agencies.

Anothery theory remains; the mastodon was either driven into the pond by enemies or waded into it to escape them. It does not seem probable that any of the beasts living at the time could have been formidable enough to have accomplished this alone. It is more likely that some of the creatures which hunt in packs, gradually wearing down their prey, would have caused him to take refuge in a pond. Wolves would therefore be the most likely suspects if we are to suppose that he was driven in by some other animal. Once separated from the herd and attacked by a pack of wolves a mastodon would be pretty much at their mercy. Although not powerful enough to kill him outright they could in course of time literally pester him to death, by keeping him moving, tiring him out, and giving him no opportunity to obtain food and water. Under such conditions a proboscidian might enter the first pond which offered itself and there, surrounded by his enemies, remain until he died.

[1] Hartnagel, C. A., and Bishop, Sherman C., The Mastodons, Mammoths, and Other Pleistocene Mammals of New York State, N. Y. State Mus. Bull. Nos. 241-242, 1921, p. 51.

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Man, like the wolf, hunts in packs. His methods are more efficient, faster, and more effective; but basically primitive man and the wolf must have hunted the larger creatures in the same way for neither had any means of killing their prey quickly. Man had many advantages over the wolf; he did not have to leap in, bite, and leap quickly out,—he could hurl his spears and cast his darts from a safer distance. Man had another weapon to aid him in this kind of hunting, fire, before which the mastodon as well as any other animal in its path would flee.

Figure 8. DART POINTS, NATURAL SIZE

It has recently been shown by Max Uhle[8] that man and the mastodon were contemporaneous, at least in South America.

Although it is impossible to directly connect the dart points found during the excavating with the Richmond mastodon, it is certain that at least one of them dates from approximately the same time, as it was found at the same depth and under the same conditions. The other was not so deeply buried but it is possible that it is equally

[8] Uhle, Max, Späte Mastodonten in Ecuador, Twenty-third International Congress of Americanists, Proceedings, New York, 1928, pp. 247–258.

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old. It seems probable that man and the Richmond mastodon were contemporaries and that humans visited the identical spot at about the same time that the mastodon died there. Beyond this less certainty exists. It has been suggested that the fire may have played a part in driving the creature into the pool and that inasmuch as no other remains of similar age were found it is not logical to assume a widespread forest fire. Man is the only agent that could have lighted and directed a small fire for the purpose of trapping a single animal.

Possibly the Richmond mastodon was killed by a band of primitive hunters. Driven, perhaps for days, prodded by stone pointed darts and finally harassed by fire he sought refuge in a little pool. The butt of the most deeply buried dart point was broken. Possibly this was done while the tip was buried in the flesh and protected. The tip of the other one was missing. It may have been broken against a tree or a bone. These darts may have pulled loose from the animal before he died. Other dart points may have been missed in the process of excavating as the clay came out in chunks and equipment did not permit a careful examination of all of these chunks.

All of the explanations advanced have assumed that the mastodon entered the pond at a season when it was not frozen. It is just as logical to assume that the pond was frozen over and that the various parts of the animal were pulled about on the ice by beasts or man.

Before discussing the age of the fossil it is necessary to present a brief interpretation of the history of the spot in which it occurred. The gravel and Clay No. 2 are of glaciofluvial origin and the basin was formed by the uneven deposition of glaciofluvial material. A section made through the side of the basin also showed waterlaid glacial material, sands, gravels, and clays, except at the top where postglacial formations occur, clay and muck. The formations thicken and thin rapidly, and the size of the sediments varies greatly indicating varying and shifting currents such as might be expected near the front of a glacier.

The area has been mapped by Leverett[8] as "Undulating gravelly or sandy drift not definitely morainic." The glacial deposits were evidently laid down as outwash in front of an ice sheet.

All the formations above the gravel have accumulated in post-

[8] Leverett, Frank, U. S. Geol. Surv., Monog. 53, Pl. 6, 1915.

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glacial times. Conditions must have been suitable for life, both plant and animal, very soon after the departure of the ice, for trees grew on the surface of the gravel. These trees grew around the margin of a little pond which occupied only the deeper part of the basin at this time. They were not closely spaced as the branches of many of them covered the trunks nearly to the ground. The roots grew landward rather than toward the water. Needles, twigs, and cones accumulated on the gravel as they do in the forest today. Molluscs lived in the pond. For some unknown reason, perhaps a minor climatic change, the pond became larger, the trees died and fell over; perhaps they were killed by flooding. Molluscs lived where previously pine needles had fallen.

All the time clay had been accumulating in the pond, and as the area covered by water became greater, the area of sedimentation increased accordingly. Clay covered the logs and stumps as well as filling in the deeper part of the pond. The clay was supplied from the higher ground by rain wash and as this material has been subjected to prolonged weathering calcite is absent. Pond plants grew and died, becoming more abundant as the water became more shallow. During the deposition of the last foot of clayey material plants became very numerous. Following the early history of the pond stage there was a time when shelled molluscs were infrequent. But they again became numerous in the deeper parts during the deposition of the upper part of the clay and the lower part of the peaty clay.

The latest depositional feature was the formation of nearly a foot of muck. The spot has been artificially drained by a tile ditch.

Estimate of Time

The mastodon probably entered the pond not earlier than the time when the peaty clay began to form, and possibly somewhat later than this as the bones may have settled since first deposited. The pond already had a long history when he entered. The greatest depth from surface to gravel was about ten and one-half feet, and at least eight feet of this had been deposited before the advent of the mastodon. It is very difficult if not impossible to make any estimates of the rates of accumulation of the sediments. They probably varied somewhat from time to time but some rather interesting and perhaps not entirely meaningless results are obtained if an even

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rate of deposition is postulated, and the length of time since glacial times is assumed to be 30,000 years. This figure is a conservative one, not leaning toward either extreme and serves to illustrate the point. The figure for the thickest accumulation of sediment is used because it is probable that this point represents the most continuous and uniform sedimentation. Practically no sedimentation took place for some time after glaciation at the points where the tree stumps were found and in other shallow parts of the basin. Based on this data it took about 2850 years for a foot of sediment to accumulate and the mastodon entered the pond 5,000 to 6,000 years ago. It is possible that the clay accumulated much more slowly than the peaty clay and the muck and this would make the creature still more recent.

Regardless of the accuracy of this data it is certain that a great many things happened between the time that the glacier left and the time when the mastodon entered the pond. Trees grew and died; molluscs throve, died out and were introduced again. The rain had time to wash in a great deal of clay, and many generations of plants lived and died.

The dart points offer another line of evidence regarding the age of the find. As has been previously noted these do not date back many thousands of years and this is not inconsistent with the estimate previously made.

The mollusc shells associated with the skeleton are interesting from the age point of view, although they offer no very exact information. Fourteen species have been identified,[4] only three of which are extinct forms. These are

Gastropods,	total—9	extinct—3
Pelecypods,	total—5	extinct—0

It is the opinion of the writer that the material is not much over 5,000 years old and that it may be considerably younger than this.

[4] Robertson, Imogene O., Hobbies, The Magazine of the Buffalo Museum of Science, Vol. 12, No. 5, Jan. 1932, pp. 108–109.

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PROCEEDINGS OF THE ROCHESTER ACADEMY OF SCIENCE
VOL. 7, PP. 157-188 MARCH, 1935

GENESEE VALLEY HYDROGRAPHY AND DRAINAGE

By Herman L. Fairchild

CONTENTS

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ILLUSTRATIONS

INTRODUCTION

The river and valley Genesee have held great interest for the historian, the economist and the geologist. The glacial phenomena and deposits are in handsome display, and have been the chief subject of the more recent scientific literature. The physiographic and hydrographic features are remarkable and require description.

The problem of supplementary water supply for the City of Rochester has brought into question the quantity and quality of water carried in the drift-filled portions of the ancient, preglacial valley. This subject has interest and importance not only to the city and villages situated in or near the old valley but also to the hydraulic engineers and to the students of glacial, physiographic and applied geology. And this scientific interest in the available artesian water justifies publication of this writing in the Proceedings of the Rochester Academy, especially because the description and proper discussion of the matter involves the entire geologic history of the Genesee drainage area and its present physiography and hydrography.

In this Genesee water problem are four general topics:—The form and features of the ancient river and its valleys; the disruption of the drainage system by the overriding glacier, which left the valleys filled with deposits; the volume and composition of the valley fillings; and the quantity and character of the water that is passing through the buried valleys.

A list of former papers by the writer which have relation to the underground water problem is appended.

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Tertiary, Preglacial, Drainage

Map of the Ancient Rivers

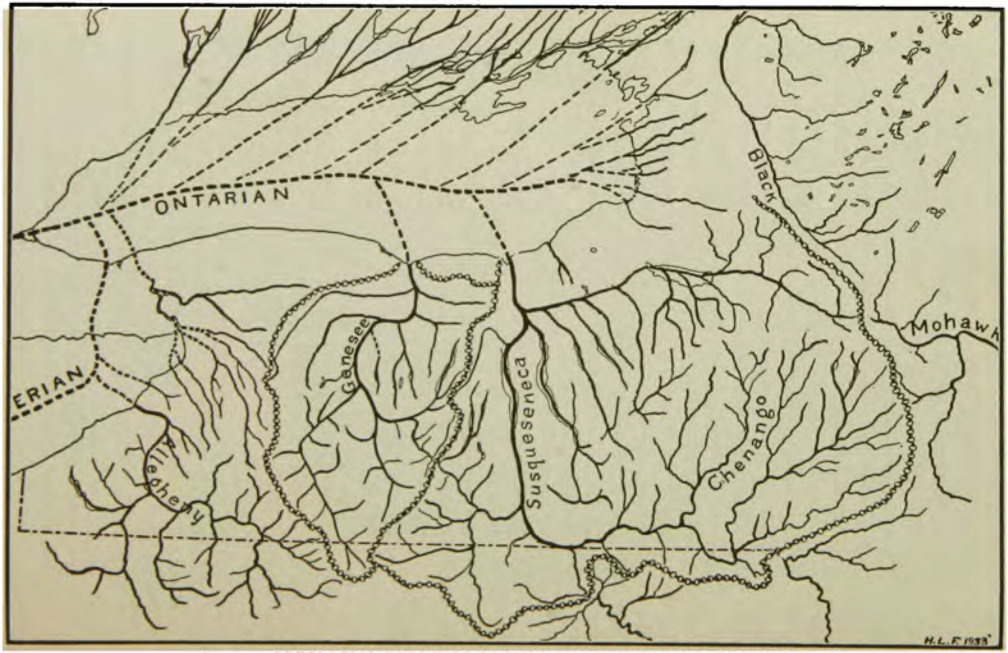
Central and Western New York had a long and eventful drainage history before the Genesee River came into existence. With that far-back stream-flow the present study has no concern. It is briefly considered in numbers 5–9 of the appended list of writings.

During the millions of years of the later division of geologic time, the Tertiary Period, the drainage was diverted into northward flow, tributary to the great river which was producing the deep Ontario Valley. The map, figure 1, shows the course of the old Genesee drainage system before it was changed and dissected by the Canadian ice sheet. It will be noted that the preglacial Genesee had two main branches. The West Branch is yet represented by the present river above (south of) Portageville. The East Branch, which produced the Canandaigua Valley, has been filled with drift and detritus and quite obscured. This branch carved the wide valley now buried beneath Naples, North Cohocton, Wayland and Dansville. The two branches united in the neighborhood of Sonyea (see figures 1, 5).

The united branches, as the main trunk of the Genesee, passed northward to about four miles north of Avon and then turned east in a depression, produced by the outcrop of the weak Salina Shales, for about 13 miles, to the vicinity of Fishers. Resuming its northward flow the river excavated the Irondequoit Valley and continued to junction with its master river, the great Ontarian. The drift-filled and abandoned stretches of the ancient valley are indicated in the map, figure 5, by the heavy lines.

The reader will note especially that all of the East Branch valley, and the main valley from Naples around to the Irondequoit Valley, are deeply filled with glacial, lake and stream deposits. The present river is lazily meandering on the surface of the deep filling from near Mount Morris to the bend in the old valley north of Avon, a right-line distance of nearly 20 miles. Except for that short stretch the present Genesee is cutting new, postglacial, channel for its flow north of Portageville.

It should also be noted that all of the drainage of central New York was concentrated in two river systems, the predecessor of the Genesee and the Susqueseneca. The only trenches or valleys cut across the east-west ridge of Niagara strata were made by these two rivers, now marked by Irondequoit and Sodus bays.



[illegible] PREGLACIAL DRAINAGE OF WESTERN AND CENTRAL NEW YORK

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River Terminology

The Genesee river has slight resemblance to its long-ago predecessor. The only portion that is similar to the ancient flow is the headward stretch above Portageville; and even there it is not flowing in the ancient rock channel but is meandering on the surface of glacial-time deposits. From Mount Morris to four miles north of Avon, a distance of eighteen miles in direct line, its sluggish flow in idle curves is double that mileage, and on the surface of glacial filling many hundreds of feet in depth. The relation of the river to the ancient valleys is shown in figure 5.

To make clear distinction and to save repetition in description it is desirable to have a name for the ancient river. The unlikeness of the two streams, and the time space between them make a distinctive name appropriate as well as convenient.

The lower stretch of the old river was in the course of the valley and bay Irondequoit. It is proposed to combine the two names, Genesee and Irondequoit into Irondogenesee. That name, retaining the music of the two Indian names, will be used hereafter.

The eastern branch of the Irondogenesee with another Indian name, Canandaigua, deserves recognition in the new appellation, but must be slighted.

The old river may thus have a name in rivalry with the original Indian name of the young river, Casconchiagon.[1]

Map of Existing Drainage

Figure 2 shows the river systems of western and central New York as they exist today, following the interference and disruption by the Canadian ice sheet. The southward drainage forced by the glacier is shown in figure 3, and those forced lines of flow are yet retained.

Instead of all the drainage being to the north, as in preglacial time, (figure 1) it now has several directions with far-spread destinations. The Genesee River is unique in retaining its ancient northward direction. Along with the singular drainage of the Finger Lakes area the Genesee water contributes to the St. Lawrence and north Atlantic.

The Allegheny goes to the Ohio and Gulf of Mexico; the Susquehanna to Chesapeake Bay; and the Mohawk to the Hudson

[1] Rochester Democrat & Chronicle, July 18, 1926. Rochester Historical Society. Pub. Fund Series. Volume 5. 1926, pages 141–145.

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estuary. These inconsistent and anomalous lines of river flow are largely an effect of glaciation.

The Niagara and Oswego rivers are in new, or postglacial, courses with rock ravines.

Physical Principles Involved

The ancient rivers have left their records in the existing gross topography, the greater valleys and hills. To translate those drainage inscriptions and to appreciate the following descriptions and inferences some physical principles in earth science must be recognized. These are:

1. The fact of vast up-and-down movements of great continental land areas, carrying the land down, to perhaps far below ocean level, or to high above. The Genesee region has experienced such changes in elevation.

2. Rivers are the valley-makers. All of the valleys in this part of the world, and everywhere in approximately horizontal strata, have been carved by running water. The great hills are only the unremoved portions, or remnants, of the original rock strata.

3. The ancient, long-lived rivers, like the older rivers of today, had well-graded channels, or paths of uniform slope, with no obstructions. Given great length of time rivers wear away all barriers, obliterating all cataracts and rapids in their primitive courses.

The map, figure 1, of preglacial stream-flow in New York, is a product of the use of these fundamental principles.

Elevation of the Land Area

During the latter part of the Tertiary Period, preceding the "Age of Ice," this northeastern part of the continent stood some thousands of feet higher than at present. One clear proof is the simple fact that the bottom of Lake Ontario, in a river-carved valley, is toward 500 feet below ocean level. And probably there are hundreds of feet depth of glacial deposits beneath the water.

The deep bays along the coasts, like the Delaware, Chesapeake and the Maine fjords, are the drowned portions of the Tertiary river valleys. Recent survey of the Atlantic sea bottom off New England coast has mapped a series of stream valleys down to the depth of 8,000 feet.

Because of the high elevation of the land in preglacial time the rivers had farther drop to reach the sea, with consequent rapid

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Rivers in Canyon-like Valleys

flow, steeper gradient, and great work of erosion. In consequence the Genesee and other rivers in central New York carved deep valleys. When the Canadian ice sheet overwhelmed the region the rivers were flowing in relatively steep-walled, canyon-like valleys. The deeper portions of all these valleys are now filled with glacial deposits, and only the drill can prove the depths.

At Watkins, many years ago, in search for salt, drilling to depth of 1,200 feet did not reach bed rock. The plain is little above Seneca Lake, with elevation 444 feet above tide. At Ithaca the drill did not reach the rock at depth of 1,250 feet; starting near the level of Cayuga Lake, 381 feet A. T.[2]

Figure 2. EXISTING RIVER SYSTEMS

Unfortunately for our present study the buried Genesee Valley has not been probed to its rock bottom. To this date the deepest drilling is the Leighton well, three miles north of Dansville, in the East Branch of the Genesee, to depth of only 450 feet. The wide plain has there elevation of 600 feet; hence the bottom of the well is 150 feet above sea-level (figure 8). The curvature of the walls of the old valley projected downward suggests a depth to rock of over 1,000 feet.

[2] Seneca Valley physiographic and glacial history. Geol. Soc. Amer., Bull. 45, 1934, 1073–1110.

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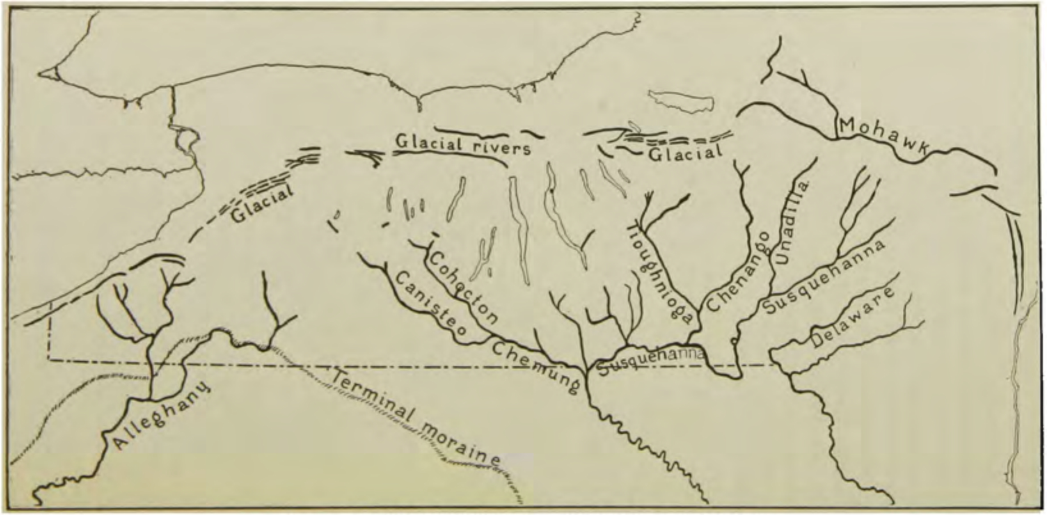

Figure 3. STREAM COURSES OF THE GLACIAL DRAINAGE

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Glacial Interference

Ice-Sheet Invasion and Overriding

The extreme altitude of northeastern America at the close of Tertiary time resulted in snow caps on the mountain tracts, that eventually coalesced into the Quebec continental glacier. The expanding ice sheet spread over all of New England and New York. With the oncoming of the ice sheet the north-flowing rivers were blocked, producing ice-dammed lakes. In further advance the ice occupied the valleys, and eventually buried the State under thousands of feet of moving ice, a condition comparable to that of Greenland of today.

The advancing ice sheet eventually forced all the waters into southward flow. The receding ice front, during the removal of the glacier, repeated the process in reverse order, and the lines of forced glacial flow are shown in figure 3.

Valley Drift Fillings

The depositional work of the ice sheet filled large portions of the ancient valleys, and radically changed the Irondogenesee drainage system. The eastern branch, which headed in the Canandaigua Valley, has been wholly obscured. The traveller going south from Naples to North Cohocton and west to Wayland and Perkinsville and then northwest to Dansville would not realize that he was passing over a deep, buried valley. Yet the high hills on either side are the upper slopes of the ancient valley.

The wide smooth plain from Dansville to north Avon is the surface of the deep valley filling (figure 7). From Mount Morris to below Avon the present river is idly coursing on lake-smoothed filling of the ancient valley.

Below, north of Avon the old valley curved east to the present Irondequoit Valley which was its northward course to the Ontario Valley. The villages of West Rush, East Rush, Mendon, Fishers and East Rochester are on the valley drift filling, that entirely conceals the ancient canyon.

The portion of the West Branch Valley northwest from Portageville to Sonyea, south of Mount Morris, was also filled, forcing the present river to cut the Portage canyon and Mount Morris High Banks. The new path of the river north from Avon includes the handsome Rochester ravine.

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Mapping by the Monroe County Planning Board of the subsurface conditions has clearly defined the rim of the old valley from north of Avon to Irondequoit Bay, as shown in figure 7.

The drift-filled portions of the preglacial valley are indicated in the map, figure 5.

Depth of the Drift Fillings

The depth or thickness of the glacial deposits in the old valleys depends, of course, upon the depth of the preglacial valleys.

The Genesee canyon should have been similar to those of the Seneca and Cayuga valleys, minimum depths of which have been stated above. A rough approximation is made by downward continuation of the curves of the exposed valley walls, where these have good display, as shown in figure 8. Under the atmospheric erosion of the valley walls, while the river was intrenching at the valley bottom, the downward slope, or pitch, of the walls steepened toward the river.

The Tertiary Irondogenesee probably was actively at work in its intrenching when the advancing ice sheet invaded the State and blocked the river, and the width of the valley bottom probably was not much wider than the width of the stream. Figure 8 is drawn with such conception.

The rock bottoms of Canandaigua Lake and Lake Ontario are, of course, the maximum depths of the valley. But these basins hold glacial deposits of unknown depth, hence those datum points are not available. However, the great depth of the valley fillings can be proven by using minimum data. We have three points of elevation known; the bottom of Canandaigua Lake, the bottom of the Dansville (Leighton) well and the bottom of Lake Ontario. Making use of the fact that old rivers have channels with uniform or graded slope, a principle stated above, we may calculate the minimum depth of drift filling for all localities of the East Branch and of the Main Valley.

In the following tables the figures indicate feet, and the figures for elevations are heights above ocean level, except those in heavy-face type which are for distance below ocean.

Recognizing the uniform slope of the line, or plane, connecting the three datum points, we can, with the distances and gradient calculate the elevation for any location along the line. Then, with the elevation of the ground surface (see the U. S. Geological Sur-

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vey topographic maps) the depth of the valley filling is found. But these are only positive *minimum* depths; the actual depths of the valley deposits are probably hundreds of feet more.

TABLE 1

Elevations of Three Datum Points

	Surface	*Depth*	*Bottom*
Canandaigua Lake	686	262	424
Dansville Well	600	450	150
Lake Ontario	246	721	475

TABLE 2

Approximate Distances and Gradients

Stations	*Fall*	*Miles*	*Gradient*
Canandaigua Lake to Dansville Well 424 150	274	34	8.0
Dansville Well to Lake Ontario 150 475	625	85	7.35
Canandaigua Lake to Lake Ontario 424 475	899	120	7.5

Following are the approximate minimum depths for several localities along the line of the buried Genesee Valley.

