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THE PINNACLE HILLS

OR

THE ROCHESTER KAME-MORAINE

BY

HERMAN L. FAIRCHILD

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CONTENTS

INTRODUCTION; HISTORICAL

The singular range of hills at the south border of the city of Rochester is the conspicuous relic of the most dramatic episode in the later geologic history of the region. The hills are the product of the great ice-cap, or continental glacier, which only yesterday, in relative time, buried this area. After millions of years of mild climate had prevailed over the continent some slight variation in climate changed the rainfall of eastern Canada to snow; and the accumulation of tens of thousands of years of snowfall made the Quebec ice-field, which overspread all of New York, New England and the Great Lakes area.

This slowly spreading ice-sheet gathered up from the surface of the invaded territory an immense quantity of rock-rubbish, which it distributed over the land on the southward, or piled at the melting border of the glacier. The most southerly accumulation, known as the "terminal moraine," lies chiefly in Pennsylvania. The Pinnacle range is a part of one of the later lines of deposition marking a pause and readvance in the recession of the ice front. It is, speaking correctly, a recessional or retreatal moraine, built at the southern edge of the waning ice-sheet while the latter yet overspread the site of Rochester and all of the northern land. The Pinnacle Hills are part of the Albion-Rochester moraine, the most northerly well defined moraine in the western end of the State.

The "Pinnacle" is the highest and the central point of the range of hills, and lacking a better name the whole line of hills has been called the Pinnacle Hills. Rising abruptly from the fairly smooth plain on which the city stands, this stretch of hills is the bold, upstanding topographic feature of the Rochester district. Only two other physiographic features about Rochester can compare with the range for size and interest. These are the Rochester Canyon of the Genesee River, and the Irondequoit Valley, the latter being the ancient or Pre-Glacial channel of the river.

Not only are the Pinnacle Hills the only hills about Rochester, and the highest and most conspicuous ground within many miles of the city, but they constitute the most striking, interesting and legible record of the Glacial Period found in this region.

Being the only conspicuous elevations found in the Rochester district the hills must have been recognized early in the settlement of the city. In an old deed, of year 1829, (Book 16, page 353, County Clerk's Office) the summit is called "Mount Monroe." But in O'Reilly's History of Rochester, 1838, the "Pinnacle" is casually mentioned as if commonly known by that name.

The earliest mention in geologic literature appears to be in James Hall's Second Annual Report of the Fourth Geological District (Assembly Document No. 200, 1838) page 328, where he says: "The highest of these hills in Monroe County is the Pinnacle, about two miles east of Rochester." Correctly, the direction is a few degrees east of south from the center of the young city, the "Four Corners," and much higher grounds lies in the southeast part of the county.

In Hall's classic volume on the Fourth District, 1843, page 323, he gives a sketch by Dr. G. W. Boyd of a section "about two miles east of Rochester," apparently the cutting at Monroe Avenue. The rough sketch and the comments are not correct. Glacial science did not then exist.

Some description or comments by Chester Dewey would be interesting, but nothing has been found.

With their conspicuous position, unusual topography and complex structure, these hills had not escaped the notice of glacial geologists. But the earliest recognition of their nature was by Professor Charles R. Dryer, in his article, "The glacial geology of the Irondequoit region" (No. 1 of the attached bibliography). He depicted the range in a sketch-map of the Irondequoit-Victor region, and devoted a paragraph of 14 lines, describing the hills as a "gigantic kame," which was a fairly correct diagnosis. His statement that the "lower half is composed of coarse gravel and the upper half of sand" is incorrect, when the whole range is considered.

Not until 1892–93 did anyone venture a detailed description or explanation of their origin. In August, 1892, the American Association for the Advancement of Science and the Geological Society of America met in Rochester. The geologists in attendance visited the range and discussed its formation briefly in Section E of the Association. At the December meeting of the Geological Society at Ottawa, Canada, Mr. Warren Upham read a paper describing these and other deposits of the region under the title "Eskers near Rochester, N. Y." This paper was published in the second volume of these Proceedings. (No. 2 of the bibliography.) In that paper Mr. Upham described the hills in some detail and concluded that the range was an *esker,* or deposit made in the bed of a glacial stream; "and that the esker was deposited in a deep ice-walled gorge, open above to the sky, eroded in the border of the ice-sheet by the melting action of the running water." (page 196.) Due to lack of topographic map and to inadequate study of the hills, this diagnosis was wrong. The deposits were not left as laggard deposits in the bed of an overloaded stream, but were built along the edge of the melting ice-sheet, as a typical frontal moraine.

In 1895 the writer published an article in the American Geologist (No. 3), proving that the range is a gravelly moraine ,or "kame-moraine." Excepting a sketch map of the district (figure 2 in this paper) the article had no illustrations.

The attached bibliographic list gives references to the later brief papers, or extracts, in print.

In several stretches of the range it has been deeply excavated for sand and gravel, and while this has revealed the structure of the deposits, as shown in the accompanying illustrations, it has unfortunately marred the form and beauty of the hills. In a few years some parts will be wholly destroyed, all the range will be occupied for residence or park purposes, and the interesting structures made by the glacial agencies will be lost to view. Hence it is desirable that the photographs taken during the past 30 years should be published as a permanent record of the form, composition, structure and origin of the Pinnacle Range.

The story of the Pinnacle Hills includes such complexity of geologic processes that it cannot be told as a continuous narrative, and the reader must therefore be prepared for some repetition. It involves the glacial history of the region previous to the time covered in "The Rochester Canyon," pages 1–55 of this Volume. These two papers, with those by Chadwick and Giles (9, 10), cover the Pleistocene history of Rochester and vicinity.

Glacial Terminology

The description of the Pinnacle Hills and the story of their making necessarily becomes a dissertation in glacial science. Like other sciences Glaciology has its own distinctive terminology, and for accuracy and conciseness in this writing many of the technical terms must be used. For the reader's convenience and general information the terms which will be used are defined in the following list.

Bowlder Clay. See Till.

Channel. The bed or path of a stream.

Crevasse. Fissures in the glacier, due to differential flow. With reference to the direction of ice-flow they may be longitudinal or transverse.