TABLE 3

Bottom, at middle, of Canandaigua Lake	elevation	424
On the moraine south of Naples	depth of drift	1.100
At Wayland	" " "	1.140
Dansville well	bottom elevation	150
By Geneseo	depth of drift	530
By Avon	" " "	574
At Rush	" " "	650
At Rochester Junction	" " "	685
At Fishers	" " "	715
At East Rochester	" " "	620
Bottom of middle of Lake Ontario	elevation	475

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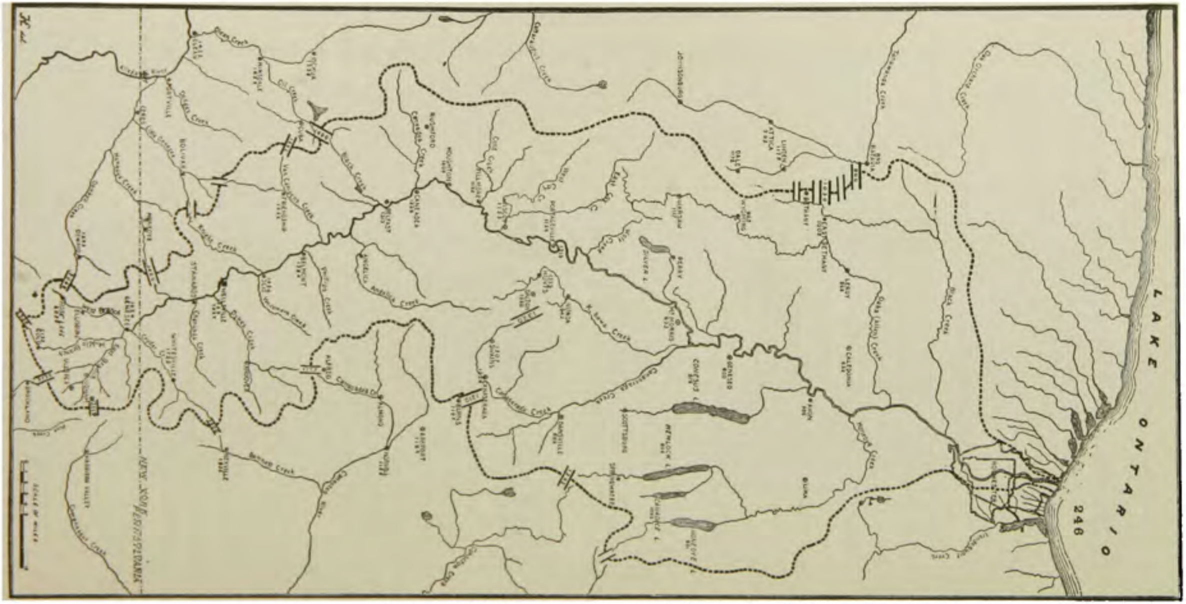

Figure 4. **HYDROGRAPHY OF THE GENESEE VALLEY**
The figures that cross the line of water parting show elevations above ocean, and locate the channels of escape of glacial waters

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Figure 5. DRIFT-FILLED PORTION OF THE IRONDOGENESEE VALLEY

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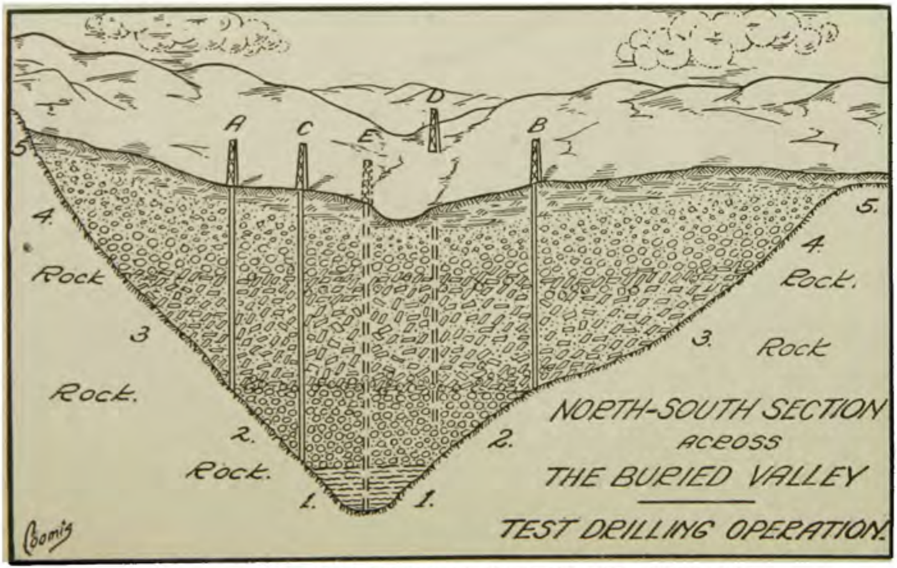

Figure 6. THEORETIC SUCCESSION OF THE GLACIAL VALLEY FILLING

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Composition of the Valley Fillings

This factor in the problem is important because of its bearing on the storage and transmission of underground water.

The typical glacial drift is the ice-laid material, the "hardpan" of the farmer, or the "till" and "ground-moraine" of the geologist. This can hold relatively small amount of water. But this compact material is the minor portion of the visible deposits. The moraines, hills and ranges of glacial origin, in central New York are largely water-laid, gravel and sand, dropped by the loaded streams which drained the ice sheet, and by the lakes held in the ice-dammed valleys. The invisible deposits in the valleys are doubtless similar to the deposits open to view.

Four classes of earth materials contributed to the deposits in the old valley. (1.) The materials pushed and rubbed into the valley by direct action of the ice sheet. This is the rock-rubbish, boulders and stony clay, similar to the "till" and "soil" of upland surfaces. (2.) Gravel and sand, washed in by the streams which flowed from the melting ice. (3.) Sand and silt deposited by the lakes that fronted the ice border during both the advance and the recession of the ice front. (4.) Sand and silt washed in by the streams from the uplands. Some suggestion in order of deposition is given below, and in figure 6.

The nature and proportions of these materials must vary from place to place, and in cross sections of the valleys. No drilling has yet penetrated the full depth of the filling. The deepest well is the one three miles north of Dansville, to depth of 450 feet, the record of which is not available.

A general succession of the deposits is suggested by the theoretic physical processes in the glacial history. Students of the history in the valley of the Mississippi River find evidences of more than one advance and removal of ice sheets. Such multiple glaciation has not been proven for New York, and for the present study only one stage of glaciation will be recognized.

We have to do with the effects and phenomena of the oncoming ice sheet; the effects of the overriding ice; and the effects and phenomena of the ice removal, the backing away, northward, of the border of the waning glacier. These changing conditions produced variation in the deposits, with, it is supposed, some difference in the succession from the bottom upward. This is suggested in figure 6.

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The earliest, and hence the bottom deposit in the filled valleys, must have been the clay, silt and sand laid down in the lakes that occupied the valleys as the advancing ice front blocked the north-

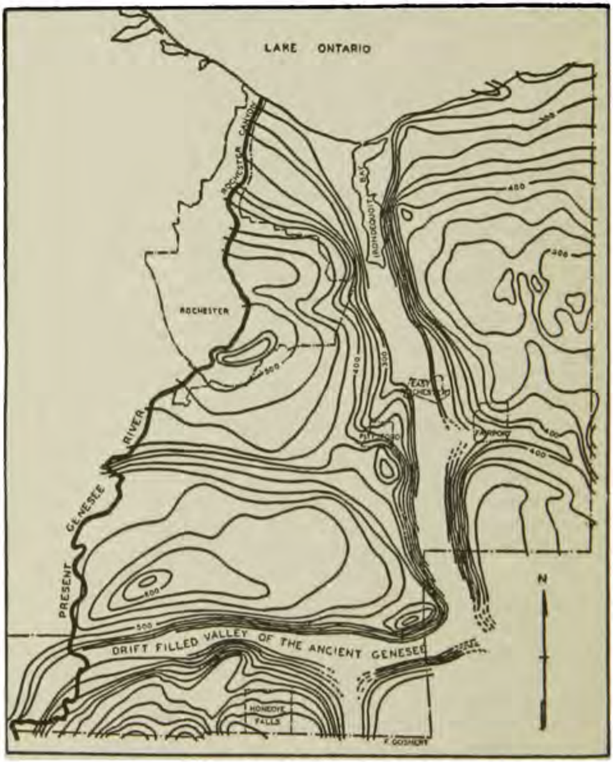

Figure 7. **THE BURIED CANYON OF THE IRONDOGENESEE RIVER**
Preliminary mapping by the Monroe County Regional Planning Board

flowing rivers. On the lake silts would be laid as the next deposit the gravel and sand supplied in quantity by the loaded streams that drained the melting ice sheet as it advanced; for it should be under-

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stood that the margin of the ice sheet was melting during the oncoming of the glacier as well as during its removal. The ice sheet expanded only because the push exceeded the melting.

The copious outwash of the coarse stream detritus derived from the ice sheet was the more abundant early deposit. Its depth can be learned only by deep probing to the rock bottom of the old valleys.

During the time, probably hundreds of thousands of years, that the continental glacier held New York in cold storage some amount of ice-laid material, stony clay-like stuff, rock-rubbish and boulders were rubbed into the valleys.

During the removal of the ice sheet the physical process was, in a general way, the reverse of that during the ice advance. Gravel and sand from the glacial outwash, capped the ice-laid drift, and in turn this was covered by the lake deposits, with included boulders rafted in by floating ice blocks. Such boulders are sometimes cause of trouble and delay in drilling.[3]

The lakes held in the valleys during the ice-front recession, probably for centuries, were responsible for most of the surface deposits in the old valleys; of finer and compact material, which largely serves as the cover for the artesian water.

The theoretical vertical succession of the valley deposits is summarized as follows. The time succession is the numerical order, as in figure 6.

6. Sand and silt from existing streams, especially in flood.
5. Glacial lake deposits, silt and sand, during the ice sheet removal; with ice-rafted boulders. (Similar to No. 3.)
4. Gravel and sand, outwash from the ice sheet by the glacial streams. (Similar to No. 2.)
3. Ice-laid drift, unassorted material, stony clay, boulders, etc.
2. Gravel and sand, outwash from the ice sheet during its advance.
1. Glacial lake sand and silt, during the ice advance.

Hydrography of the Genesee Valley

Precipitation on the Drainage Area

Reports of the U. S. Weather Bureau give the records of twelve stations in the Genesee Valley, tabulated below in geographic order

[3] Working in glacial deposits the drillers are liable to report "bed-rock" when they have merely encountered a boulder or rafted block of stone, or perhaps only cemented gravel. Records of "depth to rock" should be verified.

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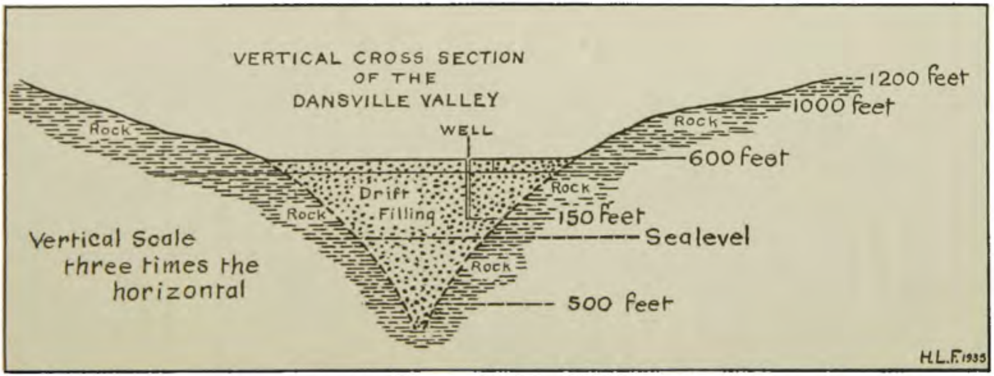

Figure 8. **CROSS SECTION OF THE DANSVILLE BURIED VALLEY**
At the site of the flowing artesian well

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from south to north. The discrepancies between near-by stations suggest probable deficiency in measurement (table 4).

TABLE 4

Genesee Valley Precipitation—Annual Average: in inches

Stations	*Record*	*Feet over Ocean*	*Years*	*Period*
Andover	32.20	1,650	8	1922–1930
Friendship	36.23	1,550	9	1877–1896
Angelica	36.29	1,420	39	1889–1930
Hunt	33.59	1,150	15	1902–1919
Letchworth Park	28.08	1,260	16	1913–1930
Dansville	26.65	703	12	1919–1930
Mount Morris	28.14	640	5	1890–1900
Hemlock	29.43	920	32	1899–1930
York	29.87	700	14	1912–1925
LeRoy	36.45	900	15	1885–1911
Avon	28.42	585	38	1891–1930
Brockport	33.26	537	31	1900–1930
Average for the valley	31.55			

It will be seen that stations on the south with higher altitude have heavier precipitation, five stations averaging 33.48 inches; while seven stations on lower ground average 30.32 inches. Stations either side of the Genesee area have high records, up to over 50 inches on the west. With the high borders of the valley poorly represented it appears that the figure for the whole drainage area should be more than 31.55 inches. Rochester, with accurate observation, has a 60-year average of 33.23 inches. For reasons stated below Rochester is not here included. However, in order to keep within conservative limitations, and also for easier computation, the figure of 32 inches will be adopted. It should be noted that any larger figure would increase the estimates for evaporation and for ultimate removal by the deep-seepage.

A complication now appears which has to be considered in all the estimates and calculations to follow. Two areas of precipitation and drainage must be recognized. One is the present surface drain-

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age area of the river, the "watershed," taken as 2,476 square miles. The other is the area which was drained by the Irondogenesee (figures 1.5), estimated as 300 square miles greater than the existing Genesee drainage. The deep ground water of this greater area even now finds ultimate escape through the drift-filled valley into Lake Ontario.

For the subsequent calculations the area of Genesee surface drainage to be used is that of the Elmwood Avenue gaging station, 2.450 square miles. The area of precipitation and deep-seepage is 2.750 square miles.

Removal of the Water; Three Factors

The removal of the atmospheric water, taken as 32 inches every year, is carried away from the 2.750 square miles in three processes. (1.) By the run-off, the surface flow, concentrated in the Genesee River. (2.) By evaporation, including the transpiration through vegetation, the fly-off. (3.) Deep-seepage, the underground flow of the water that is absorbed by the ground and which does not reappear at the surface. Some of the ground water does reappear as springs, but this becomes part of the river flow and is included in the run-off. In very dry season the river is wholly supplied from the ground water. The deep-seepage in the Genesee drainage province finds escape through the drift-filled, abandoned valley into the depths of Lake Ontario.

Two of the factors involved are measurable, in approximation, the precipitation and the run-off. The difference in volume between those two is the combined volume of both the fly-off and the deep-seepage. As these cannot be directly measured they must be estimated. The volume of water escaping through the old buried valley is the special quest of this quantitative study.

Constants and Quantities

In order to save from repetition and to enable the reader to verify the calculations, the quantitative elements used in the following pages are here given.

One gallon of water has weight, 8⅓ pounds.

One cubic foot of water has weight, 62.32 pounds.

One inch of water on one acre, 113 tons.

One inch of water on one square mile, 72,320 tons.

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One gallon of water is 231 cubic inches.

One cubic foot of water is 1,728 cubic inches.

One cubic foot of water is 7.48 gallons.

On one square foot 32 inches depth of water is 19.95 gallons.

One acre is 43,560 square feet.

One square mile is 27,878,400 square feet.

One square mile with 32 inches of water carries 556,174,080 gallons.

Total drainage by Genesee River, 2,476 square miles.

Preglacial drainage, Irondogenesee River (estimated) 2,776 square miles.

Run-off of the Genesee River

In volume and regimen of flow the Genesee River is affected by a complex of physical factors; change in land elevation and climate, varying precipitation, radical difference in channel conditions, and the unusual factor of permanent ground absorption in large amount of the precipitation.

Heading in Pennsylvania, in the elevated Allegheny Plateau, its northward course is in the old intrenched valley through the highland, and later on the Ontario lowland (figure 9). Precipitation is heavier on the highland. The permanent ground absorption, the deep-seepage, is partly effective in the upper valley, above Portageville, and largely over the abandoned East Branch Valley (figure 5). North of Portageville the river is not directly affected by the deep-seepage, and north of the old valley through Rush, Mendon, Fishers, there is no loss of water by ground absorption.

We have run-off records of five river-gaging stations. On the map, figure 5, the locations are marked by heavy bars across the line of the river. The Scio station checks on the headwaters flow.

The St. Helena station is in the post glacial course of the river, between the Portage and the Mount Morris canyons. The Jones Bridge station is a few miles north of Mount Morris, on the wide plain of filling in the ancient trunk valley. Elmwood Avenue station, at the south edge of Rochester, was abandoned in 1918 when the Rochester harbor of the Barge Canal was created. Its record, however, is sufficient to serve for the following calculations on the three elements, run-off, fly-off and deep-seepage.

Driving Park Avenue station, in the north part of Rochester, in-

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cludes in the gaging the surplus Barge Canal water from Lake Erie. This matter is discussed below.

The following tabulations certainly give an approximation to the truth. The run-off data are from the U. S. Geological survey, courtesy of Arthur W. Harrington, District Engineer. The precipitation data are from reports of the U. S. Weather Bureau.

TABLE 5

Precipitation and Run-off

	Stations			
	Scio	*St. Helena*	*Jones Bridge*	*Average*
Estimated precipitation, in inches	34.72	35.18	32.59	34.16
Measured run-off, in inches ...	17.78	16.70	15.48	16.65
Remainder, in inches	16.94	18.48	17.11	17.51
Run-off, percentage of total ...	51	47.5	47	48.5
Remainder, in percentage, includes evaporation and the deep-seepage	49	52.5	53	51.5

TABLE 6

Precipitation and Run-off in Daily Gallons

Gaging Stations, and years	*Drainage area, in square miles*	*Daily Precipitation*	*Daily Run-off*	*Percentage in Run-off*
Scio .... (1919–1934)	309	470,843,262	226,841,472	48.18
St. Helena ...... (1918–1933)	1,017	1,549,668,601	740,627,712	47.79
Jones Bridge .... (1917–1933)	1,419	2,162,221,971	1,053,423,360	48.72
Elmwood Ave. .. (1908–1918)	2,450	3,733,223,277	1,635,068,160	43.80
Driving Park Ave. (1926–1933)	2,467	3,759,127,275	1,421,798,400	37.82

In the above table, No. 6, the estimates for the Driving Park Avenue Station are inserted for comparison, but require some explanation. As previously stated, the river through Rochester carries surplus Lake Erie water from the Barge Canal.

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With close estimate of that extra water deducted the actual river flow for the last eight years is taken as 2,200 second feet, and that figure is the basis of the calculation.

But a climatic factor enters here. The last eight years include exceptionally dry years. The Rochester Weather Bureau record of precipitation for 62 years averages 33.19 inches, but for the last eight years only 30.43. The Rochester figures are significant for comparison, and in illustration of variable hydrographic conditions. The figures for the first three stations include the dry years to 1934.

Evaporation; the Fly-off

This factor in removal of the precipitation is indefinite and uncertain. Complex and variable conditions of the precipitation, in amount, character and distribution in time; character of the land surface, in composition and attitude; character of the vegetation and forest cover; soil cultivation and drainage; and especially temperature and winds following storms. These variables make any large area individual and distinctive.

Test measurements in the field are manifestly impractical. Experimental tests in laboratory and under artificial conditions are poor suggestion.

In regions where there is no ultimate removal by underground flow the evaporation, or the total fly-off must account along with the run-off for all the atmospheric supply. The Genesee area is somewhat exceptional. In cloudiness it ranks high. Most of the area is in cultivation, only the head district retaining much forest cover. The glacial mantle on the uplands is normal in volume and composition, but the wide valleys are loaded with absorbant drift.

These conditions suggest that the evaporation factor may be less than the average for the climatic province. However, the concession is made that the evaporation exceeds the deep-seepage removal. Assuming that the run-off may be fifty per cent of the total precipitation, we may allow thirty per cent for evaporation and twenty per cent for the invisible, underground removal, available for artesian water supply. The volumes, in daily gallons, will be stated below.

Deep-Seepage; the Underground Flow

In this study the term deep-seepage is applied to the volume of water which sinks into the ground and does not reappear. Of

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course some reappears at the surface as springs, but that in the Genesee drainage area is included in the run-off. A large volume of water is gushing up on the flats and contributing to the river flow. The flowing Dansville well is a fine example. Honeoye and Irondequoit creeks are partly supplied from the underground water. And probably the river between Avon and Mount Morris and above Portageville is also nourished from the subterranean supply. This all implies that the capacious valley fillings are unable to transmit all of the water which seeps into the ground.

In ancient, preglacial, time the Irondogenesee and its tributaries were flowing in rock-walled canyons and there was no deep-seepage, because all of the water which sank into the shallow earth mantle eventually found its way into the open streams. The same condition is true today of the streams and valleys outside the glaciated territory.

Today the Genesee below Mount Morris to Avon is idly swinging on the surface of the deep drift filling, while below Avon the ancient valley is buried and abandoned by the river. This gives the underground water a great invisible filtration conduit passing through the Irondequoit basin into the depth of Lake Ontario. It is only this invisible escape of the ground seepage that is included in the "deep-seepage." However, any water which pours up from deep in the valley filling and counts as run-off is yet available as pure, filtered water.

Volume of the Underground Water

Estimates of the Deep-Seepage

The quantity of water transmitted by the buried valley of the ancient Genesee has both scientific and economic interest. As a source of artesian supply it may be practically inexhaustible, but the volume should be approximately determined.

Theoretically the volume is the balance of the precipitation over 2,750 square miles after the run-off and the fly-off have been deducted. In a preceding chapter it has been concluded that the deep-seepage may be estimated as twenty per cent of the precipitation. That proportion must now be found as expressed in daily gallons. For this calculation the areas of the present and the ancient rivers will be compared, using the areas south of Elmwood Avenue gaging station.

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Comparison with Evaporation and Run-off

In the following table the annual precicpitation is taken as 32 inches. The comparison, for gallons, is between the area of underground drainage in the ancient valley (figure 5) and the Genesee surface drainage area above Elmwood Avenue station, at Rochester.

TABLE 7

Water Disposal, in Daily Gallons

	On 2,750 square miles	*On 2,450 square miles*
Precipitation yearly	1,529,478,720,000	1,362,626,496,000
Daily precipitation	4,190,352,657	3,733,223,277
River run-off, 50%	2,095,176,329	1,866,611,638
Evaporation, 30%	1,257,105,797	1,119,966,983
Deep-Seepage, 20%	838,070,532	746,644,655

Capacity of the Ground Conduit

In view of the surprising volume of water escaping through the drift filling in the valley abandoned by the river, approaching a billion daily gallons, it is desirable to question the capacity of the filter conduit. This involves the cross-section area of the filling and the character of the filling materials, as related to the transmission of the fluid.

The depth of the filling at Rochester Junction is certainly more than 680 feet. Estimating from geologic considerations the depth is probably more than 1,000 feet.

The width of the buried valley is obscured, at Rochester Junction, by hills of glacial deposition. But, judging from the open stretches above Avon, it may be taken as one mile. Then the cross-section area is a triangle, with base 5,280 feet and height (inverted) of 1,000 feet. The area is, therefore, 2,640,000 square feet. But as the walls of the buried canyon are not straight, but convex, some reduction in that area must be made. Suppose that we use only 2,000,000 square feet.

To pass the daily flow, as given in the table above, would require that each square foot of the cross-section, on the average, must pass 419 gallons in 24 hours; or 17.5 gallons per hour. Of course the seepage is under pressure of the hydraulic head of the water upstream, and especially of the water in the tall hills of porous drift which border the valley, particularly at and above Dansville, about Portageville and in the region southeast and east of Rochester Junction.

The theoretic succession and composition of the valley-filling materials have been given in an earlier chapter. It is a fact that the material deposited directly by the mechanical action of the ice sheet has relatively small porosity and function of fluid transmission. The quantitative proportion of the ice-laid drift to the porous, water-laid material can not be known. One half the total is thought to be a generous estimate. So, if we reduce the transmission or seepage capacity of the drift filling to one half the above figures for cross-section, then the aquifers or water-bearing portions must average per square foot 838 daily gallons, and 35 gallons per hour. Hydraulic engineers may check these figures.

Figure 9. GENESEE RIVER TRAVERSE OF HIGHLAND AND LOWLAND

It is evident that the valley filling at least below Avon, through Rush, Mendon and Fishers, is fully loaded and transmitting all the volume of water of which it is capable. Numerous copious springs are pouring up on the flats continuously. The Honeoye and Irondequoit creeks are supplied in part from the underground water. And it is probable that the river between Avon and Mount Morris, and above Portageville is supplied in dry seasons from upwelling, ground water. And in very dry seasons all the flow of the river is derived from ground water.

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Many examples of the springs gushing on the surface of the valley filling could be given. The most notable in the Leighton well, three miles northwest of Dansville (figure 8). This is a genuine artesian well, opened to the depth of 450 feet, in the year 1924, in the search for gas. It was stated that the pressure was 75 pounds per square inch. The 10-inch pipe was capped, but a large volume of water has been continuously escaping from and around the pipe, as a contribution to Canaseraga Creek. The flow is entirely indifferent to climatic changes.

A group of heavy-flow springs, southeast of Pittsford, on the west edge of the filled Irondequoit Valley has, from immemorial time, contributed heavily to Irondequoit Creek.

Near Sibleyville, in the Honeoye Valley the copious Jenner spring has long supplied a salable mineral water.

At the crossing of the Lehigh Valley R. R. by Clover Road a living spring was brought into life when a 5-inch pipe was withdrawn from a depth of 50 feet.

Many other examples could be given.

Quality of the Artesian Water

The ground water in the valley filling reflects in mineral content the composition of the drift filter and the nature of the enclosing rock strata.

Except for the short east and west stretch of the buried valley the drainage areas of both the existing and the ancient rivers are practically devoid of soluble minerals. South of the parallel of Avon the strata are sandstone and shale with only negligible limestone. Close north of Avon is the outcrop of the Onondaga limestone, extending east and west, passing through Honeoye Falls. This is underlain by the thick Salina shales, which, because of their nonresistance to atmospheric agencies, caused the development of the east and west valley at Rush, Mendon, Fishers.

The upper beds of the Salina contain sulphates (anhydrite and gypsum). The rock salt (halite) in the strata, reached by shaft-mining north of Mount Morris, lies below the ancient valley bottom.

The surface waters in the enclosing belt of Salina strata carry carbonates and sulphates, and some of the springs yield mineral water, derived from the leaching of the exposed and surficial rocks. Yet, at no great distance down the valley (northward) at East

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Rochester the wells, with depth less than 200 feet, produce water with hardness of about 200 parts per million.

The important fact in this connection is that the water from some depth in the valley filling is not affected by the soluble content of the rocks in the Salina belt. The surface and mineralized waters in that belt cannot mingle with the deeper water but are kept surficial and are drained off into Irondequoit and Honeoye creeks. The deeper water is mainly derived from up-state, and from the East Branch filling. It is under considerable, but as yet unmeasured, pressure from its hydraulic head. The drift filling in the lower stretch of the valley is not competent to transmit all of the ground water, in consequence of which there is flowage toward the surface; and the surface water, from the local land drainage, including the mineralized Salina water, is compelled to remain in surface flow.

Artesian water supply for domestic and heavy service taken from the old valley filling should come from depths of more than 200 feet. At the greater depths the water will probably have hardness less than 200 p. p. m., and be comparable to, or better, than the Dansville Well water. In all respects except the hardness the artesian water is superior to any surface supply.

Excessive hardness is readily removed by softening processes that are chemically and economically successful; but that is beyond the scope of this article.

Utilization of the Underground Water

Until the present time no use has been made of the available artesian supply. In this geographic province of sufficient precipitation, of topographic relief and upland lakes, only surface water has been in mind.

Three shallow wells are now installed. The village of East Rochester has one well completed and another nearly finished. The No. 1 well, to depth of 160 feet, is planned to yield 700 gallons per minute; but it is tested to 1,600,000 daily gallons, and is believed capable of yielding over 4,000,000 daily gallons. The second well is of equal capacity.

South of East Rochester, on the Marsh Road, the Monroe Golf Club has a well on the eastern rim of the buried ravine, with depth to rock of 158 feet, intended to yield 500 gallons per minute.

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Figure 10. **EAST ROCHESTER ARTESIAN WELL, NO. 1**
Preliminary test, November 8, 1934

Summary; Economic

Two elements in the Genesee hydrography have an economic bearing; the run-off, as a source of energy and the deep-seepage as an available supply of pure, filtered artesian water.

The ancient, preglacial, drainage of western and central New York, with its high elevation and deep valleys, was dismembered by the overriding ice sheet, the Quebec continental glacier. The east branch of the Irondogenesee, the Canandaigua—Dansville branch, was deeply filled with glacial, lake and stream deposits that supplanted the river. The upper portion of the west branch, above Portageville, was only partially filled, but the stretch between

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Portageville and the junction with the east branch was blocked by the drift filling and abandoned by the river.

The famous Portage Canyon and High Banks, in the Letchworth State Park, and the Mount Morris High Banks represent the recent postglacial diversion of the river. And another diversion is the final stretch from Avon northward to Lake Ontario that includes the Rochester ravine.

Figure 11. EAST ROCHESTER ARTESIAN WELL, NO. 1
Final test, February 13, 1935

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From Mount Morris to four miles below (north of) Avon the river is now meandering on the wide plain, the lake-smoothed surface of the deep glacial filling in the trunk valley. This filling continues eastward in the abandoned valley and then northward by Irondequoit Valley to Lake Ontario. The existing river, with its young ravines, is a weak descendent of its preglacial ancestor with wide valleys and deep canyons.

For many years the flow of the Genesee has been gaged by the U. S. Geological Survey and the Rochester Gas & Electric Corporation. The records show that somewhat less than one half of the thirty-odd inches of annual precipitation over the drainage area is carried away by surface run-off. Fifty per cent, or more, of the atmospheric water is removed by two agencies, evaporation, the fly off, and underground escape through the old, buried valley, the "deep-seepage." The precipitation data are on record in the publications of the U. S. Weather Bureau.

The water that sinks into the ground beyond reach of the vegetation follows the sloping rock surfaces and the drift-filled channels and concentrates in the old buried rock-walled valley, similar to the flow in the ancient valleys, open to the sky, in preglacial time. A large proportion of the ground-absorption water never emerges as springs, but as the deep-seepage it escapes invisibly into the depths of Lake Ontario. And the deep-seepage is not merely of the present river watershed but of the greater area that was drained by the ancient river.

With conservative estimates and minimum proportions it is calculated that the ultimate underground removal, the deep-seepage, is not less than twenty per cent of the precipitation, or 838 million gallons daily.

In the east-west stretch of the buried valley, beneath Rush, Mendon, Fishers, the drift filling is over 680 feet in depth, and probably is over 1,000 feet. The cross-section of the drift filling is roughly estimated at about two million square feet. To pass the deep-seepage required that each square foot should transmit, on an average, about 419 gallons daily, or 17.5 gallons per hour.

Regardless of any and all estimates and computations it is certain that the drift filling is transmitting, under pressure, all the water of which it is capable. This is proven by the numerous copious springs that are upwelling on the valley plain. Honeoye and Irondequoit creeks are well supplied from the underground surplus. The high-

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pressure flow of the Dansville well shows the abundance of artesian water, under hydraulic head, in the old east branch valley.

The chemistry of the artesian water has interesting variation due to the rock relations. The surficial water in east-west stretch of the valley is highly mineralized from contact with the Salina shales. But the wells at East Rochester, with depth less than 200 feet in the filling have hardness of only about 200 parts per million. The flowing Dansville well, depth 450 feet, and similar hardness indicates that the deeper water, from up-state on the south has only the moderate hardness characteristic of pure, spring water from nature's filter.

Test wells in the old valley are not required to prove abundance and quality of the artesian water, although necessary for location of service wells. Deep drilling is desirable to determine the water pressure at varying depths, and to learn the probability of artesian flow; also to find the depth and dimensions of the old valley as a matter of geologic interest.

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PETROLOGY OF THE NIAGARA GORGE SEDIMENTS

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ILLUSTRATIONS

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FIGURE 1

PHOTOMICROGRAPHS OF NIAGARA GORGE ROCKS

A. Fossil forms in Rochester Formation, Niagara Gorge. Original magnification x81. Polarized light. (585–S–10).

B. Cement-calcite in Whirlpool Formation. Polarized light. Original magnification x230. (577–S–27).

C. Recrystallized calcite replacing fossil, Irondequoit limestone. Polarized light. Original magnification x46. (589–S–15).

D. Clay cement in Whirlpool sandstone, 4½ feet below top. Polarized light. Original magnification x173½. (546–S–46).

E. Secondary mica in Medina sandstone, 16 feet below top of formation. Polarized light. Original magnification x173½. (547–S–29).

F. Chalcedonic quartz in Thorold sandstone. Polarized light. Original magnification x81. (564–S–48).

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J. Phosphatic nodule in grey Medina sandstone, 6 feet below top of unit. Plane light. Original magnification x47. (550–S–32).

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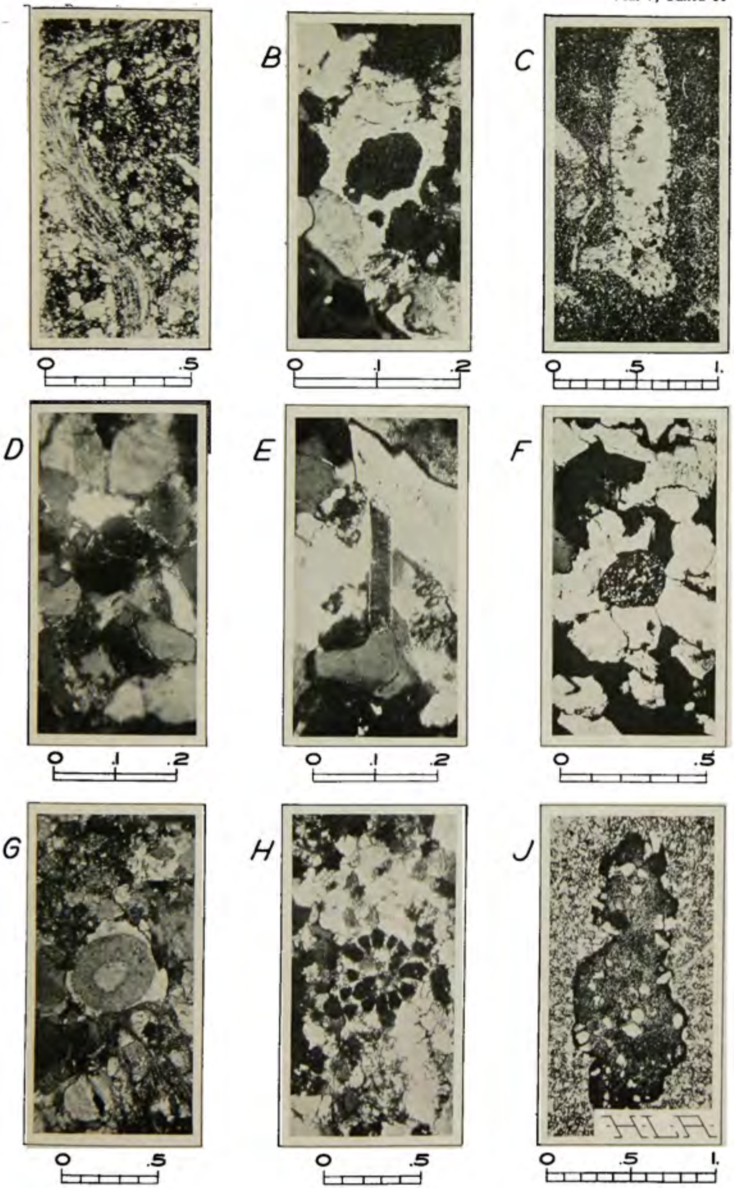

FIGURE 1

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Introduction

The sedimentary rocks of the Niagara Gorge have long been a classic for stratigraphers and paleontologists. For years I have been interested in these rocks, primarily as a source of material for petrographic thin sections. I have desired to get some conception of what unmetamorphosed sediments are like as an aid in investigating the Adirondack Grenville meta-sediments. As I have read and listened to the discussions about correlation, the conditions under which these Silurian rocks from Niagara were deposited, and the proper nomenclature that should be employed, I have reached the conclusion that additional information would be welcomed. I have long believed that the methods of the igneous petrographer, if applied to such rocks, would assist. While there is much more that can be done with the material at my disposal, I have devoted considerable time and thought to it, and desire to bring this study to some kind of conclusion even though this paper should be regarded merely as a preliminary report.

This paper is the result of investigating fifty slides from specimens taken at measured intervals in the gorge. Through the interest and helpfulness of John T. Sanford, the Buffalo Society of Natural Sciences, and the University of Rochester, these thin sections have been made available.

Preliminary Comment

I have found that these rocks are not merely aggregates of fragmental grains; they are not just sands, limes, and slimes, but are indurated and cemented sediments of complex nature unmistakably exhibiting subsequent changes and introduced materials. Recrystallization and crystal growth are observed to such an extent that the terms and principles of metamorphosed rocks can be applied with assurance. The difficulties I meet are multiplex; the rocks themselves are difficult to understand but perhaps what is more perplexing is the nomenclature that is to be applied to them. For these are not metamorphic rocks, and yet they have experienced incipient metamorphism; they are on their way but have not arrived. It is possible, therefore to catch a glimpse of what the early stages are. The true clastic grains, particularly of quartz, garnet, zircon, ilmenite, tourmaline, and other relatively stable minerals, can be readily recognized. Not so confidently, however, can the calcareous constituents be so designated. Some calcite in the limestones is fragmental;

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pieces deposited mechanically and regarded as clastic in origin. There are fragments of fossils. Many sections would seem to be capable of being identified, but apparently only a few paleontologists have had experience in fossil determination in petrographic thin sections. Still other calcite areas are different in appearance and are believed to be different in origin. Some are extremely fine grained. I have thought of this type as a chemical precipitate, perhaps biochemical in origin. This, however, I am unable to demonstrate. On the other hand, it may be pulverized lime washed into the sediments. But I am more certain, however, about the recrystallized calcite. Some slides of limestone consist largely of it. What it was originally is not positive in every case, but clastic calcite seems to have furnished most of it. In addition there is calcite cement, some of it is recognized as elastic, some is regarded as having been precipitated, and some is clearly introduced.

The dolomite usually consists of rhombs. It is much later, in its present form, than the rest of the rock. I am inclined to accept the theory of late dolmitization for many of these rocks. Dolmitic rhombs are not necessarily confined to the limestones. They occur throughout the Queenston, in certain beds of the Whirlpool, the Medina, and the Neahga shale.

The argillaceous constituents proved to be difficult material to identify. There is a good deal of colloidal clay-paste groundmass, isotropic, of various indices. Every gradation exists from these so-called amorphous substances to well crystallized and recrystallized clay minerals such as montmorillonite, sericite, and possibly kaolinite. I was surprised to find that a good deal of the argillaceous matter is in reality chlorite, serpentine, epidote, uralite, and other decomposed ferromagnesian minerals. Some clay has been formed in place from the decomposition of clastic grains, but most of it seems to be an original constituent. From slides cut parallel and perpendicular to the bedding, most of the flaky clay minerals are found to have a definite orientation, accounting for the "shaly" structure of the argillaceous rocks. Furthermore, the development of this shaly structure is caused by a surprisingly small amount of clay matter. The clay coats the individual clastic grains. Some beds of the Queenston in the hand specimen are shales, while in thin section they are sandstones if the relative amounts of the argillaceous and siliceous substances constitute the distinction between them.

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Grain Size

The matter of grain size in thin section has interested me. It is obvious that such slides are random cuts which do not reveal the maximum diameter of individual grains. The third dimension is lacking. To reduce the attendant "error" as much as possible, I have drawn distribution curves instead of calculating the average. The size of each grain was determined by measuring the area of each and from this calculating the diameter of a circle of the same area as the grain. I prefer this to the average of diameters. The areal method gives a better conception of the size as the variation in shape is to some degree reduced. Unquestionably the grains are actually larger than I have measured them. This cannot be helped.

Grain Roundness

This element proved to be one of the most interesting and at the same time one of the most perplexing problems in this investigation. The ratio of the area of the grain to the area of the smallest circumscribed circle gives a very imperfect concept of the true roundness. What this really shows is the degree of approach to a circle, that is, circularity. Roundness can only be determined by ascertaining how much the corners of the grains have been rounded. This requires the comparison with some "standard," as yet largely a matter of individual preference, or by measuring the radii of circles, some portions of the circumference of which fit the rounded surface of the grain. This can best be done on a camera lucida drawing or on a photograph. The average of such radii is helpful but leaves much to be desired. Still another method is to extend lines tangent to flat places on the grains and measure lengths of such flats and the totals of intersecting lines. Ratios can then be calculated.

In dealing with fragments, in the form of loose grains, it is possible to determine the sphericity, which is usually designated by Φ. In thin section this relationship is limited to circularity, sometimes symbolized by Ψ. Wadell[1] expresses circularity as follows: "$\frac{c}{C}$ = Degree of circularity, where c is the circumference of a circle of the same area as the plane figure, and C is the actual circumference of the plane figure."

I have preferred the ratio of the area of the smallest circumscribed circle to the area of the grain. My concept is $\frac{a}{A}$, where a is the area of the grain and A is the area of the smallest circumscribed circle.

[1] Wadell, Hakon, "Sphericity and Roundness of Rock Particles," Jour. Geol., vol. XLI, 1933, p. 321.

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Petrography

The Queenston Shale

The proportion of the argillaceous materials to the siliceous constituents is about nine to one. The latter are dominantly quartz, with minor amounts of perthite, plagioclase, garnet, zircon, rusty and leucoxenized ilmenite and opaline silica.

Small fragments of shale, although argillaceous in composition, are clastic and appear to represent detrital pieces of some pre-Queenston argillaceous sediment. There are well formed flakes of muscovitic mica, evidently recrystallized since deposition and in all probability since cementation. Likewise rhombs of dolomite which appear as "porphyry blasts," which certainly crystallized late.

Removal of the iron stain from the argillaceous groundmass paste with acid reveals a fine network of a flaky material, believed to be in part one of the chlorites. Possibly it is partial oxidation of this chloritic mineral that is the cause of the iron oxide stain. It is possible that this iron was originally a hydroxide.

A study of the grain size of the quartz content of the Queenston has been made in the form of frequency distribution curves. The curve, based upon measurements on 69 grains reveals two peaks, one at .0275—.0300 mm. and another at .0400—.0425 mm. Double peaked curves are universal except for the limestones. Does this mean that the clastic quartz came from two sources? If not, what other explanation is there?

The Whirlpool Sandstone

This is a feldspathic sandstone with a number of accessory minerals. Besides the dominant quartz there are perthite, microcline, plagioclase, garnet, chlorite, leucoxene, magnetite, phosphate pebbles, apatite, tourmaline, and zircon. There are fragments of shale as distinct clastic masses. Their microscopic characters show them to be similar to and in some cases identical with the argillaceous matters in the Queenston below. It is quite possible that they are Queenston fragments. The quartz grains are very largely "secondarily" enlarged. The added silica does not seem to fill completely the space between grains and the rock is cemented by chlorite and other unidentified argillaceous matters as well as by silica. I suggest that the bulk of the quartz has been derived from a pre-existing sandstone. This is in conformity with Grabau's suggestion that the New York Queenston-Medina is the re-worked Tuscarora-Juniata

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of Pennsylvania.[2] The frequency curves of quartz grains in the Whirlpool reveal double peaks as is the case with the Queenston, but a single peaked one for the feldspars. The peaks in the quartz curve occur at .200—.225 mm. and .300—.350 mm., corresponding to fine and medium sand respectively. The grains are therefore about ten times the size of the Queenston. The feldspars peak at .125—.150 mm., which is fine sand according to Grabau and very fine sand to fine sand on Wentworth's scale.

The argillaceous materials did not lend themselves to size analysis by camera lucida measurements alone.

Perhaps the most interesting mineral noted in the Whirlpool is the tourmaline. It shows a deep green color and considerable abrasion. One grain showed a distinct "secondary" growth. It is authigenous. Authigenous tourmaline has been noted from the Oriskany[3] and the Thorold.[4] I believe this is the first report of it in the Whirlpool.

The lack of purple red color, which in part distinguishes the Whirlpool from the Medina appears to be a transitory criterion, which petrographically is not sufficient to justify formational rank. Stratigraphically, however, it may be. The colorization in the Medina is on the grains but inside the quartz cement. If some of this cement quartz was deposited before becoming a part of the Whirlpool then the red color is not all Medinian but pre-Medinian. Perhaps the Queenston and the Medina are red because they were derived from red sediments.

The Medina Sandstone

In the accompanying charts, distinction is made between the gray and the red. The gray portion contains more argillaceous and calcareous minerals, while the gray is more siliceous. Petrographically the two grade into each other. Phosphatic masses occur in both members but perhaps more abundantly in the gray. The accessory minerals make a long list: perthite, orthoclase, plagioclase, usually an andesine, muscovite, garnet, augite, hornblende, tourmaline, ilmenite, pyrite, spinel, sillimanite, titanite, zircon, magnetite, apatite and several as yet not positively identified.

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[2] Grabau, A. W., "Early Paleozoic Delta Deposits in North America," Bull. Geol. Soc. Amer., vol. 24, 1913, pp. 431–433.
[3] Stow, M. H., "Authigenic Tourmaline in the Oriskany Sandstone," Am. Min., vol. 17, no. 4, 1932, pp. 150–152.
[4] Kremer, L. A., Unpublished M.S. thesis, University of Rochester, 1932.

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The Thorold Sandstone

At Niagara, the Thorold consists of 70% quartz, 6% feldspars, 20% argillaceous materials. Various kinds of feldspars are common—microcline, perthite, albite, oligoclase, andesine, and some untwinned feldspar which is probably plagioclase. The argillaceous materials include chlorite, muscovite, rusty biotite, and uralite. Some of the mica has experienced "secondary" growth. The list of accessory minerals is particularly extensive including recrystallized grains of calcite, calcite as a cement, opaline silica, ilmenite with attendant leucoxene, chromite, garnet, magnetite, zircon, apatite, and tourmaline.

The frequency-distribution curve of the quartz grains shows a double peak.

The grains of quartz are more angular than in the Medina, and smaller, and do not as a rule show enlargement. The size would permit the application of the theory that the rock is reworked Medina sand, the red hematitic coating of the Medina being removed by abrasion or chemical environment. If this is so, then the Thorold represents a condition rather than a distinct formation. This renders lateral correlation less certain.