Debouchure. The termination or mouth of a stream. Debouchment.

Dip. The downward inclination of beds away from the horizontal plane.

Débris. Materials derived from the destruction or breaking-down of rocks. Includes a variety of special forms.

Detritus. Literally, materials derived from attrition or wear, but applied broadly to all rock materials carried by moving water; as bowlders, cobble, gravel, sand, silt or clay.

Drift. Strictly, any material which has been carried from its original place. Applied in geology to the rock-rubbish transported by glaciers or glacial streams. The term is a relic of the old theory of a century ago that the glacial deposits were brought down from the far north by imaginary floods, enormous debacles of water.

Drumlin. Masses of subglacial till, built up by the moving ice-sheet under unusual combination of mechanical conditions, when unable to carry further all its load of drift. Varying in form from domes to slender ridges; convex profiles; longer axis parallel to the ice movement. Word of Irish (Gaelic) origin, meaning a little ridge.

(See Bulletin 111 of New York State Museum.)

Englacial. Applied to the drift which was carried within the mass of the ice-sheet. See "till."

Esker. A term of Irish origin, applied to the ridges of water-laid materials, usually coarse, laid down in the beds of heavily loaded streams that drained the melting ice-sheet. Sometimes miles in length, and sometimes interrupted or forming a string of kames. Often terminating in a group of kames, to which the esker is related, as the feeding stream. In general they parallel the direction of flow of the ice-sheet. Perhaps some were laid down in ice-walled channels, open to the sky, but certainly most of them were built in tunnels at the bottom of the glacier. When the ice-walls melted the detritus crumbled to a ridge.

(See paper by Giles, No. 12.)

Fault. The structure produced by displacement, dislocation or shifting of rock masses, or any geologic deposits, along a plane of fracture.

Frontal Moraine. Any accumulation of glacial drift at the terminus of a valley (mountain or alpine) glacier, or at the margin of a continental ice-sheet. These may be "terminal," as the one formed at the maximum advance of the glacier; or "retreatal" or "recessional" when formed at lines of ice-front recession. The Pinnacle Moraine is retreatal. See "Moraine."

Glacial Lake. A water-body held up by the damming action of a glacier. Almost non-existent today. They formed in valleys or depressions which declined toward the ice front. (See Glacial waters in central New York, N. Y. State Museum, Bulletin, 127, 1909.)

Glacial Stream. A stream flowing from the melting glacier. See "ice-border drainage."

Glaciation. The work of glaciers, in general. Especially applied to the planed and striated surfaces of rocks, features peculiar to the action of moving land ice.

Glacier. A field or stream of ice, formed from snowfall in a region of perpetual snow, and moving down a slope or spreading by its own weight. Having peculiar structure due to the differential or unequal flow; and transporting rock-rubbish (drift). Classified as "valley," "alpine" or "mountain" when originating in mountains and flowing down valleys; "continental" when covering vast areas, like Greenland or Antarctica; and "piedmont," applied to the Malaspina glacier in Alaska, which is an ice-field fed by valley glaciers from the Mt. Saint Elias alps.

Ground Moraine. An old name for subglacial drift. See till.

Ice-Border Drainage. Stream-flow along the side or the front of a glacier. In the case of valley glaciers such flow is marginal. In New York such flow was along the front of the continental ice-sheet where the exposed land surface sloped toward the ice-front. In some cases these streams were large rivers. (See N. Y. State Museum Bulletins Nos. 105, 127, 160, 209–210.)

Ice-Laid Drift. Another name for "till."

Interlobate Moraine. Morainic deposit between two contiguous or colliding lobes of an ice-sheet. Type example is in Wisconsin. Very rare in the east.

Kame. A term of Scottish origin. Now applied to mounds, knolls or hills of water-laid drift. They are outwash from the glacier, built at mouths (debouchure) of glacial streams, and mostly into standing water. Of the nature of incipent deltas. Related to "eskers." See Kame areas in western New York. Jour. of Geol., Vol. 4, 1896, pp. 129–159.

Kame-Moraine. A moraine which is partly or largely, water-laid drift, or kame knolls. The Pinnacle Hills are example.

Kettle. Basins or bowls, or sometimes large and irregular depressions, due to the melting away of enclosed or buried blocks of ice which had become detached from the ragged ice margin.

Characteristic of morainal, and especially of kame, deposits. Must not be confused with "potholes," which are holes drilled in the rock beds of streams by eddies of water armed with hard stones.

See "Kettles in glacial-lake deltas." Jour. of Geol. Vol. 6, 1898, pp. 589–596; and paper No. 9.

Moraine. Masses of rock-rubbish accumulated at the edges of glaciers, by the work of either the ice or the glacial streams; that is to say, they may be both "till" and "kame." As regards position they are frontal, lateral, medial or interlobate. According to manner of accumulation they may be pushed, dumped, etc. In this region we have only the frontal variety.

Morainal Lake. A body of water held by the damming action of moraine drift. The tens of thousands of lakes and lakelets in the northern, glaciated, areas are properly called "drift-barrier" lakes.

Morainal Apron. A term formerly applied to the sandplains in front of some moraines. See "outwash."

Outwash. Detrital materials swept out of the melting glacier by the streams draining the ice. The term is loosely applied to the water as well as to the drift burden. Also called "overwash." It may be in the form of sandplains, of true deltas, or of kames; or it may be carried far down valleys as "valley train" drift.

Proglacial. Having position in front of a glacier, or beyond the ice margin.

Retreatal Moraine. One of the successive frontal moraines built during pauses, and frequently with readvance, in the waning and shrinking of the glacier. See "moraine."

Subglacial. Beneath the glacier, or held in the bottom portion of the ice. See "till."

Striae; Striations. Scratches, grooves or furrows produced on either bed-rock or the transported stones by the rubbing and grinding action of the moving land ice. Characteristic of glacial work.

Superglacial. Applied to the drift borne at or near the surface of the glacier. See "till."

Terminal Moraine. See "frontal moraine."

Till. Drift deposited directly by the ice. Unassorted rock material of all kinds and sizes. According to position in the glacier is classed as subglacial, englacial and superglacial. The more compact subglacial till was formerly called "bowlder-clay" and "ground-moraine."