Unnamed Shale

Between the Thorold and the Neahga green shale is a bed, a foot thick, which apparently has not received a stratigraphic name. Under the microscope it is seen to be a calcareous argillaceous sandstone with marked resemblances to the Thorold. 55% of the rock is quartz, about 7% feldspar. The calcareous constituents are fine grained calcite 7%, recrystallized calcite 17%, cementing calcite 6%. There appears to have been some introduction of lime. One would suppose that the overlying formation would be a limestone such as the Reynales which the calcareous components resemble. But the Neahga green shale intervenes.

Unlike the Thorold below, the grains of quartz are a little larger and show in addition enlargement by silica. Zircon is surprisingly common although making up a small portion of the bulk of the rock are garnet, apatite and tourmaline. Ilmenite is another common accessory and in some instances the alteration product, leucoxene, acts together with quartz, argillaceous matters, and calcite as the cement.

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The Neahga Shale

Above the Thorold is a green shale. From analogy from Rochester, one would suppose it to be the Maplewood. It is perhaps wiser at the present time to refer to it as the Neahga[5] shale, deriving the name from an Indian term for the Niagara River. It is six feet thick in the Niagara Gorge. Petrographically it consists of very fine flaky argillaceous minerals which show definite orientation parallel to the bedding. The shaly material is a good deal like the Maplewood shale of Rochester. If the Neahga shale of Niagara is not the Maplewood the similarities above noted would imply similar conditions of sedimentation.

Set in the groundmass of flaky, argillaceous paste are a few rather small (averaging .0125 mm.) recrystallized rhombs of calcite, small pillets of carbonaceous matter, sometimes bunched together. Pyrite is identified with difficulty. There are a few well recognized flakes of muscovite that appear to have developed idiomorphic shapes at a late stage. No fossil indications were noted in the thin sections, although several species have been collected from the Neahga in the field.

The Reynales Limestone

The iron ore member of the Reynales is absent at Niagara so the Neahga green shale is superseded by a limestone. Near the base it is a medium grained siliceous limestone consisting of fine-grained calcite, recrystallized calcite, clastic grains of dolomitic calcite, fossil fragments, quartz, and plagioclase. The base is more siliceous than a foot higher. Here the quartz and feldspar content has dropped off to less than one per cent. The rest of the rock is much the same.

The fine-grained calcite is particularly interesting. Masses exhibit dusty centers with comparatively clear margins. The latter probably represent cementing material of a "chemical" origin. See Figure 1G. More information is needed on such structures.

The same type of sediment appears to continue to the top of the formation, consisting of clastic grains, fossil fragments, recrystallized grains and fine-grained calcite, in the order named, contrasting in relative proportions to the basal portion although composed of the same constituents. The larger per cent of clastics and the falling

[5] Sanford, John T., "The 'Clinton' in Western New York," Jour. Geol., vol. XLIII, 1935, pp. 173, 174.

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off of fine-grained calcite foreshadow the coming of the Irondequoit sedimentation.

There are relatively large grains of recrystallized calcite within masses of fine-grained calcite. These rhombs show idiomorphic forms and are undoubtedly the result of late development. It is possible that they were potentially present in the chemically precipitated lime mud and developed at the expense of some of the fine-grained material.

There are two forms of pyrite at the top of the Reynales. One type is associated with fossil fragments and is regarded as of organic origin. The other form is involved with the clastic grains. These are much smaller and appear rounded. It is quite likely that they are clastic fragments.

The Irondequoit Limestone

On the whole the Irondequoit formation at Niagara is a coarse-grained limestone, without the argillaceous content characteristic of the rock at Rochester. The clastic grains are dominant and contrast with the Reynales below. Again the pyrite exhibits two forms. One type is small and rusty, associated with fossil forms and is believed to be organic. The larger grains are fresh and show development of crystallographic outlines. Their association is not confined to any one type of calcitic constituent but occurs along lines of weakness, such as bedding planes and along micro-cryto-faults. It has been introduced into the rock by later solutions. Very little quartz occurs.

This same coarse limestone with clastic calcite, fine-grained calcite, recrystallized grains and fossil fragments continues apparently to the top of the formation without much variation.

Reef in the Irondequoit

As the top of the Irondequoit is a reef whose petrographic characters justify separate treatment. It consists, not of corals nor of their fragments, but essentially of fine-grained calcite, and to a minor degree of fossil fragments of which crinoids and brachiopods are recognizable.

The Rochester Formation

At Niagara the Rochester is much more calcareous than it is at Rochester and petrographically does not justify the term shale.

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The base of the formation contains the usual limestone constituents: fine-grained calcite, recrystallized calcite, clastic calcite, fossil fragments, and in addition, the argillaceous materials. The last contrasts with the calcareous constituents so that the rock can be regarded as composed of two distinct portions. The argillaceous substances can only be determined in part. Seemingly embedded within the argillaceous component are quartz grains and small recrystallized grains of dolomitic calcite. The quartz is without question clastic in origin. The rhombs are believed to be clastic as well, but they have experienced later recrystallization. The calcareous portions of the rock possess larger rhombs of recrystallized calcitic material directly associated with the fossil fragments. This material appears to have been deposited along with the fossil remains as lime mud adhering to them. The fine-grained calcite is associated not with fossil fragments but with the argillaceous constituents and appears to be embedded in it. This would seem to suggest that the chemically (bio-chemically, perhaps) precipitated calcite was formed before or during the deposition of the clay matters.

The Diagrams

Quantitative Analyses

Figure 2 shows the composition of the Niagara Gorge rocks, the result of quantitative graphic analyses by means of the Wentworth stage. Many of these were made by Bernard Dollen, for which my sincere thanks are due. Such a graph, I think, is more effective than a mere tabulation. It has the disadvantage, however, of not showing all of the details that were observed in some slides. For example, it was possible to recognize in some, but unfortunately not in all, the quantitative amounts of clastic calcite, fine-grained calcite, cement calcite, and fossil fragments. Likewise clastic quartz and cement quartz could be distinguished and measured. To maintain continuity these interesting determinations could not be made.

It will be noticed that some uniformity in composition is exhibited by the Queenston, the Reynales, the Irondequoit, and the Rochester, and to a lesser degree by the Whirlpool, but not by the Gray and the Red Medina. It is of interest to note the presence of calcite in the Gray Medina. The diagram would suggest that oscillatory conditions of sedimentation prevailed during these times.

Lack of specimens prevents a complete study of the Lockport.

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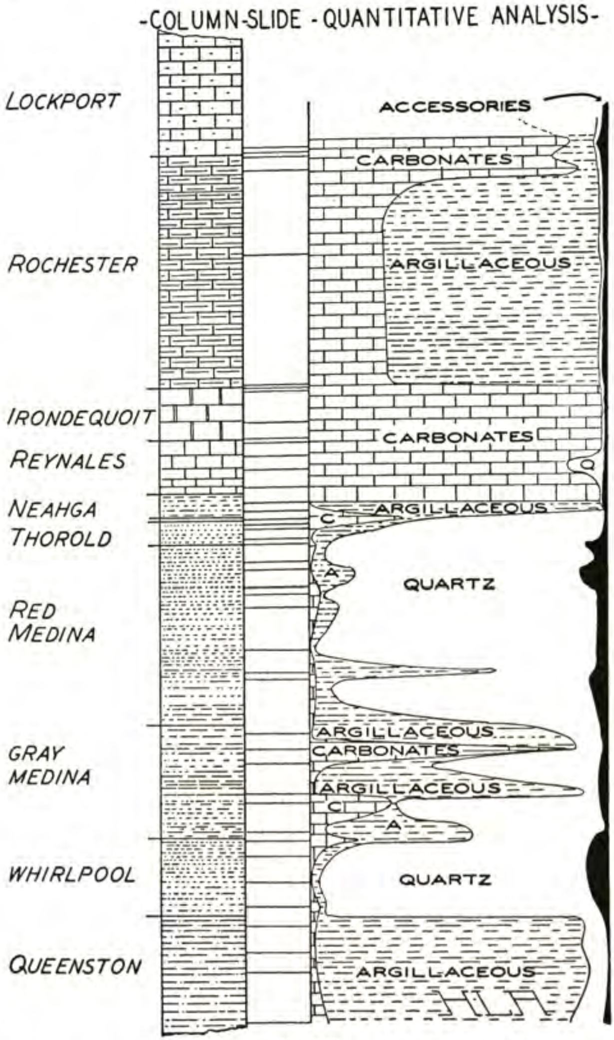

FIGURE 2

Diagram showing the quantitative composition in percent by weight of the sedimentary rocks from the Niagara Gorge, based upon linear intercepts by the use of a Wentworth stage. Many of these were made by Bernard Dollen, to whom my sincere thanks are due.

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Grain Size

Figure 3 shows frequency distribution curves of quartz grains measured in thin section. Unquestionably if more grains per slide had been measured less irregular curves would have resulted. As it

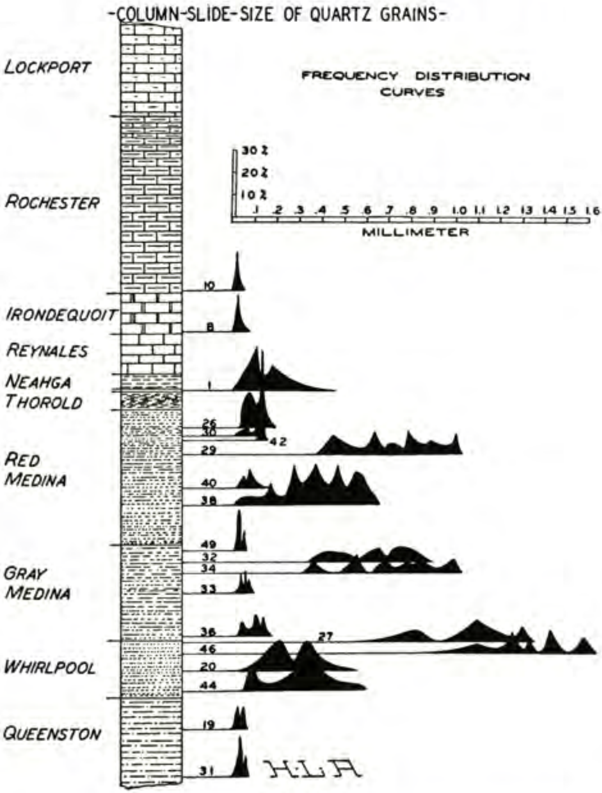

FIGURE 3

Frequency-distribution curves of the size of quartz grains in the sedimentary rocks of the Niagara Gorge. Determined in thin section by the circumscribed circle method. Many measurements were made by Bernard Dollen.

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was the images of 40 to 50 grains of each slide were drawn with the aid of a camera lucida, the areas measured by a polar planimeter and the diameter of the circle, whose area is equal to the area of the grain in question, calculated. In many cases it was possible to recognize the extent of enlargement by quartz cement and confine the size measurements to true grains themselves. In one slide, from the base of the Thorold, nine grains were measured twice, once to determine the size of the true grain and the second time to include cementing quartz as well. The average diameter of these grains is .180 mm., while with cement quartz in addition the diameter is .216 mm. Slides will reveal some facts that loose fragments will not. The multiple peaked curves suggest several sources of the materials composing these sediments.

Circularity

The degree of roundness of clastic grains would give some idea of the vigor of the transportational history back of these rocks. Unfortunately no simple satisfactory method seems available as yet. Lacking this I employed the scheme of measuring the "circularity." This is not true roundness. 25 freshly crushed grains of quartz give an average of 53% circularity. One suggestion is to regard this figure as zero. But each mineral would have a different zero. 25 freshly crushed grains of albite from Amelia, Va., gave a circularity of 49.6%. There is a difference between the cleavage of these two minerals. In spite of this obvious discrepancy between circularity and roundness, the former concept is used. Naturally the value of most of the quartz grains in the Niagara are above 53%. They range from 36 to 87%; the average is 65. It is not the largest grains that have high circularity, nor the the small ones, but rather the intermediate and the smallest. Some small grains are obviously splinters from larger ones. Studies of enlarged grains show that introduced quartz cement reduces the circularity. 9 grains in a slide (from the base of the Thorold) have a true circularity average of 64.6% while the value of those which include the cement is 61.3%.

Double or multiple peaked circularity curves are common and are comparable with size distribution curves. Also the curves of the quartz grains in the Thorold, Neahga, and the Irondequoit are simpler than those based upon measurements from stratigraphically lower beds.

I offer this paper with full knowledge that it does not solve many of the problems presented by the Niagara Gorge rocks; it does, how-

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ever, suggest a number of lines of investigation that are worth further study. After all, it is well to recognize that sedimentary petrology is still in the descriptive stage.

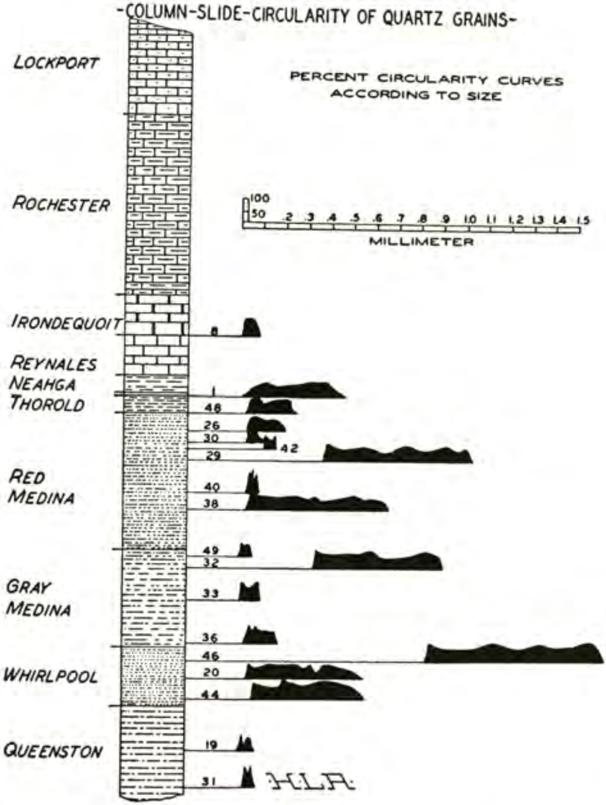

FIGURE 4

Percent circularity curves according to the size of quartz grains in the sedimentary rocks of the Niagara Gorge. Determined in thin section by calculating the ratio of the area of the smallest circumscribed circle to the area of the grain.

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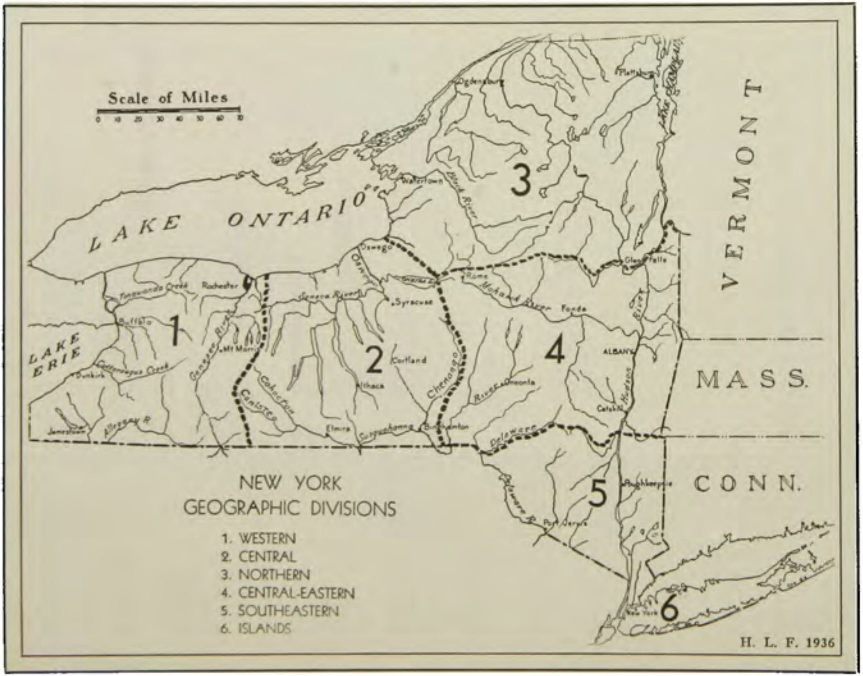

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NEW YORK GEOGRAPHIC PUZZLE

By Herman L. Fairchild

The University of Rochester

Royal grants, Indian concessions and Colonial treaties have given the state of New York a map figure which is difficult to describe and quite impossible to dissect or apportion by cardinal compass directions.

The subject is interesting as a problem in descriptive geography; and with differing opinions, suggestions are helpful. Political or county divisions are useless. The politicians divide the entire State into two divisions: New York City (metropolitan district) and the "upstate." Arbitrary lines, like the river systems and highland tracts are interlacing and confusing.

Neglecting the State's island appendages, extending northeast from Staten Island for 115 miles, to near the shore of Connecticut, the outline of the State suggests the neck and head of the Hammer-head Shark; or, to extend the homely comparison, that of a clumsy scraper of some sort. The western part of the State is relatively too large to merit the term Panhandle, as applied to West Virginia and Texas.

On account of its peculiar shape the State cannot be clearly divided into north, south, east and west portions, and no names for the large divisions have been proposed. The expressions "northern New York," "central New York" and "western New York" are in common use but without any clear application or definite limits. Geologists and geographers find difficulty in stating the location of areas or districts. The writer has used the terms western, central and west-central without precise application or limitation.

For the purpose of clearer discussion of this subject the accompanying map shows a dissection of the State into five provinces. The boundaries are arbitrary. Any dividing of the State by drainage systems or by physiographic features is complex and confusing.

The simplest compass division of the State would be into:

> Western New York, to include provinces 1 and 2; and Eastern New York, including provinces 3, 4 and 5.

Such division is entirely accurate, and useful in a broad way, but of no value in general use. And it eliminates northern, western and central divisions.

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Another method of division, also correct but too comprehensive, is

Northern New York, including province 3 and southward to the Mohawk River.

Southeastern New York, including provinces 4 and 5 and perhaps the islands.

Western New York, provinces 1 and 2.

This scheme leaves no space for eastern and central divisions.

The more detailed and feasible compass divisions may be taken as follows:

Northern New York

The only division of the State with fairly accurate compass designation without requiring description is that of northern. Province number 3 of the map suggests a definite area, although the common usage appears to include as "northern" all of the territory north of the Mohawk River. As limited in province 3 the area is wholly north of all the rest of the State, even provinces 1 and 2.

Eastern New York

The term eastern is so comprehensive that it is very indefinite and is used only loosely. The term with correctness must include all of the provinces 3, 4 and 5, or about two thirds of the State. That is the only fair application of the term. An arbitrary western limit by some meridian, say 75° 30′, would cut off the western part of province 3, and would leave no area for "southern." The term eastern is impractical.

Southern New York

The only portion of the State which can appropriately use the term "southern" as against the remainder of the State is the province 5. The chain of islands could be included; but would better make a sixth province.

This application of the term southern deprives provinces 1 and 2 of any claim on such division. A common usage speaks of the counties bordering on Pennsylvania as the "southern tier." As noted below province 5 is more correctly designated as Southeastern New York.

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Central New York

The term central is in common use, but with no precise limitation. It has frequent reference to the Finger Lakes district; and also to the area east and west of Syracuse.

As a physiographic district the Finger Lakes region is properly called central, although partly west of the middle of the State. The term is elastic and no better limits than suggested for province 2.

Western New York

In the broad way the term "western" would certainly include all of the provinces 1 and 2, thus leaving no place for "central." In the precise and restricted division western is province 1. This includes the Genesee drainage area, and the four "Thumb" lakes, Conesus, Hemlock, Canadice and Honeoye, as distinguished from the Finger Lakes, all on the left hand.

Central-eastern New York

In the above division of the State "eastern" finds no place in the final division, and province 4 has been neglected. This illustrates the difficulty in apportioning the State.

Province 4 is certainly "eastern," yet no more so than 3 and 5. Hence it must be recognized by some distinctive term if we recognize any eastern area by name.

The tentative divisions of the map now appear to be the best that we find. These are:

1. Western New York.
2. Central New York.
3. Northern New York.
4. Central-eastern New York.
5. Southeastern New York.
6. Islands of New York.

In the lack of any well-known and universally recognized map of the divisions of the State, accepted for popular use, the general public will continue the practice of indefinite, inaccurate and careless reference to location of place names. But students in geographic science should strive for precision.

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PROCEEDINGS OF THE ROCHESTER ACADEMY OF SCIENCE
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THE BERGEN SWAMP: AN ECOLOGICAL STUDY

PAUL A. STEWART and WILLIAM D. MERRELL *

From the Department of Botany
The University of Rochester

CONTENTS

ILLUSTRATIONS

* The original draft of this paper was written by Mr. Stewart as a thesis in the department of Botany. In his absence from Rochester I have been asked to prepare his article for publication and to add my name as joint author. It will be understood that the credit for the actual field work and for writing the original paper belongs to Mr. Stewart. Having followed his work closely I have undertaken this revision, and have also contributed the photographs for the four Plates. I have avoided too extensive a condensation for two reasons: first, because of the special interest of local botanists, and second, I wish to retain as much as possible of the personal style and the flavor of discovery seen in the original paper. Any significant additions or amendments on my part will bear my initials. . . . W. D. M.

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EXPLANATION OF PLATES

(Somewhat reduced from photographs taken by Mr. A. A. Lohwater, July 28, 1936.)

PLATE I. View across open marl in rather an advanced stage. Triglochin maritima, Deschampsia caespitosa, Cladium mariscoides, Scirpus caespitosus, Rhynchospora capillacea. Salix candida on mound to left of camera. Pine-Hemlock forest in background.

PLATE II. Open marl close to woodland. Solidago ohioensis at left. Juniperus horizontalis in tuft at right. Small white pines and larches at border of woodland. Hemlock Knoll in background, large white pines conspicuous.

PLATE III. Border close-up to woodland. Open marl in foreground. Young Secondary Marl, with Solidago Houghtonii, Zygadenus chloranthus, Potentilla fruticosa, Phragmites communis. Small white pines and larches bordering the Pine-Hemlock.

PLATE IV. View along outer border of swamp. Less than a rod from mesophytic grassland to a mixture of swamp grasses and sedges, Aspidium Thelypteris, and Typha latifolia. The trees and shrubs in the background are a part of the Beech-Maple zone.

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PLATE I

PLATE II

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PLATE III

PLATE IV

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Introduction

In the northern part of western New York there are several large swamps in various stages of transition from an open water condition to the climax forest. They form a series extending westward from the Genesee river toward Lake Erie and the Niagara river. Prominent among these is the Bergen Swamp, which is drained by the Black Creek into the Genesee river. So far as it has been possible to determine, no detailed ecological work has been done on the vegetation of this region, although the Bergen Swamp has long been known to both botanists and zoölogists as an ideal place for collecting purposes, and has been mentioned specifically in the papers by Bray (1930) and Zenkert (1934).

The present paper deals with the general flora of the Bergen Swamp; the ecological formations recognized, with their special floras and underlying soils; the geology of the region; the past history, present status and possible future of the swamp, and a comparison of Bergen with other swamp regions.

Such aspects as the water content of the soil, humidity, light and temperature studies, precipitation and wind records were not worked out in detail, although the government records of average temperatures and precipitation for this region have been used in comparing it with other general localities.

The field work on this problem was carried out during the more open seasons of 1932 and 1933. Fully labeled specimens collected by the writer have been deposited in the University Herbarium. In all cases the nomenclature used is that of Gray's New Manual of Botany, seventh edition.

The method finally adopted for the determination of soil acidity was that of the Youden Hydrogen Ion Determination apparatus as described and discussed by Clark (1922). Clark admits that there are possibilities for error in this method, but for general use it is preferable to the more common colorimetric methods because of its ease of operation and rapidity of determination, combined with a high degree of efficiency.