Water-Laid Drift. Materials deposited by direct action of water. Usually more or less assorted in size, and stratified. Fragments are rounded by attrition in transportation. See "detritus."

Outline of the Glacial History

During the enormous length of time represented by the record contained in the rock strata of the globe, covering probably some hundreds of millions of years, the atmospheric conditions, or climatic factors, had considerable variation. Periods of low temperature and severe glaciation occurred in very ancient geologic time, and at long intervals down to the present. We are living in the latest cold period, called the Pleistocene, for glaciers are lingering in all quarters of the earth.

In Tertiary time, preceding the present cold period, the climate was mild, even in the polar regions. Then, through some causes not yet fully known, there appears to have been a slight fall in world temperature, perhaps accompanied by high land elevation in Canada. Excessive snow replaced rain in some regions, and eventually permanent fields of snow-ice formed in the district of heaviest snow fall, thus initiating the continental glaciers which invaded the northern United States. It should be realized that in cooler climates snow is as normal as rain, and that ice fields or glaciers are just as natural as lakes. But, what is important, the glaciers form on high ground where water could not stand. The lowering of our present average annual temperature a very few degrees would quite certainly cause another ice-cap in Quebec, adjacent to the path of the cyclonic storms which pass northeast down the St. Lawrence valley.

The Glacial Period of the present time, or Pleistocene, did not produce merely a single ice-sheet, but included a series of cold, or glacial, epochs with warm or mild interglacial epochs. It is believed that several ice-sheets successively invaded the region of the Great Lakes and the upper Mississippi Valley. The latest ice invasion, to which we are indebted for all the glacial features in New York had its center of snow accumulation in eastern Canada, and is called the Quebec glacier (formerly called Labradorian).

At its maximum development the Quebec ice-cap buried all of

New England, all the Great Lakes area and practically all of New York. The spreading flow of the ice-sheet over central and western New York was, in general, from the northeast; but the latest movement, of the thinner, marginal portion, was directed by the stronger topography, and the latest flow in the district of the Finger Lakes was parallel with the valleys.

The geologic effect of a glacier is partly erosional, but chiefly transportational. It rubs down some of the minor inequalities of the land surface, picks up loose materials, and thus incorporates great quantity of rock-rubbish. This transported drift must eventually be dropped at the terminus of the ice-sheet, and is sometimes amassed as frontal moraines.

The southernmost reach of the Quebec ice-sheet is marked in Pennsylvania by a belt of drift, known as the "Terminal Moraine." (See figure 1.) In some localities this has the form of ridges and knolls, similar to the Pinnacle Hills, but over most of the distance it is an indefinite, scattered deposit.

East and southeast of New England the ice-sheet pushed into the sea, and the terminal moraine lies beyond the marine shoreline. Along the north side of Long Island it forms the belt of hills which makes the backbone of the island. It crosses the Hudson Valley at the Narrows, south of the New York Bay, comprising the hills which make the constriction in the valley, on which are located the fortresses that guard the entrance to New York harbor. Across New Jersey the moraine passes northwestward, continuing across the northeast part of Pennsylvania to Salamanca, N. Y., and from there turns southwestward along the Allegany and Ohio valleys to southern Illinois; and then swings northwest.

Tens of thousands of years must have been required for the Quebec ice-sheet to creep down from the northland, with its pauses, retreats and readvances, due to variations of climate. After the long standstill at the terminal belt the removal of the ice-sheet must have been in a similar slow and hesitating manner. We may not properly speak of the "retreat" of the glacier, as the ice-body was always pushing southward. The front of the glacier receded or retreated when the wastage of the ice by melting exceeded the supply by the southward flow, and it readvanced when the flow exceeded the melting, thus producing long-period oscillations of the margin. The lines of heavier drift, the retreatal moraines, mark the longer or more persistent readvanced positions. In the southern part of New York the moraines are scattering and dis-

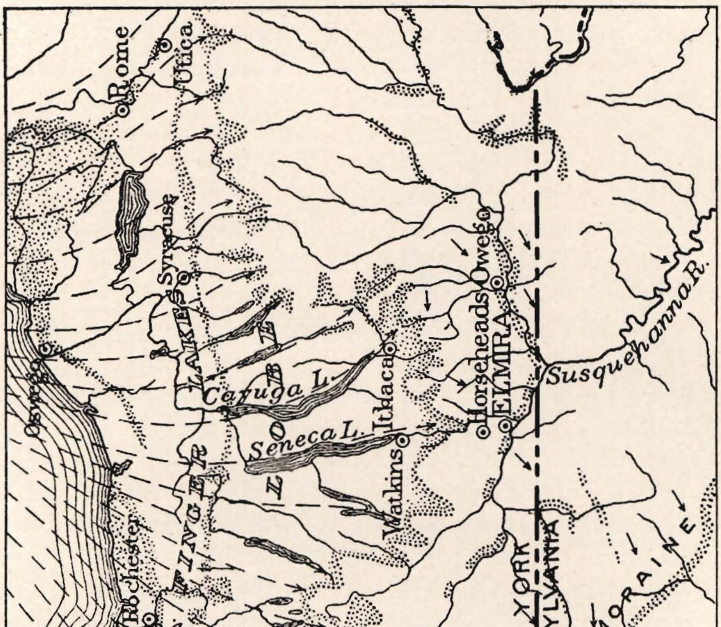


FIGURE 1. *Moraines in Central and Western New York*

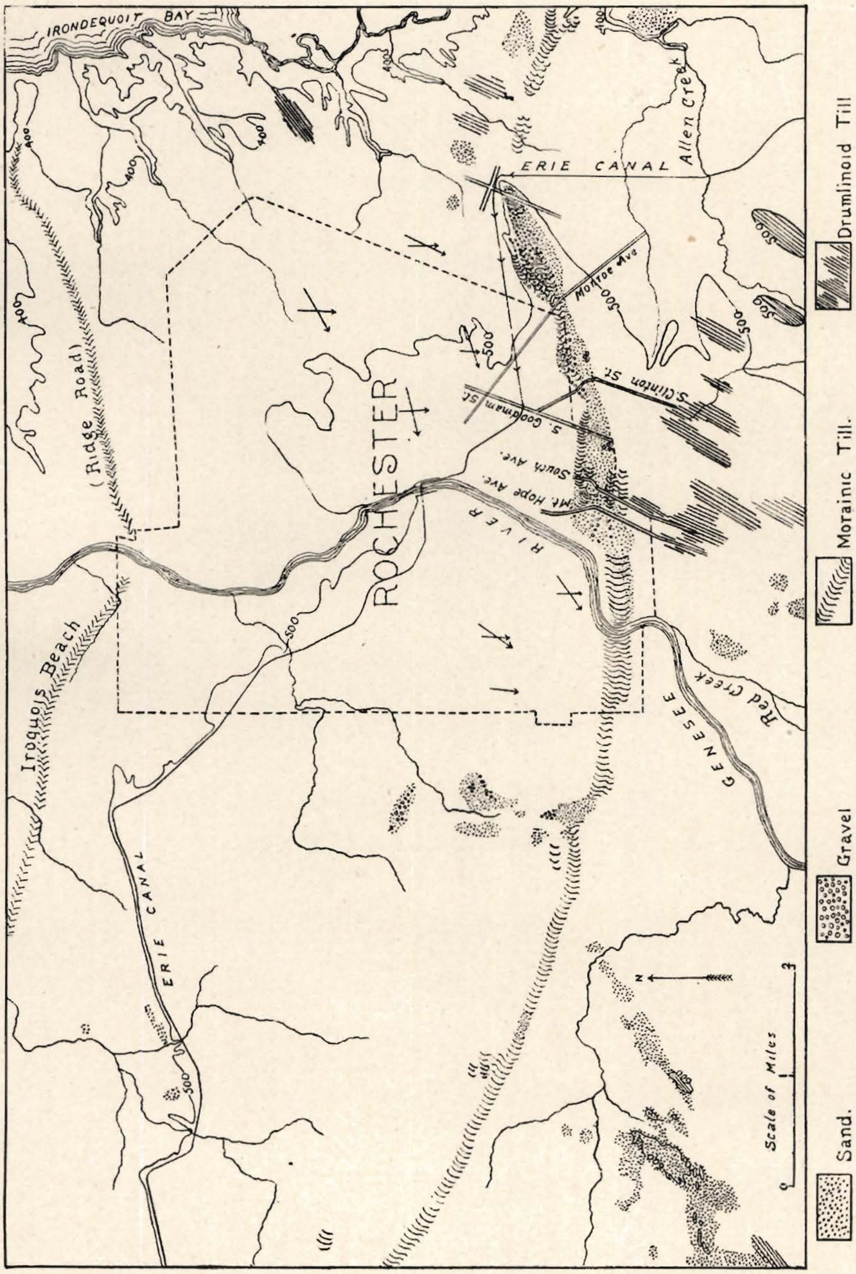


FIGURE 2. *The Pinnacle Hills; Albion-Rochester Moraine*
The arrows show directions of the glacial flow. The city boundary is that of 1895

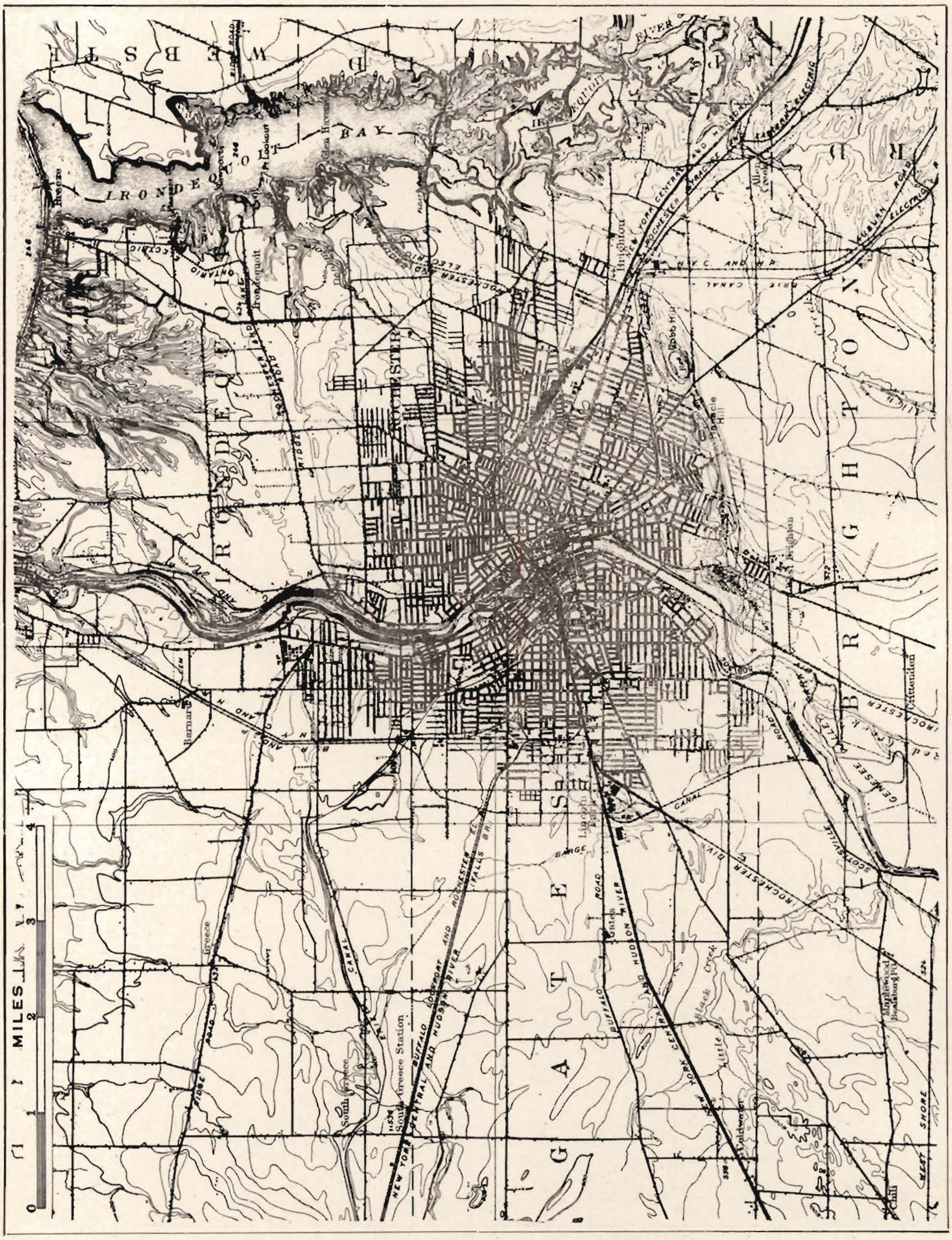


FIGURE 3. *Physiography of the Rochester District*
From the Rochester topographic sheet