The writer wishes to express his sincere gratitude to Dr. W. D. Merrell, of the department of Botany, who suggested the problem and aided in the work; to Mr. Milton S. Baxter, curator of the Herbarium; to Dr. J. Edward Hoffmeister, of the department of Geology; and to Dr. Willard R. Line, of the department of Chemistry; also to many others for their helpful suggestions and criticisms.

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Description of Bergen Swamp

Definition of Terms

Klugh (1913) recommends the following definition of terms used in ecological work, and they will be followed as closely as possible:

Community: an ecological division of unspecified rank; sometimes called a *society* in a general sense.

Zone: a term used for specific communities which show a well marked concentric or parallel arrangement.

Formation (Grisebach): "a group of plants such as a meadow or forest that has a definite physiognomic character." The Brussels Congress (1910) defined the formation as "the actual expression of certain definite conditions of life. It is composed of associations that differ in their floristic composition, but are in agreement firstly with reference to conditions of habitat, and secondly as regards forms." Klugh, however, would abandon this term.

Association (Brussels Congress 1910): "an association is a plant community of definite floristic composition, presenting a uniform physiognomy, and growing in uniform habitat conditions. The association is the fundamental unit in synecology." Nichols (1923) defines the association as "a community of plants which occupy a common habitat," constituting a "qualitatively and quantitatively homogeneous plant society."

Succession: Clements (1905) defines succession as "the phenomena by which a series of invasions occur in the same spot."

Bog: Rigg (1922a) defines a bog as "that stage in the physiographic succession of an area during which its surface is entirely devoid of ordinary hard soil and is composed completely of living sphagnum moss, under which is to be found fibrous brown peat, composed mainly or entirely of partially decayed sphagnum." Kurz (1928) says that the bog is an area in which the soil is either acid or neutral. Transeau (1903) names Drosera, Sarracenia, Larix and Vaccinium as characteristic plants of bog areas.

Swamp: A swamp is usually defined as "soft low ground, saturated, but not usually covered, with water." Kurz says that the characteristic bog plants are absent in the swamp and the substratum is either alkaline or neutral.

The Bergen area is therefore correctly called a swamp because of its general physiognomy, although some portions of it are typically bog like.

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Geographical Features of the Swamp

The Bergen Swamp covers an area of several hundred acres in the townships of Bergen and Byron in the northeast corner of Genesee county, New York. The swamp is about twenty-four miles west of Rochester and about three miles west of the village of Bergen (Figure 1). It is readily accessible by highway at several points. In shape the swamp is generally oval (Figure 2), but on the northeast side its regularity is interrupted by Torpy Hill which runs in toward the center of the swamp. Baxter and House (1924) say of the region that it is an irregular marl bed surrounded by a dense cedar swamp. In dry weather the surface of the marl becomes desiccated and hard, while in wet weather the marl is soft and miry, but at no times dangerous. The original swamp had dimensions considerably greater than those of the present actual swamp, but in general the boundary lines of the older swamp may be recognized by the presence of some swamp vegetation in the otherwise climax forest.

Geology and Physical Characteristics of the Swamp

H. L. Fairchild in his contribution to the "Plants of Monroe County" (Beckwith and Macauley 1894), gives the following information regarding this region. The Black Creek, which drains Bergen Swamp, empties into the Genesee River a few miles south of the city of Rochester. The general area along the south shore of Lake Ontario, in which region the swamp is located, is a plain sloping north to the Lake (Figure 1). The altitude at Bergen Swamp is 590–600 feet above tide level.

The rock strata underlying this region rest in a nearly horizontal position, without marks of any serious disturbance. The strike of the formations is nearly east-west and consequently the formations appear as bands running in that direction. These rock formations are however rarely seen at the surface, even in stream beds and other natural depressions, due to the large amount of till deposited upon them by the last glacier. Bergen Swamp proper lies over the shales of the Salina formation of the Silurian age.

Fairchild further states that during the millions of years following the deposition of the Devonian rocks this entire area was exposed to continuous atmospheric erosion and decay. At the close of the Pliocene the climate became considerably colder and resulted in accumulations of snow and ice over Canada and northeastern United States. The natural result of this change was that the former sub-

Figure 1. APPROXIMATE LIMITS OF STRATA

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aërial denudation of the region became subglacial and consequently much of the superficial rock was crushed and removed to the south with the general movement of the glacier. As the glacier retreated to the north a considerable layer of glacial drift was left over this entire region, and it is this glacial drift which now covers the underlying strata.

As the glacier advanced southward over this general region not only did it remove the superficial rock southward but it also brought from the country north and northeast much of the rock of the Archaean area. Furthermore the lake which washed the foot of the retreating glacier deposited large amounts of silt and clayey soils. As a result of these several factors the glacial till and superficial soils which now overlie the regular subjacent geological formations are extremely heterogeneous. In the region of Bergen Swamp and other localities situated above the Salina shales the drift is comparatively thick and without question contains rocks that have been formed by action of atmospheric agencies, glacial action, stream drainage, lake action, and subsequent exposure following the retreat of the last glacier.

The influence of this geologic glacial activity on the soils and the plant life to be found on these soils will be considered later in the paper.

Soil Types at Bergen Swamp

In the main, two distinct soil types are recognizable. The first of these is the marl type previously mentioned as being located in the central portion of the swamp. Taylor (1928) mentions marl as being one of the two principal types of soil and as being a mineral soil. The marl is not a pure white, even at the surface of those portions least covered with vegetation. At the surface it is tinged with gray, while underneath it is a clean creamy white, the grayish tinge being the result of the decay of the vegetation formerly supported on the marl.

The second type of soil in the swamp is the humus soil, entirely surrounding the marl center. Taylor (1928) states that the humus soil differs from the mineral in that it can be burned off or otherwise destroyed, and also that it varies with the plant life growing upon it. At the Bergen Swamp the humus soil has many types and these are in practically all cases the direct result of the plant types growing in that exact locality. In general there are three main humus soils in the swamp. First, there is the humus that is formed

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by decaying sphagnum and associated plants. This is one of the first types to extend out over the marl. The second type is the humus formed by the decaying conifers and the undergrowth associated with them. This humus is punky, acid, and succeeds the sphagnum humus. The third type is the humus formed by the decay of the deciduous vegetation. This is generally darker and sweeter, and is third in the line of succession. It must be remembered that there are variations and all degrees of intergrades of these humus types.

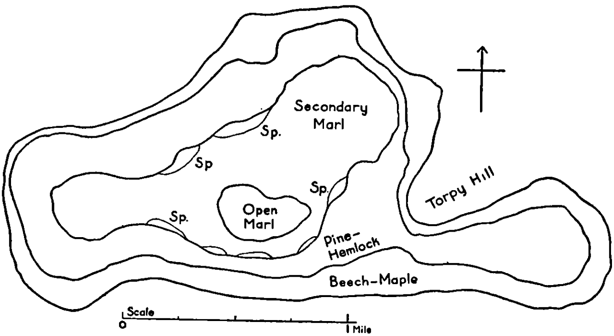

Figure 2. DIAGRAM OF VEGETATIVE ZONES—Sp., Sphagnum

Vegetative Zones

The following five zones and associations are to be found within the swamp. In each case a list of the dominant or subdominant species characteristic of the community is given.

1. *The Open Marl Association:* This occupies the center of several of the marl beds and has the following typical plants:

Juniperus horizontalis	Solidago Houghtonii
Phragmites communis	Solidago ohioensis
Cladium mariscoides	Deschampsia caespitosa
Scirpus caespitosus	Triglochin maritima
Lobelia Kalmii	Carex Crawei
Senecio Balsamitae	Carex flava

2. *The Secondary Marl Zone:* This zone is so called because, although it is likewise found on the marl, it represents a more ad-

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vanced stage in the succession of the swamp vegetation. It is located around the edge of the open marl beds and in a few islands in the middle of some of these beds. Its type plants are:

Larix laricina
Typha latifolia
Cypripedium candidum
Cypripedium parviflorum var. pubescens
Salix candida
Gaylussacia baccata
Ledum groenlandicum
Lonicera oblongifolia

3. *Sphagnum Association:* This association is found on the marl in little humps, but more frequently near the edge of the marl where, at times, it forms a fairly large mat. In most cases it is practically a pure stand of Sphagnum and the other plants that may occur with it are Sarracenia purpurea, Gaylussacia baccata, and Vaccinium Oxycoccos.

4. *The Pine-Hemlock Zone:* This zone surrounds all the marl beds and in general extends back from the marl for a considerable distance. It varies considerably within itself between pine and hemlock domination, but not sufficiently, in the writer's opinion, to warrant dividing the zone into separate units. Type plants of the zone are:

Taxus canadensis
Pinus Strobus
Thuja occidentalis
Tsuga canadensis
Clintonia borealis
Coptis trifolia
Drosera rotundifolia
Chamaedaphne calyculata
Chiogenes hispidula
Trientalis americana
Mitchella repens

5. *The Beech-Maple Zone:* This zone represents the climax association of this general area (Livingston and Shreve 1921). It forms the outer band of vegetation of the swamp and completely surrounds the zones already mentioned. Type plants of this association are:

Aspidium marginale
Aspidium spinulosum var. intermedia
Pteris aquilina
Osmunda cinnamomea
Erythronium americanum
Smilacina racemosa
Populus tremuloides
Fagus grandifolia
Ulmus americana
Claytonia virginica
Acer spicatum
Acer rubrum

The general location of these zones may be seen in Figures 2 and 3.

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Plant Lists of the Swamp

The following list includes all the species of plants which have been reported from Bergen Swamp in the papers by Beckwith and Macauley (1894) and Baxter and House (1924), together with those collected by the present writer. The list, as a result, is as complete as it is possible to compile at the present time, and only by further collection within the swamp can it be expected materially to enlarge the list.

The plants in this list are arranged by families, the latter being in the systematic order given in Gray's New Manual of Botany, seventh edition. Within each family the genera and species are listed alphabetically. The nomenclature throughout the paper being strictly according to Gray's Manual, the names of the authors of the species have been omitted from all lists except this systematic list.

Complete Systematic List

Polypodiaceae

†Adiantum pedatum L.
†Aspidium Boottii Tuckerm.
Aspidium cristatum (L.) Sw.
*Aspidium Goldianum Hook.
†Aspidium marginale (L.) Sw.
*Aspidium noveboracense (L.) Sw.
†Aspidium spinulosum (O. F. Miller) Sw.
†Aspidium spinulosum var. intermedia (Muhl.) D. C. Eaton.
*Aspidium Thelypteris (L.) Sw.
†Asplenium acrostichoides Sw.
*Asplenium filix-femina (L.) Bernh.
*Cystopteris bulbifera (L.) Bernh.
*Cystopteris fragilis (L.) Bernh.
†Onoclea sensibilis L.
Phegopteris Dryopteris (L.) Fee
†Polystichum acrostichoides (Michx.) Schott.
†Pteris aquilina L.
†Woodwardia virginica (L.) Sm.

Osmundaceae

†Osmunda cinnamomea L.
Osmunda Claytoniana L.

Ophioglossaceae

Botrychium ternatum (Thunb.) Sw.
*Botrychium virginianum (L.) Sw.

Equisetaceae

†Equisetum arvense L.
Equisetum fluviatile L.
Equisetum hyemale L.
†Equisetum pratense Ehrb.

Lycopodiaceae

*Lycopodium clavatum L.
*Lycopodium lucidulum Michx.
*Lycopodium obscurum L.

Taxaceae

*Taxus canadensis Marsh.

An asterisk (*) preceding the name indicates a plant previously reported, and collected by the present writer; the sign "†" indicates a plant collected by the writer but not previously reported; names without these marks have simply been reported in previous literature.

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Pinaceae
*Juniperus horizontalis Moensch.
*Larix laricina (DuRoi) Koch
*Picea rubra (DuRoi) Dietr.
*Pinus Strobus L.
*Thuja occidentalis L.
*Tsuga canadensis (L.) Carr.

Typhaceae
*Typha latifolia L.

Sparganiaceae
Sparganium eurycarpum Eng.
Sparganium simplex Huds.

Juncaginaceae
Scheuchzeria palustris L.
*Triglochin maritima L.
Triglochin palustris L.

Gramineae
Cinna arundinacea L.
†Deschampsia caespitosa (L.) Beauv.
†Deschampsia flexuosa (L.) Trin.
Leersia oryzoides (L.) Sw.
Panicum Lindheimeri Nash
*Phragmites communis Trin.
*Sorgastrum nutans (L.) Nash
Sphenopholis palustris (Michx.) Scribn.

Cyperaceae
Carex aurea Nutt.
Carex Bebbii Olney
Carex bromoides Schk.
Carex cephalantha (Bailey) Fernald, var. angustata Carey
*Carex Crawei Dewey.
*Carex cristata Schwein.
*Carex eburnea Boott
Carex filiformis L.
*Carex flava L.
Carex granularis Muhl.
Carex gynocrates Wormsk.
†Carex hystericina Muhl.
*Carex leptalea Wahl.
Carex lupulina Muhl.
Carex lurida Wahl.
Carex Oederi Retz.

Cyperaceae—cont'd.
Carex pedunculata Muhl.
Carex polygama Schkuhr.
Carex Pseudo-Cyperus L.
Carex rosea Schk.
*Carex rostrata Stokes
Carex scabrata Schwein.
Carex siccata Dewey
Carex sterilis Willd.
Carex trisperma Dewey
Carex vaginata Tausch.
†Carex vulpinoidea Michx.
*Cladium mariscoides (Muhl.) Torr.
Cyperus diandrus Torr.
Eleocharis acuminata (Muhl.) Ness.
Eleocharis rostellata Torr.
Eriophorum virginicum L.
Eriophorum viridi-carinatum (Engelm.) Fern.
Rynchospora alba (L.) Vahl.
*Rynchospora capillacea Torr.
R. capillacea var. leviseta Hill
Scirpus americanus Pers.
*Scirpus atrovirens Muhl.
*Scirpus caespitosus L.
†Scirpus cyperinus (L.) Kunth.
Scirpus pauciflorus Lightf.
Scirpus Torreyi Olney
†Scirpus validus Vahl.
Scleria verticillata Muhl.

Araceae
†Arisaema triphyllum (L.) Schott.
Calla palustris L.
*Symplocarpus foetidus (L.) Nutt.

Juncaceae
Juncus acuminatus Mich.
Juncus balticus Willd. var. littoralis Eng.
Juncus brachycephalus (Engelm.) Buch.
Juncus bufonium L.
Juncus canadensis Gay
Juncus Dudleyi Wiegand
†Juncus effusus L.

Liliaceae
†Allium tricoccum Ait.
*Clintonia borealis (Ait.) Raf.

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Liliaceae—cont'd.
†Erythronium americanum Ker.
Lilium superbum L.
†Maianthemum canadense Desf.
*Medeola virginiana L.
†Polygonatum biflorum (Walt.) Ell.
†Smilacina racemosa (L.) Desf.
*Smilacina stellata (L.) Desf.
Smilacina trifolia (L.) Desf.
*Tofieldia glutinosa (Michx.) Pers.
Trillium erectum L.
†Trillium grandiflorum (Michx.) Salisb.
Uvularia grandiflora Sm.
Uvularia perfoliata L.
†Zygadenus chloranthus Richards

Orchidaceae
Arethusa bulbosa L.
Calopogon pulchellus (Sw.) R. Br.
Calypso bulbosa (L.) Oakes
†Corallorrhiza maculata Raf.
Corallorrhiza trifida Chatelain
Cypripedium acaule Ait.
*Cypripedium candidum Muhl.
Cypripedium hirsutum Mill.
*Cypripedium parviflorum Salisb., var. pubescens (Willd.) Knight
Epipactis pubescens (Will.) Eaton
Epipactis repens (L.) Crantz
Habenaria blephariglottis (Willd.) Torr.
Habenaria bracteata (Willd.) R.Br.
*Habenaria dilatata (Pursh.) Gray
Habenaria Hookeri Torr.
Habenaria hyperborea (L.) R.Br.
Habenaria orbiculata (Pursh.) Torr.
Habenaria psycodes (L.) Sw.
Liparis Loeselii (L.) Richard
Listera cordata (L.) R.Br.
Microstylis monophyllos (L.) Lindl.
*Pogonia ophioglossoides (L.) Ker.

Piperaceae
Saururus cernuus L.

Salicaceae
†Populus alba L.
†Populus balsamifera L.
†Populus tremuloides Michx.
*Salix candida Flugge
Salix lucida Muhl.
Salix rostrata Richards

Myricaceae
*Myrica carolinensis Mill.

Betulaceae
Alnus incana (L.) Moench
†Betula lutea Michx.
*Carpinus caroliniana Walt.
†Ostrya virginiana (Mill.) K.Koch

Fagaceae
*Fagus grandifolia Ehrb.
*Quercus alba L.
*Quercus bicolor Willd.
†Quercus rubra L.

Urticaceae
*Laportea canadensis (L.) Gaud.
†Pilea pumila (L.) Gray
†Ulmus americana L.
†Ulmus racemosa Thomas
Urtica Lyalli Wats.

Santalaceae
†Comandra umbellata (L.) Nutt.

Aristolochiaceae
†Asarum canadense L.

Polygonaceae
Polygonum dumetorum L.
†Polygonum Persicaria L.
Polygonum sagittatum L.
Rumex Brittanica L.
Rumex verticillatus L.

Caryophyllaceae
Stellaria graminea L.
Stellaria longifolia Muhl.
Stellaria media (L.) Cyrill

Portulacaceae
*Claytonia virginica L.

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Ranunculaceae
†Actaea alba (L.) Mill.
Anemone cylindrica Gray
Anemone virginiana L.
†Aquilegia canadensis L.
*Caltha palustris L.
Clematis virginiana L.
*Coptis trifolia (L.) Salisb.
Hepatica acutiloba DC.
*Hepatica triloba Chaix.
Hydrastis canadensis L.
Ranunculus abortivus L.
†Ranunculus acris L.
Ranunculus aquatilis L.
Ranunculus delphinifolius Torr.
Ranunculus repens L.

Berberidaceae
†Caulophyllum thalictroides (L.) Michx.
*Podophyllum peltatum L.

Lauraceae
Benzoin aestivale (L.) Nees

Papaveraceae
Sanguinaria canadensis L.

Fumariaceae
Dicentra canadensis (Goldie) Walp.
Dicentra Cucullaria (L.) Bernh.

Cruciferae
Alyssum alyssoides L.
†Arabis hirsuta (L.) Scop.
†Cardamine bulbosa (Schreb.) BSP
*Dentaria diphylla Michx.
Dentaria laciniata Muhl.

Sarraceniaceae
*Sarracenia purpurea L.

Droseraceae
*Drosera rotundifolia L.

Crassulaceae
Sedum purpureum Tausch.

Saxifragaceae
Chrysosplenium americanum Schw.
*Mitella diphylla L.

Saxifragaceae—cont'd.
Mitella nuda L.
*Parnassia caroliniana Michx.
Ribes Cynosbati L.
Saxifraga pennsylvanica L.
†Tiarella cordifolia L.

Rosaceae
†Agrimonia gryposepala Wallr.
*Amelanchier canadensis (L.) Medic.
Dalibarda repens L.
Fragaria vesca L.
*Fragaria virginiana Duchesne
*Geum strictum Ait.
*Potentilla fruticosa L.
†Prunus virginiana L.
Pyrus arbutifolia (L.) Lf.
Rosa carolina L.
Rubus allegheniensis Porter
Rubus hispidus L.
†Rubus idaeus L., var. aculeatissimus (C.A.Mey.) Regel & Tiling
*Rubus odoratus L.
†Rubus triflorus Richards

Leguminosae
Apios tuberosa Moensch.
Desmodium bracteosum (Michx.) DC.
Desmodium canescens (L.) DC.
Desmodium grandiflorum (Walt.) DC.

Geraniaceae
*Geranium maculatum L.
†Geranium Robertianum L.

Polygalaceae
*Polygala pauciflora Willd.

Limnanthaceae
Floerkea proserpinacoides Willd.

Anacardiaceae
*Rhus Toxicodendron L.
*Rhus typhina L.
Rhus Vernix L.

Aquifoliaceae
*Ilex verticillata (L.) Gray

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Aceraceae
*Acer pennsylvanicum L.
†Acer rubrum L.
Acer saccharinum L.
†Acer saccharum Marsh.
*Acer spicatum Lam.

Balsaminaceae
*Impatiens biflora Walt.

Rhamnaceae
*Rhamnus alnifolia L'Her.

Vitaceae
Psedera quinquefolia (L.) Greene

Tiliaceae
*Tilia americana L.

Malvaceae
Hibiscus Moscheutos L.

Hypericaceae
Hypericum boreale (Britton) Bicknell
Hypericum punctatum Lam.
Hypericum virginicum L.

Violaceae
Viola blanda Willd.
†Viola conspersa Reichenb.
*Viola nephrophylla Greene
*Viola pallens (Banks) Brainerd
Viola palmata L.
†Viola papilionacea Pursh.
*Viola scabriuscula Schwein.
†Viola renifolia Gray
*Viola rostrata Pursh.
Viola rotundifolia Michx.
Viola sororia Willd.
†Viola canadensis L.

Onagraceae
*Circaea alpina L.
†Circaea intermedia Ehrb.
†Circaea lutetiana L.
*Epilobium angustifolium L.
†Oenothera biennis L.

Araliaceae
†Aralia hispida Vent.
†Aralia nudicaulis L.

Umbelliferae
Cicuta maculata L.
Conioselinum chinense (L.) BSP.
†Cryptotaenia canadensis (L.) DC.
*Daucus Carota L.
*Osmorhiza Claytoni (Michx.) Clarke
†Sanicula marilandica L.

Cornaceae
†Cornus canadensis L.
†Cornus circinata L'Her
†Cornus stolonifera Michx.

Ericaceae
*Chamaedaphne calyculata (L.) Moench.
*Chiogenes hispidula (L.) T. & G.
†Gaultheria procumbens L.
*Gaylussacia baccata (Wang.) C. Koch.
*Ledum groenlandicum Oeder
Moneses uniflora (L.) Gray
Monotropa uniflora L.
†Pyrola americana Sweet
Pyrola asarifolia Michx., var. incarnata (Fisch.) Fernald
Pyrola chlorantha Sw.
Pyrola elliptica Nutt.
Pyrola secunda L.
†Rhododendron nudiflorum (L.) Torr.
Vaccinium corymbosum L.
Vaccinium macrocarpon Ait.
†Vaccinium Oxycoccos L.
†Vaccinium pennsylvanicum Lam.
Vaccinium stamineum L.

Primulaceae
Lysimachia Nummularia L.
Lysimachia terrestris (L.) BSP.
†Samolus Valerendi L.
*Steironema ciliatum (L.) Raf.
*Trientalis americana (Pers.) Pursh.

Oleaceae
*Fraxinus americana L.
Fraxinus nigra Marsh.

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Gentianaceae

Menyanthes trifoliata L.

Apocynaceae

†Apocynum cannabinum L.

Asclepiadaceae

Asclepias quadrifolia Jacq.

Polemoniaceae

Phlox divaricata L.

Boraginaceae

*Myosotis laxa Lehm.

Labiatae

*Lycopus americanus Muhl.
†Prunella vulgaris L.
Scutellaria laterifolia L.
Teucrium canadense L.

Solanaceae

*Solanum Dulcamara L.

Scrophulariaceae

Chelone glabra L.
Gerardia purpurea L.
Mimulus ringens L.
Veronica americana Schwein.
Veronica scutellaria L.