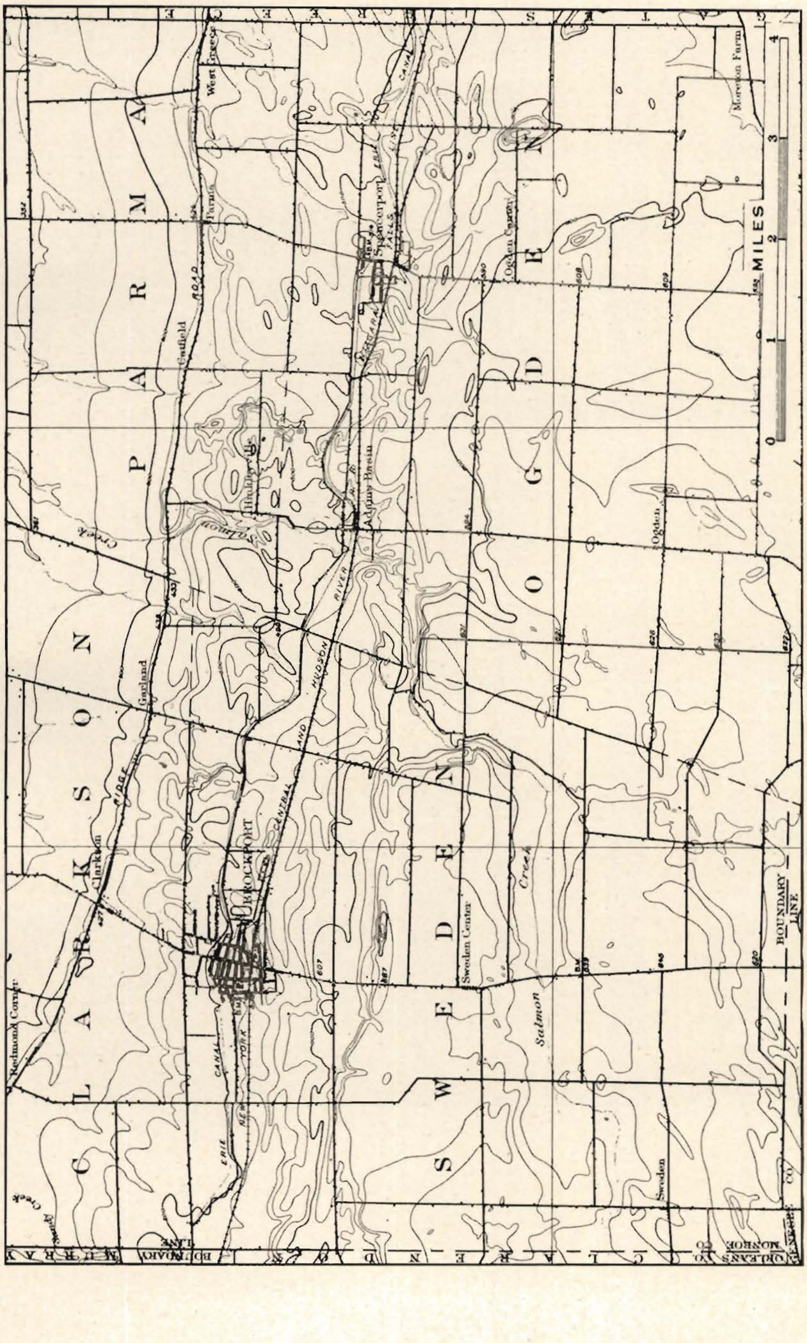


FIGURE 4. *Westward Extension of the Moraine*
From the Brockport topographic sheet

continuous, partly on account of the hilly surface and strong relief in the southern counties. The sketch-map, figure 1, shows a line of moraines in the valleys of the Chemung and Susquehanna.

The heaviest of the recessional moraines forms the massive deposits at the south ends, or heads, of the central New York valleys, constituting the present divides between north and south drainage. These moraine fillings in the valleys are conspicuous from all the railways and highways leading south. This "Valley-Heads" moraine lies just south of Dansville, and crosses the Genesee Valley at Portage, where it is wide and massive. It is this moraine that blocks the ancient valley and has forced the river into the new channel, the Portage Canyon. The moraine lies close south of Warsaw and then swings southwest to join other drift belts along the steep slope facing Lake Erie.

A morainic belt stretches eastward from Batavia, and includes the Mendon Ponds kame-area (figure 5) ; the drift hills in the south end of the Irondequoit Valley; the heavy gravels of Baker Mill, north of Victor; and probably the Junius Ponds kame-area north of Geneva. This drift belt is responsible, at least in part, for the blocking of the Pre-Glacial valley of the Genesee in the Rush-Mendon district, thereby diverting the river into its present channel through Rochester.

As stated above, the Pinnacle range is a part of the Albion-Rochester moraine; and is the latest morainic belt well-marked in the western end of the State. It is possible that later moraines lie under the waters of Lake Ontario.

Since the Quebec ice-sheet disappeared, some tens of thousands of years ago, the climate has been milder than today, as evidenced by the abundant remains of elephants in Alaska and northern Siberia, and by a subtropical fauna in England. The present is a time of refrigeration.

General Description of the Range of Hills

Location; Form; Dimensions; Altitudes

In restricted use of the name, the Pinnacle Hills extend from the village of Brighton, on the east, to the Genesee River, a distance of four miles, with the general direction west 15 degrees south. As a whole the belt has a decided linear form, with some curvature, convex southward.

The east end at Brighton is definite, partly due to the erosion by Lake Dawson (see page 2 and page 12 of this volume). The Erie Canal, now converted to a subway for the railways, made a sharp bend in passing around this eastern terminus. The western terminus of the hills, at the river, is not, however, the end of the moraine, which extends westward beyond Albion and Medina. (Figures 1–4.)

The range is not of uniform width and volume, but is a series of knolls, or groups of knolls and irregular ridges, of distinctly morainic character. (Figure 2.) Three main divisions of the range are recognized. First, the Brighton-Cobbs Hill group, extending from Brighton to Monroe Avenue. Fortunately the greater part of the group is now conserved as the Cobbs Hill Reservoir Park. The eastern portion is a fine example of morainal topography, with a number of handsome kettles. Cobbs Hill before it was truncated for the reservoir had two crests (plates 44, 46), the northern and higher being 663 feet elevation above tide. The sag which was cut for Monroe Avenue had original elevation 560 feet. The plain north and south of the range is 500–520 feet.

The second division is more compact, containing the "Pinnacle" high point, which has elevation 749 feet, about 230 feet over the city plain. It extends from Monroe Avenue to about one-fourth mile west of South Clinton Street (formerly called Pinnacle Road). The cutting for Clinton street, and especially the extensive excavations both east and west of the street, have pitifully marred the ridge. (Plates 57, 61, 62.) The old Catholic cemetery yet holds the north slope east of the street.

The third division includes the remainder of the range, westward to the river, and is broader and less definite. In succession, westward, it includes the knoll east of South Goodman Street; Highland Park, between Goodman Street and South Avenue; the "Warner Tract," between South and Mount Mope avenues; the Mount Hope Cemetery and "Oak Hill," which extends to a bend in the Genesee River. In this division the highest points are the knoll which carries the Memorial Pavilion, 650 feet, and summits in the Cemetery up to 675 feet. The water surface in both the Cobbs Hill and the Highland (Mt. Hope) reservoirs is 636 feet.

The irregularity of the range is great, in both lengthwise and crosswise sections. Only at the Pinnacle is the cross-section a single ridge; and this is better described as an elongated and irregular mound. The crestline or longitudinal profile is very irregular, with extreme vertical variation of about 190 feet. The northern slopes of the range are the most irregular, with spurs and deep ravines, partly erosional and partly the form of the ice-contact. Some of these slopes are as steep as the coarse material will stand, 25 to 30 degrees. The southern slopes are usually less steep, while the lower portions are fairly smooth and uniform, blending with gentle inclination into the plain on the south, which was lake-bottom. These lower southern slopes are the glacial outwash, and were laved by the glacial lake waters (Plate 53).

One peculiar and important geologic feature is the presence of many deep basins or kettles, which are especially characteristic of morainal deposits. No better examples of mound-and-basin topography may be desired than occur in Mt. Hope Cemetery and in Reservoir Park. East of Goodman Street two large kettles on the low ground at the north side had impervious bottoms, one holding a lakelet (plate 67), and the other a peatmarsh. (Paper No. 9.) Both of these very beautiful and interesting features have been destroyed by the march of human "improvement."

To find any ground equaling the height of the Pinnacle we must go south seven miles, to the kames about the Mendon Ponds; or southeast ten miles to the hills south of Fairport. On the parallel of Rochester no equal elevation is found short of the hills north of Oneida Lake, 100 miles away, or westward 30 miles to the drumlins north of Elba, in Genesee County.

Composition and Structure

No existing glacier fully illustrates the behavior and work of the ice-sheet which covered this region. The glaciers of alpine districts exhibit the peculiar work of moving ice-streams in mountain valleys, but they do not have the volume, sweep and broad intensive effects of the vast ice-cap which overwhelmed Rochester for scores of thousands of years. The continental glaciers of Greenland and Antarctica illustrate the general character of the Quebec glacier, but these high-latitude ice-caps probably have a behavior at the margins unlike that of the Quebec, in our lower latitude, under the summer heat of more nearly vertical solar radiation.

The materials composing the range are so various and of such irregular structure that a brief description is inadequate. In composition the range is not wholly the sort of jumbled rock-rubbish, or till, which is deposited by the direct mechanical work of the ice. It is largely sand and gravel, dropped at the ice margin by the copious streams which drained the melting ice-sheet. During their flow of miles, back within or beneath the ice-sheet, the streams acquired a great volume of detritus, which they had to drop at their debouchure. The earliest construction, forming the base of the range, was in standing water, in a glacial lake that lay over the territory on the south. Hence the basal beds of the range, wherever exposed and undisturbed, are horizontal sand or gravel. At the time of this deposition the front of the ice-sheet might have been at least some little distance northward. The bulk of the knolls are coarse gravel, and therefore kames. The ice-laid drift or till is a minor quantity, and occurs mainly on the summits of the ridges and along the northern base. A late readvance of the ice-sheet produced a push and thrust against the north flank which has crushed, crumpled and in some places mingled all the deposits. In some stretches, certainly at Brighton and Cobbs Hill, the ice overrode the hills and left very heavy and bowldery till on the summits. (Plates 33–37, 47–50.) In many excavations, especially on the north flank, the original bedding is found to be tilted, faulted and veined, or even crumpled into a structureless mass (plates 42, 50, 60, 63–65).

Blocks of local limestone (Niagara) occur on the apex of the Pinnacle, and on other high points, and in prodigious numbers on the crests of the Cobbs Hill ridges (plates 46–49) and on the summit of the Brighton hills. As these were carried by the ice but a short distance, only two or three miles, they did not suffer much wear, and are mostly angular; although some of them are planed and scored.

In this anomalous structure of the range we have clear proof of some oscillation of the ice front. The lake beds at the base prove the absence of the ice, while the till and bowlders at the crests of the ridges, and the crushed sands and gravels, are equally clear proof of a readvance.

Along the north side of the range in some stretches, as by the eastern "wide-waters," and at Goodman street, are small ridges and mounds of till which mark the last stand of the ice edge before it made its final and rapid retreat.