Orobanchaceae

Orobanche uniflora L.

Phrymaceae

†Phryma Leptostachya L.

Rubiaceae

Galium boreale L.
Galium triflorum Michx.
†Mitchella repens L.

Caprifoliaceae

†Linnaea borealis L., var. americana (Forbes) Rehder
*Lonicera oblongifolia (Goldie) Hook
†Sambucus racemosa L.
†Viburnum acerifolium L.
†Viburnum cassinoides L.

Valerianaceae

*Valeriana uliginosa (T. & G.) Rydb.

Lobeliaceae

*Lobelia Kalmii L.
†Lobelia siphilitica L.

Compositae

†Achillea Millefolium L.
†Anaphalis margaritacea (L.) B. & H.
Aster juncus Ait.
Aster macrophyllus L.
Aster novae-angliae L.
Aster paniculatus Lam.
Aster puniceus L.
Aster Tradescanti L.
†Aster umbellatus Mill.
*Bidens cernua L.
Bidens frondosa L.
†Chrysanthemum Leucanthemum L.
Erechtites hieracifolia (L.) Raf.
†Erigeron philadelphicus L.
*Eupatorium perfoliatum L.
*Eupatorium purpureum L.
†Eupatorium urticaefolium Reichard
*Helenium autumnale L.
†Hieracium aurantiacum L.
†Hieracium pratense Tausch.
Onopordum Acanthium L.
†Polymnia canadensis L.
*Polymnia uvidalia L.
Rudbeckia laciniata L.
*Prenanthes alba L.
*Senecio aureus L.
*Senecio Balsamitae Muhl.
Solidago arguta Ait.
†Solidago graminifolia (L.) Salisb.
*Solidago Houghtonii T. & G.
†Solidago latifolia L.
Solidago neglecta T. & G.
*Solidago ohioensis Riddell
*Solidago patula Muhl.
†Solidago rugosa Mill.
†Solidago canadensis L.
Solidago uliginosa Nutt.
Solidago ulmifolia Muhl.
*Solidago uniligulata (DC) Porter
†Tussilago Farfara L.

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The foregoing list contains a surprisingly large number of plants marked "not previously reported" (†), many of which are quite common in and around any swamp region in this general latitude. Reasons for this fact are not difficult to find. The flora of the swamp is constantly changing. Not only have some of the characteristic plants been disappearing, but many other forms have migrated inward from the surrounding mesophytic border. It is also likely that this border area, formerly a part of the swamp, has now been more fully studied than heretofore. Moreover, it is obvious that former reports have paid major attention to the unusual and rare plants, without attempting a complete list,—as is well illustrated by the next list.

RARER PLANTS OF BERGEN SWAMP REPORTED BY BAXTER AND HOUSE (1924)
(An asterisk marks the species collected by the present writer. The nomenclature follows Gray's Manual.)

Aspidium cristatum
*Aspidium Goldianum
Phegopteris Dryopteris
Equisetum fluviatile
*Lycopodium lucidulum
*Lycopodium obscurum
*Taxus canadensis
*Picea mariana (? M.S.B.)
Scheuchzeria palustris
Panicum Lindheimeri
Sphenopholis palustris
Carex aurea
Carex Bebbii
Carex bromoides
*Carex cristata
*Carex flava
*Carex granularis
*Carex leptalea
Carex pedunculata
Carex Pseudo-Cyperus
Carex rosea
Carex trisperma
*Cladium mariscoides
Eleocharis acuminata
Rhynchospora alba
Calla palustris
Juncus brachycephalus
Juncus Dudleyi
*Clintonia borealis
Smilacina trifolia
Cypripedium acaule
*Cypripedium parviflorum
var. pubescens
Epipactis pubescens
Habenaria blephariglottis
Habenaria bracteata
*Habenaria dilatata
Habenaria orbiculata
*Pogonia ophioglossoides
Stellaria longifolia
*Sarracenia purpurea
*Drosera rotundifolia
Dalibarda repens
Mitella nuda
*Parnassia caroliniana
Saxifraga pennsylvanica
Rhus Vernix
*Acer spicatum
*Rhamnus alnifolia
Hypericum boreale
*Viola nephrophylla
Pyrola asarifolia
var. incarnata
Pyrola chlorantha
Pyrola secunda
*Lonicera oblongifolia
*Lobelia Kalmii
Aster juncus
Solidago uliginosa
Solidago ulmifolia
*Solidago uniligulata

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It is possible that some of the plants reported by Baxter and House have disappeared since their list was compiled. This selected list will be of value in comparing the Bergen flora with that of other regions. The species here mentioned are rarely found elsewhere in northwestern New York.

In addition to the above list Baxter and House (1924) give the following species as being reported from Bergen Swamp by Paine in his "Catalogue of the Plants of Oneida County" (N.Y.) with the statement that they are "common" within the swamp but found sparingly elsewhere. As in the other lists an asterisk marks the species collected by the present writer.

Arethusa bulbosa
Carex polygama
*Carex Crawei
*Carex eburnea
Carex gynocrates
Carex Oederi
Carex sterilis
Carex vaginata
Calopogon pulchellus
Calypso bulbosa
*Comandra umbellata
*Cypripedium candidum
Eleocharis rostellata
Galium boreale
Juncus acuminatus
Juncus balticus
*Juniperus horizontalis
Liparis Loeselii
Microstylis monophyllos
Myrica carolinensis
*Phragmites communis
*Potentilla fruticosa
*Rhynchospora capillacea
*Salix candida
*Scirpus caespitosus
Scirpus pauciflorus
Scirpus Torreyi
*Senecio Balsamitae
*Solidago Houghtonii
*Solidago ohioense
*Tofieldia glutinosa
*Triglochin maritima
Triglochin palustre
*Valeriana uliginosa

Here again the changes which have taken place within the swamp since Paine compiled his "Catalogue," in the latter part of the nineteenth century, have undoubtedly removed or at least made rare some of the species which at that time were found. The present writer, however, wishes to emphasize the fact that he has not attempted to make an exhaustive collection, that work being only one part of the purpose of the present study.

Specific Zones and Associations of the Swamp

In discussing the specific zones and associations of the swamp the method of presentation will be as follows:

a. Location of the association within the swamp, and a list of its dominant and subdominant plants.

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b. Characteristics of the association as to physiognomy, plant types, soil types, and soil acidity.

c. History of the association, so far as it can be determined, and its interpretation *as a unit.*

d. Relative position of the association in the succession of the swamp as it stands today.

Only those plants which have been observed by the writer will be used in the following lists. Those species which are marked with the letter *b* are either boreal, or at least much more common in latitudes farther north than Bergen Swamp.

It must be remembered that the formations mentioned do not stand as distinct and easily separable units, there being many transitional stages between them. In this way the classification of the associations is more or less artificial, although necessary to a clear presentation.

The Open Marl Association

(Figure 3; Plates I, II)

The open marl association in the swamp is not continuous, but consists of several beds varying in size from small areas of only a few hundred square feet to large tracts several acres in extent. In general these beds are located in the center of the swamp, but some of them extend for considerable distances toward its margins.

Dominant Species of the Open Marl Association are:

b. Triglochin maritima
b. Deschampsia caespitosa
Phragmites communis
b. Carex Crawei
b. Carex flava
Cladium mariscoides
Zygadenus chloranthus
b. Juniperus horizontalis
b. Scirpus caespitosus

Major Sub-dominant Species are:

Deschampsia flexuosa
b. Rhynchospora capillacea
Cypripedium parviflorum var. pubescens
Cypripedium candidum
Lobelia Kalmii
Senecio Balsamitae
b. Parnassia caroliniana
Solidago ohioense

The open marl association at first appears to be rather barren of plant life. There are patches of varying size, usually small, upon which there is no vegetation whatsoever, but in general the grasses and sedges have succeeded in covering the marl. The vegetation is all low growing and consequently it is possible to see the entire

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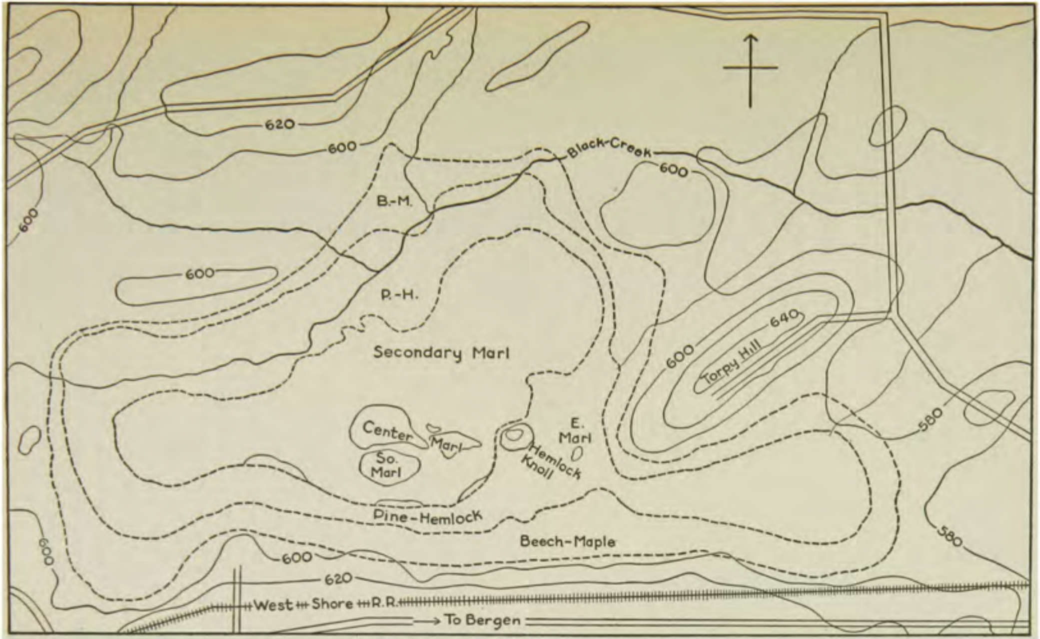

Figure 3. DETAILS OF VEGETATIVE ZONES IN BERGEN SWAMP

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extent of the association from any given point within it. Due to the formation of the marl beds by aqueous vegetation, primarily Chara, they are almost perfectly flat and without contours. The open marl associations occupy the lowest points in the swamp and consequently in the spring and early summer they are frequently covered with water several inches deep. The soil in this association is almost pure marl, which in dry weather becomes desiccated and powdery.

The plant types of the open marl association are almost entirely grasses and sedges. A few other plant groups are represented here, such as the Compositae, Pinaceae, Rosaceae, and Orchidaceae, but in general the association will support only the grasses and sedges. All the plants in this association are low and hardy, and are of a type that will thrive on a distinctly alkaline soil. The pH readings made in this association are given in Table I.

TABLE I

pH Readings in the Open Marl Association

	pH	Location	Date
1.	7.80	First Marl Bed west of Hemlock Knoll; bare marl	7/2/33
2.	7.53	Same as No. 1. Pure marl 6″ below surface	7/3/33
3.	7.20	Same as No. 2	7/3/33
4.	7.20	East Marl Bed; pure marl	7/19/33
5.	7.13	East Marl Bed; pure marl	7/19/33
6.	7.20	Central Marl Bed; pure marl	7/19/33
7.	7.20	Inner end, West Trail	8/5/33

Average = 7.32 Average Dev. = ± 0.19

These readings are quite uniform and the average deviation is consequently low. They indicate that the open marl beds are pronouncedly alkaline; and practically all the plants mentioned as dominants and sub-dominants are characteristic of a marly alkaline soil and find here their natural habitat.

The open marl association is undoubtedly one of the early associations in the succession following the open water associations. Even today there are seasons of the year when the open marl is flooded with water. The open marl associations at one time surrounded an open water association, and through the deposition of lime from Chara and other plants marl was deposited and the ground level raised above the water table. This process naturally led to the encroachment of the open marl upon the water, until at the

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present time the marl occupies the center of the swamp, and now represents the earliest successional stage present in the swamp. The open marl is destined to be the first to disappear from the swamp by the encroachment of the zones which now stand adjacent to it. This association at Bergen Swamp is unquestionably a transitional association from the aquatic to the terrestrial, and as it stands today it is in its last stages of existence.

The Secondary Marl Zone

The secondary marl zone surrounds each of the open marl associations, and stands between the open marl and the pine-hemlock zone (Plates II, III). It varies in width from only a few feet in those places where the pine-hemlock closely approaches the open marl, to several hundred feet; and in some portions of the swamp it has advanced to such an extent that it has completely obliterated the open marl. The secondary marl is also to be found as islands in the center of some of the open marl associations.

Dominant Species of this zone are:

b. Larix laricina
Gaylussacia baccata
b. Ledum groenlandicum
b. Lonicera oblongifolia
Typha latifolia
Cypripedium candidum
b. Salix candida
Cladium mariscoides
b. Potentilla fruticosa

Sub dominant Species are:

b. Juniperus horizontalis
Carex hystericina
Scirpus cyperinus
b. Scirpus caespitosus
b. Parnassia caroliniana
b. Chamaedaphne calyculata
b. Vaccinium pennsylvanicum
Solidago ohioense
b. Habenaria dilatata

The secondary marl zone shows a distinctly taller growth and is more terrestrial in appearance than the open marl. It is largely composed of shrubs and bushes which grow to a height of ten and twelve feet in many places. The only trees present in the zone are dwarfed Larix laricina and an occasional Thuja occidentalis which has advanced in from the pine-hemlock zone. The vegetation is quite thick, making the zone almost inaccessible except on well cleared trails (over Figure 3). The under vegetation is composed largely of grasses, a few orchids and other herbaceous plants, but is almost entirely devoid of ferns. The soil is firmer and dryer than in the open marl, but it still is marl, although highly admixed with

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humus and in some portions entirely covered with a thin layer of humus. There are practically no mosses present in the zone due to the alkalinity of the soil. As in the open marl this zone is practically level since it rests on a soil formed by the deposition of aquatic vegetation. Wherever there is any distinct rise in the ground level there is a change in the nature of the vegetation. The secondary marl, in spite of its almost level surface, is not subject to such complete coverings of water in the spring as is the open marl, due in part to the increased absorptive power of the soil resulting from the presence of the humus, and also to the slightly higher level of the ground resulting from the superficial humus formation.

The pH readings of the soil in the secondary marl are given in the following table.

TABLE II

pH Readings in the Secondary Marl Zone

	pH	Location	Date
1.	6.52	Rain puddle west of Hemlock Knoll	7/3/33
2.	6.94	20 yds. west of Hemlock Knoll; thin humus layer on marl.	7/3/33
3.	7.25	Central Marl Bed,—secondary	7/12/33
4.	7.27	East Marl Bed,—soil under Potentilla	7/12/33
5.	7.12	South Marl Bed,—secondary	8/5/33
6.	7.20	South Marl Bed,—by stream	8/5/33
	Average = 7.05	Average Dev. = ± 0.21	

These pH readings for the secondary marl zone are fairly constant, the only two which deviate radically being the first and second. The first reading was made from the soil in a rain puddle and the writer is at a loss to explain its strong acidity. The reading may possibly be the result of error in determination, or of contamination of the sample; but as three determinations were made from the same sample and all three were in approximate agreement, the average for the three is given in the table. In the second reading, which is just slightly acidic, it is possible that the presence of a very definite humus layer composed of some decaying coniferous vegetation on top of the marl where the sample was taken may have affected the acidity. The remaining readings in the table are considerably less alkaline on the average than those made in the open marl. This decrease in alkalinity is due to a change in the type of the plants growing in the zone, i. e., the inclusion of some coniferous species such as Larix and Juniperus, which are frequent in occurrence and decidedly acid when in decay, and to the accumulation of some

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humus in and on the marl. The average of the pH readings for the zone, 7.05, closely approaches the neutral point and shows an intermediate state in soil acidity between the decidedly alkaline open marl and the pine-hemlock zone which is distinctly acidic.

The development of the secondary marl may be explained as follows: The open marl association, having established itself, naturally deposited some humus resulting from the decay of the vegetation which it supported. This humus served to reduce to some extent the strong alkalinity of the pure marl and to prepare a soil hospitable to those plants characteristic of a habitat not so alkaline. It is known (Taylor 1928) that pioneer plants in a succession are seldom capable of providing for their own perpetuation, that the change of vegetation is normally toward the climax condition, which for the region in which the Bergen Swamp is located is a beech-maple-birch forest (Bray 1930). Further, it is an accepted principle (Clements 1905) that each stage in succession ultimately reacts in such a way as to produce physical and chemical changes more or less unfavorable to its own permanence. In view of these facts it could hardly be expected that the open marl association would be permanent to any degree. Through its own activity the open marl has provided a suitable habitat for the shrubs and other plants characteristic of the secondary marl zone. As a result this zone has succeeded the open marl as rapidly as the open marl has provided the right habitat; the primary requirements for the succession being a reduction in the alkalinity of the soil and the presence of some humus.

The Sphagnum Association

Within the swamp there is a considerable amount of Sphagnum growing in almost a pure stand, there being only a few other plants consistently associated with it. The sphagnum growth within the swamp is minor in comparison with the other type plants to be found; but since it has a soil type distinctly different from that in other zones and associations, and because these sphagnum growths are not consistently to be related to any of the other zones, the writer has chosen to consider them as a separate association. Although the sphagnum areas are arranged in a more or less concentric manner they do not, at least now, show a definite zonal relation to any of the other zones, sometimes even being found growing upon them.

The Sphagnum association is in general located outside the secondary marl zone, but in separate areas as just described. In no places

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are these sphagnum areas more than thirty feet in diameter. Since the sphagnum is not continuous the pine-hemlock, which is the next distinct zone, frequently comes in direct contact with the secondary marl. It is interesting to note that small hummocks of Sphagnum occur on the secondary marl (Plate IV), and even out on the pure marl where they seem to thrive almost as well as back in the more protected regions outside the secondary marl and nearer to the acidic soil of the pine-hemlock zone. The only species occurring with sufficient frequency in the Sphagnum association to warrant mention are Drosera rotundifolia, Sarracenia purpurea, Gaylussacia baccata, and Vaccinium pennsylvanicum.

No pH readings of the soil in this association were made, but in view of the findings of other workers (Moore and Taylor 1921, Kurz 1928) we may safely assume that the soil is acidic.

Whether or not the sphagnum has played an important rôle in the filling in of the swamp is a question. It is known that Sphagnum is an important factor in the filling in of an acid bog and that the presence of Sphagnum has a profound effect upon the acidity of the bog (Moore and Taylor 1921, Kurz 1928). MacMillan (1896) states that the occurrence of Sphagnum in a bog is a transitional step from the aquatic toward the climax condition, that it serves both to fill in the swamp and to form a suitable substrate for more terrestrial plants, and finally that the location of the sphagnum within the swamp depends upon the depth of water beneath it; the sphagnum naturally occurring only in shallow places as along the shore line or over old reefs. The Bergen Swamp presents two factors which might explain its filling in: the occurrence of considerable marl and the occurrence of Sphagnum. It is known that some bogs left by glaciation are filled in by peat and some by marl, and that the majority of those showing marl action are located in Indiana, Michigan, Wisconsin and Minnesota (Thiel 1930). Since there are such extensive marl beds at Bergen, because marl soil is distinctly alkaline and sphagnum soil is acidic (Kurz 1928), and finally because no reference can be found reporting simultaneous filling in of any swamp by marl and sphagnum activity, the writer prefers to interpret the occurrence of the sphagnum in Bergen Swamp as incidental. Whether the sphagnum has played an important rôle in the filling in of the swamp is another question which will be considered later, but it might be said at this point that there is evidence that such has been the case. In the succession of the

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swamp some habitats have been produced which have been well adapted to sphagnum growth and consequently the sphagnum has appeared in those regions. It so happens that most of the proper habitats have been just inside the pine-hemlock zone.

In view of the above, the Sphagnum associations as they occur in the swamp today are interpreted as incidental associations having no definite part in the general succession of the swamp.

The Pine-Hemlock Zone

(Plates II, III)

In spite of the fact that the white pine, Pinus Strobus, is intolerant of the shade of other trees and consequently cannot encroach upon the hemlock growth, and also that it is incapable of existing with the beech and maple growth (Taylor 1928), the writer has chosen to group the pine and hemlock together as one zone because in all other characteristics they are very similar and they are so close to each other in the swamp as to form a regular zone. The pine-hemlock zone is located just outside the secondary marl zone and completely surrounds it. As the form of the secondary marl is affected by the irregularity of the open marl beds so also is the pine-hemlock zone irregular, though not to the same degree as the secondary marl; but in no place does a complete absence of the pine-hemlock zone allow the beech-maple growth to come into direct contact with the secondary marl zone.

Dominant plants in the Pine-Hemlock Zone are:

b. Taxus canadensis
b. Pinus Strobus
b. Thuja occidentalis
b. Tsuga canadensis
b. Coptis trifolia
b. Cornus canadensis
b. Chamaedaphne calyculata
b. Chiogenes hispidula
b. Gaultheria procumbens
Mitchella repens

Sub-dominant Plants in this Zone are:

b. Clintonia borealis
b. Maianthemum canadense
b. Drosera rotundifolia
b. Ledum groenlandicum
Rhododendron nudiflorum
b. Linnaea borealis
var. americana
b. Lonicera oblongifolia
Viburnum acerifolium

In general appearance the pine-hemlock zone is heavily wooded with conifers and possesses a low floor vegetation. There are considerable variations from this condition and in some portions of the zone young trees from the beech-maple zone have begun to appear

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and with them has come a light sprinkling of the beech-maple floor vegetation. The floor vegetation of the zone is dominated by ericaceous plants which seem to thrive on the underlying soil (Bird 1923). In the regions bordering on the secondary marl the coniferous trees are younger and smaller than elsewhere and they increase in size back in the older portions of the zone. It is at the inner margin and the outer limits of the zone that the pine occurs in dominant frequency, while in the middle regions the hemlock is dominant. Except in such areas as that found at Hemlock Knoll where there is a considerable rise in the ground level, the soil is quite moist. The zone is almost level but is interrupted at intervals by knolls and slight rises, and at these points the zone vegetation is more advanced than in the other portions. As the soil here is comparatively dry and other factors are favorable, some of the beech-maple vegetation is beginning to appear. The zone is further characterized by heavy shade and a low floor vegetation except at the inner and outer margins where, in the first case, the trees are small and low and where, in the second case, the shrubs characteristic of the beech-maple have begun to appear and make a heavy and impassable ground vegetation.

The soil in the zone is decidedly acidic (Table III) and in appearance varies from a black muck in the more moist portions to a dark, sandy and brownish soil in the dryer parts. All readings reported in Table III were made in portions of the swamp which were undoubtedly pine-hemlock and represent the characteristic pH for that zone. The average deviation of $\pm$ 0.66 is relatively large, but may be explained by those readings which are exceptionally low and represent extreme conditions within the zone. The acidity of the zone is caused primarily by the vegetation growing upon it (Bird 1921) and, to a limited extent, by the poor drainage afforded some parts of the zone (Cowles and Schwitalla 1923, Waterman 1926). Ericaceous plants are exceptionally well adapted to the acid condition caused by the rotting of the coniferous vegetation and consequently are frequent in occurrence (Bird 1921). Working on a similar bog at Mt. Desert Island, Maine, Moore and Taylor (1921) found that the humus under the coniferous growth had a pH of 6.0, and Taylor (1928) found that hemlock soil was quite acid, pH 6.2, while a sample from a rotting hemlock log gave a reading of 4.6, which coincides with readings 4 and 5 above. This information indicates that the acid condition in the pine-hemlock zone is of com-

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mon occurrence, that the acidity is caused largely by the rotting of the coniferous vegetation, and that the acid soil of the zone makes a good habitat for the ericaceous plants so prevalent in the floor vegetation.

TABLE III

pH Readings in the Pine-Hemlock Zone

	pH	Location	Date
1.	8.35	Hemlock Knoll, sandy soil	7/3/33
2.	7.45	20 yds. south of Hemlock Knoll, muck	7/3/33
3.	6.52	Hemlock Knoll, sandy muck on south side	7/3/33
4.	4.49	Hemlock Knoll, soil by rotting log	7/3/33
5.	4.75	Hemlock Knoll, portion of rotting log	7/3/33
6.	6.85	Hemlock Knoll, soil 6″ below surface	7/3/33
7.	5.67	Center Trail, ½ way in, spongy soil	7/12/33
8.	6.95	Center Trail, ½ way in, spongy soil	7/12/33
9.	6.69	East of Hemlock Knoll, Arbor Vitae thicket	7/12/33
10.	5.50	Center Trail, ⅔ way in, Coptis, Cornus	7/12/33
11.	6.18	West of East Marl Bed, zone climax	7/12/33
12.	5.40	East Trail, ½ way in, under moss	7/19/33
13.	7.03	50 yds. north of East Marl Bed	7/19/33
14.	5.53	50 yds. north of East Marl Bed	7/19/33
15.	7.60	50 yds. east of East Marl Bed, 6″ depth	7/19/33
16.	5.67	100 yds. north of Hemlock Knoll	7/19/33
17.	6.18	Hemlock Knoll, gray soil	8/1/33
18.	5.74	½ way in East Trail, rotting stump	8/1/33
19.	6.35	½ way in East Trail, Pinus, Coptis, Cornus	8/1/33
20.	6.69	South of Hemlock Knoll, pine stump	8/5/33
21.	5.35	Hemlock Knoll, rotting log	8/5/33
	Average = 6.12	Average Dev. = ± 0.68	

The pine-hemlock zone represents the first forest vegetation to advance into the swamp and the first definitely humus soil to occur. The secondary marl zone supported no trees, with the possible exception of the dwarfed Larix laricina, and had primarily a mineral soil. The Sphagnum association, which in some portions of the swamp is a forerunner of the pine-hemlock zone, does have a humus soil, but no trees of any kind are present. The pine-hemlock is a transitional zone, not representing the climax vegetation of the region, and being incapable of providing for its own perpetuation.

In the successional filling in of the swamp, the marl vegetation deposited a fairly firm substrate and produced sufficient humus to allow invasion by some pioneer plants which could not be supported on a strongly alkaline soil. In some places Sphagnum appeared and

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as a result there occurred an acid condition in the soil (Kurz 1928). In addition to these changes in the nature of the soil, the marl zones in their older portions created a somewhat drier condition than had formerly existed, and these factors together made a habitat favorable for the pine-hemlock vegetation. This zone, as it succeeded into the localities formerly occupied by the marl and Sphagnum vegetation, formed a definitely acidic humus soil. The result of this change, brought about by the decay of coniferous vegetation, was that the other plants, not capable of pioneering in a sweet soil, as is the pine, but fond of an acid soil and associated with the pine and hemlock, came in with the association. Most of the plants of this type are herbaceous and form the floor vegetation of the zone.

Starting from the outside of the swamp, the pine-hemlock zone has followed the secondary marl in the general succession and stands today well toward the middle of the swamp, surrounding the marl beds and constantly encroaching upon them. It is logical to assume that in time the pine-hemlock zone will completely obliterate the marl beds. In such a position it would form the center association of the swamp. In the succession we find that the pine sometimes precedes the hemlock. It is seldom found mixed with it, as it is incapable of growing under the hemlock on account of the shade. In other places the pine follows the hemlock, standing thus between the latter and the beech-maple vegetation.

The pine-hemlock zone is thus interpreted as a transitional zone in the general succession and filling in of the swamp. It stands between the pioneer marl vegetation and the climax beech-maple zone, represents the first forest vegetation in the succession, and is found on the first true humus soil occurring in the swamp.

The Beech-Maple Zone

This zone, the vegetation of which is the climax for the region of the country in which the Bergen Swamp is located (Bray 1930), forms a complete ring around the outside of the swamp, entirely enclosing the pine-hemlock zone (Figure 3). It follows closely the general shape of the swamp as originally determined by glacial activity. The beech-maple zone is thus the outside zone of the swamp, and in some places fuses directly with the surrounding natural climax forest vegetation, while in other places it is interrupted by clearings and farm land.

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Dominant Plants of the Beech-Maple Zone are:

Aspidium marginale
Aspidium spinulosum
var. intermedia
Cystopteris bulbifera
Pteris aquilina
Smilacina racemosa
Smilacina stellata
Trillium grandiflorum
b. Populus tremuloides
b. Betula lutea
Fagus grandifolia
Claytonia virginica
Hepatica triloba
Acer rubrum
Acer spicatum
Circaea alpina
Circaea intermedia
Circaea lutetiana
Eupatorium perfoliatum
b. Solidago graminifolia

Subdominant Plants of this Zone are:

Adiantum pedatum
Aspidium Thelypteris
Onoclea sensibilis
Arisaema triphyllum
Erythronium americanum
Populus alba
Carpinus caroliniana
Fraxinus americana
Bidens cornua
Quercus alba
Quercus rubra
Ulmus americana
Sanguinaria canadensis
Mitella diphylla
Amelanchier canadensis
Rhus typhina
Rhamnus alnifolia
Viola conspersa
Cornus circinata
b. Ostrya virginiana
b. Caltha palustris
Eupatorium purpureum
Prenanthes alba
Solidago serotina

With a few minor exceptions the physiognomy of the beech-maple zone is the same as that of the regular beech-maple climax forest. The soil is more moist than it is in the climax forest and consequently the growth of ferns and mosses is quite luxuriant. The vegetation is varied, there being an abundance of herbaceous, shrub and tree growth; and this vegetation is permanent as it is the climax vegetation of the region. At intervals there are to be found remnants of the pine-hemlock vegetation which formerly occupied the area, such as small growths of Taxus canadensis and occasionally some herbaceous forms. A more common remnant of the pine-hemlock vegetation is Tsuga canadensis, which stands high and usually above the surrounding beech-maple growth. These trees are lingering and growing old in the beech-maple which has moved in around them. The occurrence of these hemlocks is not of sufficient frequency to affect the type of the zone, and it is a question whether or not they will be able to perpetuate themselves.

The region now occupied by the beech-maple zone was undoubtedly at one time open swamp. This is proved by the occurrence at

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the outermost reaches of the zone of a minor growth of Thuja occidentalis and Typha latifolia (Plate IV). Such forms as these do not grow in normal forests of beech-maple. Their occurrence at the outside of the swamp may be explained only by the assumption that the original limits of the swamp included the localities now occupied by these plants, and that their persistence there is possibly due to poor drainage and other sufficiently favorable environmental factors.

The soil within the beech-maple zone is still slightly acidic (Table IV), somewhat drier than that of the pine-hemlock zone, and nowhere does it have the sandy quality of the soil of the pine-hemlock. The abundant humus at the surface is composed almost entirely of decaying deciduous vegetation. In Table IV the readings vary from pH 5.00 to pH 7.69 and consequently the average deviation, ± 0.72, is high. It is possible, however, to derive from the table a general idea as to the soil acidity within the zone, and more than 50% of the readings are on the alkaline side of the neutral point. This would indicate that the vegetation of the beech-maple zone has a decided effect as a neutralizing agent on the acid soil left by the pine-hemlock. The fact that the average of the readings, 6.45,

TABLE IV

pH Readings of the Beech-Maple Zone

	pH	Location	Date
1.	5.84	Southern edge, moist soil	7/12/33
2.	6.69	100 yds. from south edge, black soil	7/12/33
3.	6.85	50 yds. from south edge, black soil	7/19/33
4.	7.60	Entrance, east trail	7/19/33
5.	6.69	100 yds. south of Torpy Hill, dry soil	7/27/33
6.	7.37	South edge of Torpy Hill	7/27/33
7.	7.53	Clearing on Torpy Trail, black humus	7/27/33
8.	6.69	West end of Torpy Hill, gray soil	7/27/33
9.	7.20	Clearing on Torpy Trail, dry soil	7/27/33
10.	7.37	Torpy Hill, black humus	7/27/33
11.	7.37	Clearing on Torpy Hill, gray soil	7/27/33
12.	7.53	East Trail, ½ way in, whitish soil	8/1/33
13.	5.00	East Trail, ½ way in	8/1/33
14.	7.37	Southeast edge, moist soil	8/1/33
15.	6.75	Southeast edge	8/1/33
16.	7.20	South edge, black soil	8/5/33
17.	7.12	Center Trail, ½ way in	8/5/33
18.	6.93	South edge	8/5/33

Average = 6.45 Average Dev. = ± 0.72

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is acidic would indicate that the acid soil of the pine-hemlock zone, upon which the beech-maple is constantly encroaching, has not as yet been completely neutralized by the invading vegetation. This process of neutralization is very likely being retarded by the presence of remnants of the pine-hemlock vegetation still persisting.

The history of the beech-maple zone, when compared with that of the other zones and associations which have preceded it, is comparatively simple. Before it was possible for the vegetation of the beech-maple zone to appear within the swamp several environmental factors had to become adjusted in such a manner as to form a suitable habitat for the zone. The more important adjustments in the environment were a firm substrate, sufficient drainage, and a terrestrial humus soil not as distinctly acid as that found in the pine-hemlock zone. Practically all these conditions were supplied by the zones preceding the beech-maple in the succession of the swamp. In the older portions of the pine-hemlock zone the only major factor not suitable for the beech-maple invasion was the excessive acidity of the soil. For every vegetational zone there are those plants which will act as pioneers (Taylor 1928). These pioneers are seldom capable of providing for their own perpetuation, are seldom found growing in the true climax forest, but will repeat themselves in a given locality until they have created conditions sufficiently favorable for the establishment of the new type to which they really belong. Among the more important pioneers for the beech-maple vegetation are Populus tremuloides, Pteris aquilina, Solidago rugosa, Aspidium marginale, and the like. These pioneer plants have been able to encroach on the soil of the pine-hemlock zone and reduce the acidity sufficiently to allow the beech-maple vegetation to come in on a soil formerly unsuited for it. It is perfectly natural that the climax forest of the surrounding country should commence to advance into the swamp as soon as conditions were even partially favorable for its entrance, and this is exactly what has happened in the case of the beech-maple zone.

This zone, having commenced its succession into the swamp, will undoubtedly continue its advance until it ultimately reaches the center of the swamp and covers the entire area with true climax forest. The zone as it stands today around the edge of the swamp is not a pure beech-maple growth in the climax state. It has not been within the limits of the swamp long enough to thoroughly establish itself as such, and there are still some aspects of the zone which

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are quite transitional. On the other hand the zone is sufficiently climactic to indicate beyond doubt that the filling in of the swamp by a climax vegetation has finally set in, and no further type of vegetation will succeed it as the climax of the region has already begun its invasion. The presence of the beech-maple zone thus marks the beginning of the end of the Bergen Swamp.

History and Development of the Swamp

Origin of the Depression

One of the primary requirements for the swamp condition is a depression in the surface of the land in which the drainage is not complete. Regarding the origin of such a depression it is only possible to theorize, since we have no direct evidence as to its exact cause. It is possible that the general east-west depression running from Lake Erie to the Genesee River, in which Bergen Swamp rests, is correlated with the underlying rock formations. This depression, as already mentioned, is directly above the soft Salina shales, and these shales are bounded on the north by the hard Niagara limestones and on the south by the equally hard Onondaga limestones (Figure 1). It is easy to imagine that during the ice erosion of the glacial periods more rock was removed from the comparatively soft shales than from the harder neighboring limestones and that a trough was thus formed over the Salina shales. This will explain the general east-west depression, but not the limited depression in which Bergen Swamp itself rests.

Transeau (1903) states that frequently those swamps found on glacial deposit, as is Bergen Swamp, are due to the breaking off of a portion of the glacier as it retreated. Such a detached ice cake would remain for some time after the departure of the main glacier and prevent the deposition of silts and like material from the post-glacial lake. When such a portion of the glacier finally melted it would leave a depression in the area it formerly occupied, due to the deposition of silts around its resting place but not under it. Bray (1930), on the other hand, is of the opinion that many of the depressions on glacial till now occupied by swamps and bogs have been caused by deposition of till and débris in such a manner as to prevent proper drainage of an otherwise well-drained depression. These two ideas are not so different in final analysis as they may at first appear. The breaking off of a portion of a glacier,

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as suggested by Transeau, would prevent deposition of glacial débris in the one locality in which it was forming the depression and allow deposition in the surrounding areas, thus preventing drainage of the depression. Bergen Swamp is located on glacial till and we may be reasonably sure that it was through some activity of the glacier that the depression it occupies was formed. We are unable to tell the exact cause of the depression and the two theories presented above are merely suggestions as to how the original swamp bed may have been formed.

Causes of the Filling in of the Depression

Any poorly drained depression, such as that which must have been left at Bergen following the glacier, would naturally become filled with water and form a pond or small lake. We know, as has previously been stated, that for every given region there is a climax vegetation, that toward such a vegetation all portions of a given region will tend to progress, and finally that for the region in which Bergen Swamp is located the climax vegetation is a beech-maple forest. Any changes necessary to produce the climax vegetation are of course possible only if the environmental factors are of such a nature that it is possible to modify them and produce a habitat suitable for the climax. As Bray (1930) pointedly states, it is obvious that there must be intermediate stages in the succession from the original non-climax habitat to the climax. Clements (1905) indicates that the reproduction of a plant in a locality gives rise to a potential, if not an actual association. Now the permanence of such an association is dependent upon the immobility of the individuals which compose it. Hence it is perfectly natural to assume that those aquatic and semi-aquatic transitional individuals which normally would occur around and in such a pond would by their own reproduction tend to form an association or zone which, not being climactic, would be transitional in the general succession and filling in process. Since the individuals in these associations possess a high degree of mobility, as has been formerly demonstrated, they were capable of migrating into the open water and acting as agents in its filling in. Following these primary associations came the secondary more terrestrial zones. The fact that such an invasion of one zone after another has occurred indicates that the environmental factors have not been such as to prevent the gradual creation

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of a habitat suitable to the climax forest. The causes of the filling in of the swamp are, then, that the open water flora does not represent the climax vegetation of the region, that the environmental factors have been susceptible of modification, and finally that there have been transitional forms and associations of sufficient variety to be capable of modifying these factors and preparing a climax habitat.

Stages in the Filling in of the Depression

In order to derive a complete picture of the stages of swamp succession we shall compare the known steps at Bergen with those found by workers in other localities. As has already been stated, the order of associations and zones now present in the swamp is: open marl, secondary marl, Sphagnum, Pine-Hemlock, and finally the near-climax Beech-Maple zone. We have, at Bergen, the last half of the story of the succession; of what has gone before, we can only surmise.

Bray (1930) gives the order in which he believes that plant types succeed into a lake as follows:

1. Floating plants (microscopic, visible algae, duckweeds)
2. Wholly submerged vegetation (pondweeds, etc.)
3. Floating-leaf plants (water lilies, etc.)
4. Marsh plants (sedges, bulrushes, cattails, etc.)
5. Marsh-meadow plants (sedges, grasses)
6. Marsh-shrub or swamp-shrub (willows, alders, etc.)
7. Swamp-forest (black ash, red maple)
8. Climax forest (maple, beech, birch, pine, hemlock, etc.)

Of the stages mentioned by Bray we have at Bergen stages four to eight inclusive, although they are not in exactly the same groupings as Bray indicates.

Transeau (1905) states that in the normal succession of the bogs of the Huron River Valley the order is: bog sedge, bog shrub, and then conifer. This is exactly the condition at Bergen, under different descriptive terms.

Cowles (1901) in his report on Chicago and vicinity states that following the advance of the shrubs into the swamp the first trees to appear are Larix laricina and Thuja occidentalis, and that closely following comes Pinus Strobus. Under these coniferous trees he reports the dominant herbs as being Coptis trifolia, Cornus canadensis, etc. Again we report an identical condition at Bergen Swamp.

Transeau (1903) in discussing the bogs of northern Michigan

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gives a gradation of vegetation from the center of a swamp to the outside. His list of plants is too long to present in full, but his groupings of plant types are as follows:

1. Aquatic Society,—Potamogeton, Nymphaea, Castalia.
2. Cattail-Dulichium Society,—Typha, Phragmites, etc.
3. Cassandra Society,—Chamaedaphne, Kalmia, Ledum, etc.
4. Shrub and young tree Society,—Aronia, Ilex, Larix.
5. Conifer Society,—Larix, Pinus, Thuja, etc.
6. Climax forest,—Acer, Betula, etc.

At Bergen all the above stages of succession with the exception of the first are found and they occur in this same order.

Waterman (1926) lists the stages found in the swamps of northern Illinois as follows:

1. Free-floating aquatics.
2. Aquatics whose roots are in the soil at the bottom.
3. Aquatics whose roots are in the soil at the bottom and which extend above the surface.
4. Plants which grow in very shallow water, as the sedges.
5. Water-loving shrubs.
6. Swamp trees.
7. Vegetation of the surrounding uplands (climax).

The condition at Bergen is very similar to this plan, presenting the stages four to seven inclusive.

From a comparison of the above plans of succession with the stages now existing at Bergen, it is obvious that this swamp now presents the last portion of a perfectly normal program of succession, a program which in general is followed in practically the same manner in all swamps. As to what stages have gone before the earliest ones now existent at Bergen we can only theorize. The close similarity of the present stages to those reported by Waterman, Transeau, and Bray leads us to think that very likely Bergen Swamp had earlier stages likewise similar to those reported by these other workers. The occurrence of considerable marl in the swamp indicates the former presence of aquatic vegetation. We are therefore safe in believing that in the past history of the swamp, as well as in its present condition, a normal pattern of succession has been followed.

Bray (1930) states that the swamp forest, which merges into the climax and in many cases is identical with it, is the result of a relatively high water table due to poor drainage. He states further that peat and marl are characteristic of such regions where the drain-

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age is poor and that conifers, as Larix, Pinus and Tsuga, are quite characteristic of such a forest. Bray lists two main effects of such a swamp forest upon the substratum:

1. Rapid and unequal elevation of the land, due to the spreading rather than the penetration of the roots.
2. Dead trees accentuating effect No. 1, both No. 1 and No. 2 tending to bring about a rapid change in the soil environment.

The swamp forest now existent at Bergen has, in the main, the characteristics just mentioned. The forest floor is quite uneven, the roots spread over the soil rather than penetrating it, the forest is primarily coniferous and follows the peat and marl in the general succession, these features being closely similar to those reported from other localities.

Causes of the Sequence of Stages

It has already been made clear that the filling in of the swamp has taken place in definite stages, each with its typical floral structure and each to be designated as a zone or formation; that this filling in has of necessity been gradual; and that its success has been due largely to pioneer plants. The next question is why the stages follow each other in the succession of the swamp in the order we have observed.

It is a well-known ecological principle that within any given locality the vegetational structure will change unless that structure is the climax for that locality. As Taylor (1928) points out this change may be in either of two possible directions: toward the climax, which is the more normal condition, or away from it, as in the case of fire. It is difficult to tell by mere observation in what direction the succession is moving, but in the absence of marks of serious fires, storms, or cuttings, and for other reasons mentioned above it is safe to assume that progress is being made toward the climax vegetation.

Clements (1905) states that this process of invasion, or succession, depends upon the ability of some plants to enter a region of a certain character different from that from which they have come. If these two regions are in close approximation, as is the case at Bergen, the invasion is continuous. It is obvious that no change in the vegetational make-up of a locality could ever come about if the above were not true; it would be impossible to reach the climax condition if there were not those plants which were capable of

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leaving one environment and entering another, and by their presence in the second environment so modify it as to eventually bring it into close likeness to the first. Such plants are the pioneers. It is obvious that no plant, no matter how active a pioneer it might be, could be capable of modifying the open water condition, which was originally present within the swamp, directly into the climax beech-maple forest. This process must be accomplished by a series of pioneers, which will create environments suitable for their own types of vegetation and will be merely transitional. When one such step has been taken a second will follow, and so on until the climax is reached.

So far the question of the cause of the arrangement of the successive stages in the filling in process has been approached almost entirely as being a function of the activities of various pioneer plants. It is quite possible that there are some physical factors which are important in causing this succession and which function entirely independently of the vegetation of the region. Shaw (1902) is inclined to place these physical factors first in importance. The main physical factor which Shaw mentions is the deposition of silts from the drainage of the surrounding territory. It is undoubtedly true that in regions where the contour of the land is such as to cause active drainage into the swamp such a factor might be important. In so far as the writer has been able to determine there are, today, no physical factors of any major importance functioning in the succession at Bergen. As far as the past is concerned no definite statement can be made, but it is very doubtful whether such physical factors have played any important rôle in the history of this swamp.

A final question on this point is why the climax remains the climax and does not lead to something else. Taylor (1928) answers the question by pointing out that the beech-maple climax, such as is found at Bergen, reacts in the forest in such a manner as to give it its main characteristics. The beech and maple are very tolerant of shade and consequently the young trees are not suppressed by the shade from the dense canopy created by the older trees: i. e., these trees are self-perpetuating in their own shade. This shade further serves to keep out the seedlings of other trees and plants which might disrupt the climax condition. The only factor which will allow outside plants to get into the beech-maple climax forest is light, and in the climax at Bergen there are several light spots

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where timbering has been going on. In such places pioneer plants have rushed in, plants not characteristic of the climax, but plants which will make for an environment suitable to the climax. Hence the climax is permanent because it is able to endure in the environment created by itself and this environment keeps out non-climax plants.

As a fitting conclusion to this discussion some of the laws of succession as set down by Clements (1905) might be mentioned. Clements states that the causation of succession is either the creation of a new habitat or the efficient change of an existing one. At Bergen both causes have operated. The new habitat was created by glacial activity, and was later modified by the activity of pioneer plants. The second law is that each stage in the succession reacts in such a manner as to make its own permanence more or less impossible, with the exception of the climax stage. Thirdly, stabilization is the normal tendency of all vegetation, and finally the pioneer plants are those plants in the closest proximity and possessing the greatest mobility. The initial pioneers in swamp succession are usually the algae and fungi. These laws have all been found operative in the succession at Bergen.

Certain Aspects of the Marl and Peat within the Swamp

Regarding the source of the marl, such as is found in the extensive and deep beds in Bergen Swamp, Bray (1930) says "the formation of the numerous and rather extensive marl beds in lake bottoms and in swamp soils built up under water is now ascribed largely to water vegetation; in part the blue green algae . . . and particularly to Chara and to a lesser degree to the Potamogetons, etc."

The action of Chara in the deposition of marl is described by Davis (1900) as follows: "We have in Chara a plant of relatively simple organization, able to grow in abundance under most conditions of light and soil which are unfavorable to more highly developed types, a chief agent in gathering and rendering insoluble calcium and other mineral salts brought into the lake . . . by springs, streams and seepage water. After precipitation is accomplished and the plant is dislodged or dies, it drifts ashore, where, after the decomposition and drying out of the relatively small amount of vegetable matter, the various erosive agents along the shore break up the encrusted chalky matter, and the finer fragments are carried into the deeper water and the coarser are left along the lines of wave action." This

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explanation seems plausible, especially when Bray indicates Chara as a very active plant in this process. At Bergen it is possible to find a small amount of Chara in a few of the more moist portions of the marl beds, but practically all deposition has ceased.*

Oosting (1933) does not attribute marl formation to any specific plant, but states that the filling in is due primarily to accumulations of marl and that "all borings in the filled areas showed, at depths of more than a few feet, a mere scattering of plant fragments appearing superficial to almost pure marl." This same condition was found existing at Bergen and will be commented upon later.