The larger percentage of the gravel and cobble, sometimes one-half, is Medina, the only supply of sandstone which the ice-sheet found this side of Canada. This red Medina also constitutes a large part of the sands, giving a reddish color to most of the coarser deposits. The silt and clay, derived from the very thick shale strata in the Ontario Basin, were mostly swept out by the drainage into the lake waters on the south, forming the clays that furnished the supply for the brick factories on Monroe Avenue and at Maplewood, west of the river; and the thick clay and silt of the plain on which is located the Medical College and Hospital of the University of Rochester.

Upon the north flank of the hills, and even to the heart and summit as shown at Monroe Avenue and at South Clinton Street, the beds have suffered great disturbance. In the coarse gravels this is shown by the loss of all stratification; and in the sands and silts by their contorted, tumultuous, disordered character. In all the pits much faulting is exposed. This is the more common sort of disturbance in the deeper portions of the range, which in some sections gives very complicated forms and surprising brecciated structures (plates 32, 60, 64). The sand beds along the south flank of the range are usually approximately horizontal and without much faulting or other disturbance.

The best general statement regarding the distribution of the material is, that the coarser deposits lie along the north side of the range, while the base and the southern slope are mostly fine sand and usually undisturbed. This will be explained in the next chapter.

The original dip of the water-laid beds is not lengthwise of the range, or westward, nor away from a median line, as would be the case in esker construction, but is generally southward, or across the range. (Plates 30, 40, 43.) Some of the steeper dip along the north flank was produced by the push of the ice-front in its last readvance.

At the east end of the range, at Brighton, the gravels dip in different directions. In the large pit on the southwest side of the Pinnacle 80 feet of the lower gravels have a dip 12 to 15 degrees east of south. There are many exceptions to the prevailing southward dip, mostly in the gravels. Some sections show inclinations in several directions. It is evident that some of the local variation is due to some sort of interference subsequent to the deposition. The interfering factors are, the thrust of the readvancing ice; faulting, by consolidation of the deposits; unequal settling by the melting of buried ice blocks and frozen masses of the deposits: and slipping or slumping of the steeper upper beds.

The ice-front was subject to rapid change in form and position during the summer melting, and the shifting flow of the waters probably tended to pile the coarser materials into conical masses thus giving the beds steep inclination in various directions. Probably most of the glacial outflow was subglacial, the streams emerging from tunnels beneath the ice sheet; and sometimes being under hydraulic pressure. When such streams poured out into standing water their detritus was partially piled in masses or mounds, as kames. These conditions may explain the variable original inclination of the sand and gravel beds. But very steep beds, approaching the vertical, must, like folds and faults, be attributed to some disturbance subsequent to the deposition (plate 65).

Morainic Characters

The morainal succession across the State, from south to north, and the position of the Rochester moraine as the latest of the series, are shown in figure 1.

The origin of the Pinnacle range as a frontal moraine implies its continuation east and west, and such extension is seen in figures 1–3. Southeastward from Brighton the ice front has apparently left its record in till ridges and bowlder-fields, until intercepted by Irondequoit Valley. Beyond the valley, in Penfield and Walworth, the moraine is a wide, scattered belt with conspicuous bowlder-fields of Niagara limestone, often piled in large masses.

West of the Genesee River the moraine continues the curving, arcuate line of the Pinnacle range. It includes a belt of knolls and gravel deposits along Brooks Avenue, and as far as the Buffalo, Rochester and Pittsburgh Railroad. West of the railroad the moraine is a fairly distinct ridge of stony drift, with northwest trend. Toward Spencerport the moraine becomes an irregular belt of hills and short ridges, and so continues past Adams Basin, Brockport, Holley and Albion (figure 4). The irregular and stony surface seen along the Falls Branch of the N. Y. Central Railroad from South Greece to Holley is the moraine. From Holley to Albion the north edge of the moraine lies a mile south of the railroad.

Glacier ice flows as a plastic body, and the glacier margins conform to the larger features of the land surface. Such conformation must have been pronounced in this lower latitude. Lobes or tongues of ice were pushed into the valleys, with reentrants of the ice-front on higher points. This implies that a strong ice-lobe should have occupied the capacious Irondequoit Valley. We find the beginning of the moraine which was laid along the west side of that lobe on East and Highland avenues to the Kelly Road. Beyond this the drift was scattered by the Dana lake waters and the succeeding lakes Dawson and Iroquois, or is buried under the lake deposits. In Professor Chadwick's paper on the Irondequoit (10 of the appended list) his plate 4 depicts a later stage of this Irondequoit lobation., It must have been blunted by the melting and buoyant action of the deep lake waters.

The glaciated surface of the limestone of the Rochester plain is found to carry two sets of striae. The stronger and older set has direction south 40° to 60° west. Another set of scratches, later and lighter, sometimes no more than a polishing, has radiating directions perpendicular to the Pinnacle range. Theoretically the flow of the marginal ice is normal to the line of ice-limit. The older set of striae was made when the ice-sheet extended far south and was unaffected by the topography of the Rochester region. The later set records the spreading flow and the weak abrasion of the thinner ice when the moraine was building. West of the Genesee River the latest ice movement was S. 5°–15° W., as shown in several places. Figure 2 shows by the arrows the direction of the striae.

The compact, linear form of the Pinnacle range is in striking contrast with the continuation of the moraine west of Spencerport and east of the Irondequoit. This difference is due to the fact that the Rochester moraine stands on somewhat lower ground, and was washed and limited by the Dana Lake waters. Apparently along this stretch the ice-edge had been forced back by the lake, because it was weak on account of the lines of drainage, which built the kames.

The comparison of the arcuate moraine from Brighton to near Spencerport is also in contrast to the Mendon Ponds kame area (figure 5), eight miles south, with its correlating groups east and west (plate 2 of this volume).

General Conditions and Relations

Our knowledge of the constructional process in moraine-building is derived from observation of such work by the existing glaciers. The piling of drift by the melting ice can be seen at the terminus of any mountain glacier, like those of Switzerland, but the broad-fronted glaciers of Alaska give better illustration of the work of the Quebec glacier.