Thiel (1930) in a paper bearing directly upon the question of marl beds states that the marl is composed largely of $CaCO_3$ and that its hardness is dependent upon the degree of drainage in the region. These two factors were found to be in perfect accord with the conditions at Bergen. Thiel gives us some valuable information on the source of the lime for the formation of marl. He attributes it directly to the heterogeneous masses of clay, sand, boulders, and drift deposited upon an area of glaciation. Water percolates through this mass and carries the lime dissolved from the rocks and clay to the center of drainage,—the lake or pond. Thiel points out a nice correlation between the areas affected by glacial activity and those in which marl is deposited. Regarding the method of deposition he mentions three theories:

1. A direct chemical precipitation of $CaCO_3$ resulting from the release of CO_2 from $Ca(HCO_3)_2$, the loss of CO_2 being caused by a reduction in pressure and an increase in temperature as the underground water is released into the lake.
2. Mechanical precipitation as carried out by Chara and possibly some other algae.
3. Mechanical sedimentation.

It is quite possible that all three of these theories are based upon fact, but the writer is inclined to agree with Bray (1930) and Davis (1900) in believing that Chara is chiefly responsible for marl

*The active formation of marl by Chara is beautifully seen in Blue Pond, in the town of Wheatland, Monroe County, a few miles southeast of Bergen. Here the Chara is piled in great masses near the shore, in all stages of disintegration. As late as sixty years ago the pond was partly fenced in to prevent cattle from being bogged down in the "quicksand." The open water is now surrounded by a wide border of totally bare marl, into which the sedge vegetation is encroaching.—(W. D. M.)

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deposition in swamps. The extensive and deep marl beds at Bergen need more than chemical precipitation or mechanical deposition to explain the large amounts of marl present.

All theories regarding the formation of marl agree that it was produced under aquatic conditions. It is logical to assume, therefore, that the region now occupied by marl beds at Bergen was formerly covered by open water. Now we also find at Bergen considerable Sphagnum growing upon the marl. In this connection Transeau (1905) states that as a result of his work on marl beds in Indiana and Michigan it is evident that the marl usually forms the substratum upon which the peat is later deposited, due to the fact that marl is formed by aquatic plants (Chara), and peat by swamp forms. In other words the aquatic stage, which would naturally precede the swamp stage, deposits the marl and through this action creates a habitat adverse to its own permanence (Clements 1905). This results in the formation of a swamp condition and at this time Sphagnum becomes active and forms peat over the marl. MacMillan (1896) considers the occurrence of muskeag (peat) a normal transitional step in the filling in of glacial depressions. He says that "typical muskeag may clearly be taken as an intermediate physiognomic distribution of vegetation linking the original open lake with the later glade or forest." The statements of these authors coincide perfectly with the conditions found at Bergen. The marl has been deposited primarily through the action of Chara, and represents the aquatic stage in the succession. Following the disappearance of the aquatic stage the swamp appeared and with it Sphagnum, which has formed the peat layer on the marl in many places. The arrangement found at Bergen is apparently quite normal.

On December 1, 1933, Dr. Merrell and the writer investigated the marl beds to a depth of two to three feet. It was discovered that the marl was interrupted at a depth of 20–25 inches by a layer of peat varying in thickness from three to eight inches. Below this peat layer pure marl was again found. Investigation at several points in the marl beds indicated that this condition was general throughout the swamp. Microscopic examination of this sub-marl peat indicated that it was an almost pure Sphagnum deposit. No exact explanation of this sub-marl peat layer can be offered at this time, but it seems logical that it may be the result of a sudden raising of the level of the water table in the swamp. It is possible that the water table was at one time lower than it is today and

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that the succession in the swamp had reached such a point that marl deposition had ceased and Sphagnum had formed on top of it to quite an extent. At this time a blocking of the drainage, or any other activity which might suddenly raise the water table would re-create aquatic conditions over the sphagnum. As a result marl deposition would be resumed and consequently bury the sphagnum between two layers of marl. The writer offers this merely as a possible explanation of the condition existing.

The idea of a change in the level of the water table as just presented is again offered as a possible explanation of a second curious condition found. On some of the open marl beds there are found a great many large dead trees, easily identified as arbor-vitaes (Thuja). These trees could not have started upon the open marl. It is thought that the marl was at one time covered by Sphagnum peat, upon which the trees gained a foothold. A subsequent rise of the water table would have drowned out the trees and left them standing as they are today. An alternative idea is that possibly a swamp fire in the peat may have burned it off, killing the trees, and exposing the marl. Some char-markings on the trees indicate that fire has occurred at some time in this part of the swamp. The writer makes no attempt to prove either of these two ideas.

Effects upon the Vegetation Caused by the Soil Left by the Glacier

In a discussion of the stages of succession within the swamp it is important to consider the soil and its possible effects upon the vegetational composition of zones present. The glacial till, which through subsequent erosion formed the soil of the region, has no effect upon the vegetation of Bergen Swamp because this vegetation is supported entirely upon the humus formed by the decay of former vegetation. Even the vegetation outside the swamp which does grow upon the glacial till is not affected because the till was so heterogeneous and evenly mixed that a uniform soil has resulted. The underlying sedimentary rocks have no effect upon the vegetation because, with the exception of small outcrops, they are entirely covered by glacial débris (Beckwith and Macauley 1894). The only noticeable effect of the soil upon the vegetation is that in the central portion of the swamp some of the peat soils of the Sphagnum and Pine-Hemlock zones seem to be comparatively cool, possibly as a result of a high rate of evaporation from their surfaces, and this

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coolness seems to create a condition quite satisfactory for some plants which are boreal. This idea is suggested by Bray (1930), and the writer is convinced that it is in effect at Bergen Swamp.

In the foregoing paragraphs we have considered the history of Bergen Swamp in so far as it has been possible to tell anything of its past. The present status of the swamp has been discussed earlier in the paper. For the future of the swamp we can only say that if left to its natural development it will in time become stabilized as a climax forest, which at Bergen would be of the beech-maple type.

On the Boreal Nature of Bergen Swamp

Evidences of Boreality

Since no weather observations were made at Bergen Swamp, it is impossible to compare the swamp itself with the various surrounding regions as to climate. It being safe to assume, however, that the general weather conditions of the swamp, with the possible exception of temperature, are approximately the same as those at Rochester, 23 miles distant, the weather reports at Rochester (Vanderpool 1933) may be used as a basis for a general comparison with other portions of the country.

Using the U.S.D.A. Report for 1932, Vanderpool gives us the following information regarding the climatic conditions at Rochester. Table V, based on records for the last 103 years, gives the mean monthly and annual temperatures.

TABLE V

Mean Monthly and Annual Temperatures, Rochester, N. Y.

January	25.1°F	May	56.4	September	61.8
February	24.4	June	62.2	October	49.4
March	32.6	July	71.0	November	38.9
April	44.6	August	68.6	December	28.6
		Annual	47.0		

The average date for the last killing frost in the spring is April 29, and the average date for the first killing frost in the autumn is October 20.

The monthly and annual precipitation records, Table VI, from the same source, are adequate for the purpose of a general description. This rainfall record, the writer believes, is almost directly applicable to Bergen Swamp.

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TABLE VI

Mean Monthly and Annual Precipitation, Rochester, N. Y.

January	2.59″	May	3.01	September	2.78
February	2.40	June	3.10	October	2.91
March	2.64	July	3.13	November	2.67
April	2.47	August	2.78	December	2.62
		Annual	33.10		

According to Vanderpool Rochester has a frostless season which averages 153 days in duration. The figures in Table VII, from Livingston and Shreve (1921) will orient the Rochester region in respect to other general localities.

TABLE VII

Length of Average Frostless Season

New Hampshire	131 days	Ohio (north)	163 days
Vermont	132	Indiana (north)	163
Maine	135	Massachusetts	163
Wisconsin	136	Illinois	165
Minnesota	138	Pennsylvania	162
Michigan	147	New Jersey	177
New York	154	Delaware	181
Connecticut	158	Rhode Island	197

The frostless season, as an index of climatic conditions, would indicate that the climate of Rochester was in general similar to that of the state as a whole, and also to that of Michigan, northern Ohio, northern Indiana, and Massachusetts.

The above information is given for two reasons, first to make clear the climatic conditions of the general region in which Bergen Swamp is located, and second to indicate to what general regions the Rochester climate is similar and with what regions it differs and in what respects these differences are expressed. The information presented in the first part of the section may give some idea of the climate in the swamp itself.

Vegetational Aspects

The comparison of the vegetation of Bergen Swamp with that of general regions will depend upon the distribution of swamps which are similar to Bergen and would consequently have a like vegetation, and also upon the distribution of those regions in which the climax vegetation is similar to the typical vegetation found

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at Bergen. It must be remembered that, while the climax vegetation now encroaching upon Bergen Swamp is the Beech-Maple forest, the typical swamp vegetation is that found in the Pine-Hemlock, Sphagnum and marl zones.

Transeau (1903) states that the maximum occurrence of the typical bog which he describes, and which is very similar to Bergen, is an area extending from the Mackenzie basin to the Atlantic, and lying in general to the north of a line passing through northern Minnesota, Wisconsin and Michigan, across Ontario to Kingston, across northern New York, Vermont, New Hampshire and Maine, and thence easterly to Newfoundland. He speaks of a secondary band of swamp occurrence south of this area which runs as far south as Chicago, Detroit, Buffalo, Scranton, and New York.

This information would indicate that the general territory occupied by the swamps of which Bergen is a type is located well to the north of New York State. An indication that Bergen Swamp is very similar to the "typical swamp" upon which Transeau has based the boundaries mentioned above is seen in the fact that of the fifteen species which he reports as being especially typical of the boreal swamp, we report 70% from Bergen, most of them occurring in abundance.

Livingston and Shreve (1921), speaking of the northern evergreen mesophytic forest, state that it occupies all alpine regions, portions of the Pacific coast to the north, northern Minnesota, Wisconsin and Michigan, and from northern Maine to the south along the Alleghenies as far south as North Carolina. They report as type species of this forest Pinus Strobus, Larix laricina, Picea mariana, Picea canadensis, Thuja occidentalis, Tilia americana and Acer saccharum. All of these, with the exception of Picea mariana, are reported in abundance from Bergen. They also report Cornus canadensis as being one of the most typical herbs of this northern transcontinental range, and again we report it as abundant in Bergen. In Figure 4 the dotted line marks the southernmost distribution of Cornus canadensis, showing clearly that the principal occurrence of Cornus canadensis lies well to the north of western New York.

Campbell (1926), in speaking of the vegetation of northern Maine and the adjacent islands, says that it is distinctly northern and in some cases almost subarctic. He continues his description by stating that "an undergrowth of such boreal plants as Linnaea borealis, Cornus canadensis and Coptis trifolia is characteristic."

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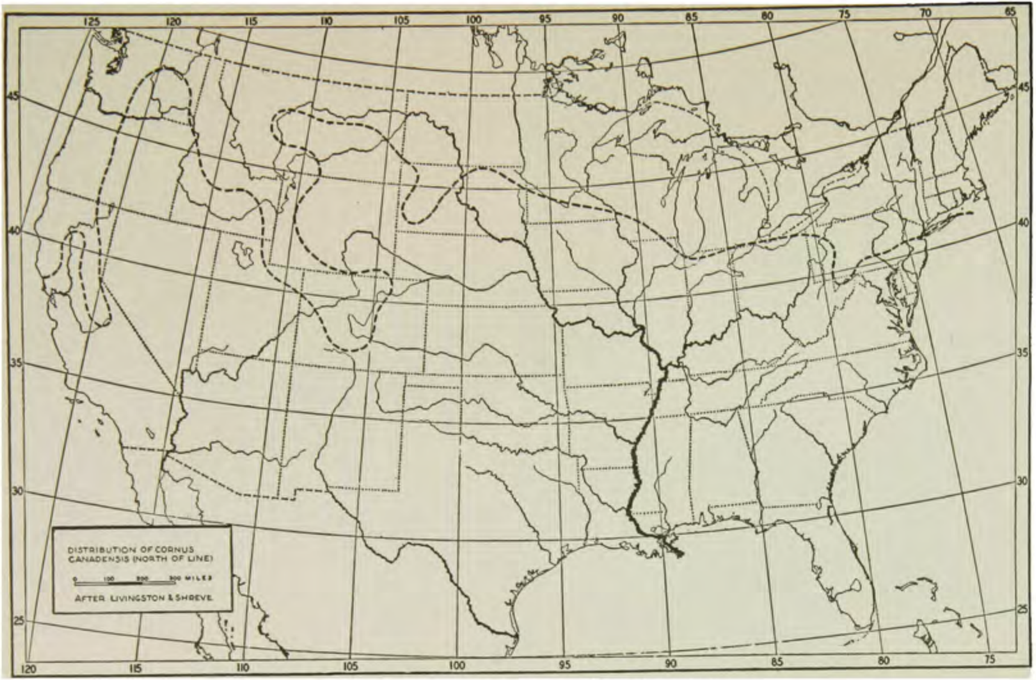

Figure 4. DISTRIBUTION OF CORNUS CANADENSIS

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The fact that he mentions these species as "boreal," that they occur in abundance in Bergen, and that the region of which he is speaking, Maine, is decidedly cooler than New York, as reported above, would seem to indicate that Bergen Swamp is distinctly boreal in relation to its surrounding vegetation.

Eaton (1909), in discussing the climate of western New York, says that the northeastern corner of Genesee County is decidedly in the Canadian climatic zone. Bergen Swamp occupies a large portion of this corner of the county and it is undoubtedly the swamp to which he is referring. Bray (1930), in mentioning this Canadian zone, says that it is the southernmost and most valuable part of the boreal conifer vegetation and describes its extent as being Maine, New Hampshire, south along the Alleghenies, and the southern part of Canada. Of the 22 species which Bray lists as being especially typical of the Canadian zone we report 60% from Bergen, and of the sixteen he gives for the Canadian Transitional zone there are 68% occurring in the swamp. These facts, together with those mentioned above, point very strongly to the decidedly boreal nature of the vegetation in Bergen Swamp. Comparison of the location of these boreal vegetations, aside from that of Bergen, shows a nice correlation with the climatic factors mentioned in the first part of this section.

Comparison of the Swamp with Specific Localities

In order to substantiate the general idea that Bergen Swamp is boreal, as mentioned above, the following comparisons with specific localities are listed. In all cases comparisons are based upon species actually collected within the swamp by the writer. Plant lists are not given because they would not materially add to the value of this phase of our study and because they are too large and cumbersome to handle efficiently at this point.

Rowlee (1897), studying the bogs of Oswego County, New York, reported 54 species as being especially typical of that region. At Bergen we report 65% of those reported by Rowlee, a percentage which would indicate that the bogs of the two regions were quite similar in character, as might be expected from their geographical proximity.

From a glacial moraine bog located in the Allegheny State Park in the southern part of this state, House and Alexander (1927) report a list of 70 typical species of which we report 62% at Bergen.

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The bog reported is similar to Bergen and probably boreal, even though some distance to the south, because of the elevation of the region it occupies.

Taylor (1828) reports 108 species from the entire Allegheny State Park and from Bergen we report 50% of his list. Taylor states that some of the species reported are typical of the vegetation to the south and it is possible that for this reason our correlation is low.

In reference to a bog on Mazuma Dome, Rigg (1922b) states that the bog is 6000 feet above sea level and decidedly alpine in nature. Of his list we report 80% from Bergen Swamp.

Cooper (1913) reports 27 species as especially typical of the vegetation of Isle Royale in Lake Superior, and of that number we report 68%.

MacMillan (1892) reports 200 species from the swamps and bogs of Minnesota, and of this list we report 58% from Bergen.

Transeau (1905) gives a list of 106 species from the bogs of the Huron River Valley in Michigan. Of his list 58% occur in Bergen Swamp. Again Transeau (1903) in his report on the swamps of northern Michigan presents a list of 52 species, of which we have 63% at Bergen. These two comparisons indicate that Bergen Swamp resembles the bogs of northern Michigan more than it does those of the southern part, the Huron river being located in the extreme southeast corner of the state.

Reference at this point to the plant lists given under the discussion of the specific zones and associations of the swamp will strengthen the argument for the boreal nature of the swamp. In those lists the boreal species are indicated by the letter *b*. It is interesting to note that the percentage of boreal species is high in the associations which are not climactic and are considered boreal, whereas in the beech-maple, which is climactic, the percentage of boreal species is quite low.

The percentages listed above may at first appear to be low, but when it is remembered that in nearly all cases, including Bergen Swamp, the lists were not complete, it will become evident that the percentages, in most cases, represent higher correlations than would be indicated by their numerical values. This fact will become more evident when we compare the vegetation at Bergen with that of Spruce Mountain, West Virginia, as reported by Core (1929) and find that the correlation value has dropped to 40%.

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The comparisons presented above indicate rather strongly that the Bergen Swamp is boreal in nature, especially when compared with the vegetation of the region in which it is located. The climatic factors show that the general region surrounding the swamp is perfectly normal; and yet when the vegetation of the swamp is compared with that of the Canadian zone there is a high degree of correlation, indicating that Bergen Swamp is a "little island of boreal vegetation" representing the Canadian zone and located in the transitional zone of western New York State.

Theories Regarding the Boreal Nature of the Swamp

The theoretical causes of the boreal condition in swamps and bogs, such as that at Bergen, will be discussed in the next paragraph, while at this time we mention briefly the one outstanding theory regarding this boreal nature of bogs. This theory is that the soil in these bogs has a lower temperature than that in the surrounding regions. Transeau (1905) has found this to be the case in his investigations of the bogs of the Huron River Valley. He is of the opinion that this cold soil has a very definite effect upon the natural selection of the plants struggling to occupy the bog and that only those plants best fitted for such a cold soil are successful in invasion. For this reason, he claims, the vegetation of these bogs is typically boreal since the boreal plants are best adapted to invade such a soil. Working his argument backwards we might reason that the occurrence of boreal species in Bergen Swamp indicated a comparatively cold soil. On the same question Bray (1930) states that "certainly it is a common experience that bog waters are cold;" and further regarding the bogs of New York State he mentions that in every case there is a predominance of boreal species and that the bog is a "boreal island." It is obvious that if the bog waters are cold the soil will likewise be cold, and hence we have a probable explanation of the occurrence of so many boreal plants. No completely satisfactory reason has yet been given as to why the bog water and the bog soil should be cold in comparison with the surrounding territory, although Bray believes that the rapid evaporation from Sphagnum peat and similar soft soils in the swamp serves materially to reduce the temperature of the soil. It is clear, then, that the main theory of the boreal nature of these bogs is that the soil and soil water are comparatively cold and hence form a better habitat

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for boreal plants than for those of the climax vegetation of the surrounding regions.

Causes of the Boreal Condition of the Swamp

Bray and Transeau thus present very similar and satisfactory explanations of the boreal condition as it exists in such swamps as Bergen. Other theories have been presented by various workers, most of which are modifications of those offered by Bray and Transeau.

Bray makes the following additional statements: that at the advent of the glacier the present floristic make-up of the country was in existence, with the present types of adaptations in effect and with the vegetation segregated into floral zones much as they are today. He then points out that the glacial invasion destroyed the floral cover of New York State and that the species existent in the state were either forced to migrate to the south or were exterminated. He continues that the present floristic make-up of the state has been derived from the vegetation to the south at the time of the glacial retreat; and that the New York species as well as those from farther north, having been forced southward by the advancing glacier, migrated north again following its retreat and reoccupied the regions they had formerly inhabited. This northward migration of the plants was, of course, possible only as the climate became milder with the retreat of the glacier. It is normal to assume that the boreal species came back first and were followed by the transitional and austral vegetations. This migration was subject to the same ecological rules as were mentioned earlier in the paper.

Transeau (1903) presents the same idea and in addition makes the very interesting speculation that during the duration of the glacial invasion the bog species had the same position in relation to the ice lobe as they now have in relation to the timber line. Regarding the postglacial northward migration Transeau says "With the renewal of a milder climate and consequent recession of the glacier the plant societies would gradually spread . . . and generally northward. The bog and tundra types would be the first to push into the barren ground left by the retreating ice. In the small glacial depressions where the absence of wave action would favor littoral vegetation, the bog plants would become firmly estab-

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lished." Transeau attributes the continuance of these bog plant societies in the poorly drained depressions to the following factors:

1. The lower temperatures prevailing in the bogs.
2. The sterile nature of the substratum.
3. The completeness with which the substratum is occupied by bog plants (preventing other invasion).*

Transeau concludes from his study of the bogs that these boreal habitats, which are relics of early postglacial times, are due to the favorable low temperatures of the undrained depressions.

The above explanation of how the boreal vegetation came to occur in the swamps and bogs, such as Bergen, when the surrounding vegetation is far from boreal, seems to be quite satisfactory. In brief it may be stated that the glacier, as it moved south, either exterminated all the vegetation in its path or drove it south; the vegetation south of the glacier bearing the same relation to the glacier as it now bears to the timber line. During its invasion the glacier created the depressions now occupied by the swamps. As the glacier retreated the vegetation naturally migrated to the north to occupy the barren ground left by the glacier, the boreal types coming first. Finally the boreal plants in their migration northward found in the depressions left by the glacier suitable habitats and became well established in those places and have remained there ever since. These plants have remained in the depressions in spite of the development of a transitional and partially austral vegetation in the surrounding regions because the habitat has been especially well suited to their ecological needs. The writer is satisfied that some process similar to that just described is responsible for the boreal vegetation at Bergen Swamp.

Summary

1. Bergen Swamp has been described as to its geology, soil types, and general physical features and it has been found to be normal in every respect.

2. The flora of the swamp, in so far as possible, has been studied and a list of those species collected and identified, combined with a list of species formerly reported from the swamp.

3. The type associations within the swamp have been described as to their floral structure, position in the succession, soil acidity,

*Parentheses the writer's.

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and history within the swamp. The floral structure of the associations is perfectly normal, and the succession within the swamp today is in the order of open marl, secondary marl, Sphagnum, pine-hemlock, and beech-maple zones. The soil acidity readings indicate that the marl zones are pronouncedly alkaline, the pine-hemlock zone is decidedly acidic and the beech-maple zone is nearly neutral. No explanation of the relation between soil acidity and plant types is offered, although certain plants are noted as being characteristic of soils of limited acidity.

4. The history and development of the swamp has been discussed. The depression in which the swamp rests is ascribed to glacial activity and the cause of the filling in is thought to be the tendency of every region to move toward stabilization in the climax type of vegetation. The succession in the filling in is attributed to pioneer plants which act to modify the soil and create habitats favorable for the next step in succession.

5. The occurrence of sub-marl peat has been mentioned and no explanation has been offered, although an idea that secondary inundation has caused its being covered by marl has been suggested.

6. The idea that the soils left by the glacier might have had some effect upon the vegetation in the swamp has been considered and the conclusion reached that no such effects are visible.

7. Evidences of the boreal nature of the swamp have been presented; these evidences being based upon climatic factors, vegetational comparison of the swamp with both general areas and specific localities, and the theories and findings as presented by other workers. The results of these comparisons indicate that the Bergen Swamp is, in fact, a "boreal island" located in the temperate climate.

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