From the activity of the living glaciers and study of the relics

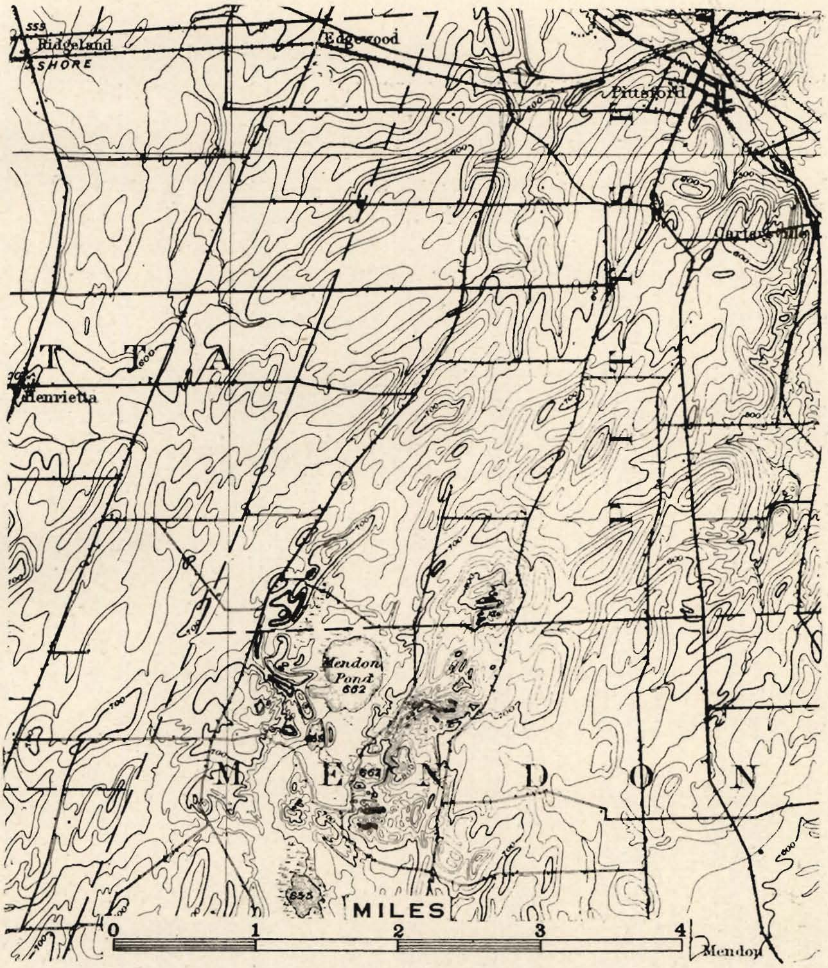


Figure 5. *The Mendon Kame-Moraine*
From the Rochester topographic sheet

of the ancient ice-sheets the science of glaciology has been built. We find that the deposit left directly by the ice is a heterogeneous mixture of rock fragments of all sizes and shapes, and of all the various kinds which the mountain glacier gathers from the valley-walls, or which the continental glacier acquires from the overridden land surface. Many of the stones are scratched and planed by friction among themselves, or by contact, under pressure, with the bed-rock beneath the glacier. Glaciated stones are alone sufficient evidence of ice-work, as no other geologic agency can produce these peculiar structures.

The material beneath the ice-sheet, or held in the lower ice, has been subjected to intense grinding pressure, and may be largely pulverized rock, or "rock flour," forming a clayey or pasty mass, charged with striated stones. This subglacial drift, or "ground-moraine" is also peculiar to ice-work. Farmers call it "hardpan." Streams flowing from glaciers have, after they drop their coarser burden, a milky or opalescent tint due to the suspended "rock flour," the product of the "glacial mill," which is not true clay; the latter being a product of rock decay.

The drift borne within the ice, englacial, or on the surface as superglacial, is less compact than the subglacial, and the mass of rock-rubbish piled at the ice margin as a moraine is largely this looser and incoherent drift. But to all the varied deposit left by the ice itself, whether loose or compact, the geologist applies the name "till."

However, the greater part of the Pinnacle moraine is not ice-laid drift, or till, but is sand and gravel, and hence is water-laid. The fact is evident in the many excavations for building materials. On first thought this fact might appear inconsistent with the glacial origin of the hills. But it should be understood that the ice disappeared by melting, and that turbulent and muddy rivers poured from the glacier, especially in summer, carrying very heavy loads of detritus.

In districts where the land and the valleys sloped away from the ice margin the glacial streams bore their loads of sand and gravel down the slopes, and swept the finer material even to the ocean. Such was the condition when the glacier front was lying across the country in the southern part of the State, where we find the south-leading valleys deeply filled with the glacial outwash. The Cohocton Valley, below Wayland and Cohocton, is a fine example.

In districts where the down-slope of the land was toward the glacier, thus producing a basin between the glacier and the highland, standing water, as glacial lakes, was held up by the ice front;

and when the glacial streams emerged from the ice they had to drop their burden in the lake. This relation is the key to the origin and structure of the Pinnacle Hills.

From the time that the ice front had receded north of the present divide between waters flowing south toward Pennsylvania and those flowing north to the Ontario Basin it had been faced by a series of glacial lakes. The story of these waters has been told in several writings (see N. Y. State Museum Bulletin 127, 1909). These glacial waters, with falling levels, sometimes escaping west to the Mississippi and sometimes east through the Mohawk Valley, had fallen away until at the time when the ice front stood at the line of the Pinnacle range relatively lower water faced the glacier. These waters were a phase of Lake Dana, which had its control at Marcellus, in the Otisco Valley. The theoretic altitude of the Dana level is here about 725 feet. The eastward escape would have been through the valley at Victor. The next recognized lake is Dawson, with outlet by the Fairport-Lyons channel, with closing elevation 480 feet. The waters in which the Pinnacle Hills were built were either Lake Dana at its full height, or an early phase of its falling waters intermediate between Dana and Dawson. Into this shallow water was pouring the Genesee River, from the south, and the glacial drainage from the north. The silts and brickclays which overlie the till in the towns of Brighton, Henrietta, Gates and Chili are the commingled deposits from these two sources. Some material has come from northern Pennsylvania, and some from Canada and the Adirondacks.

This lake water laved the front of the glacier when the Pinnacle moraine began, and the sand strata spread out in the lake, and forming the base of the moraine, were the earliest deposits. On these were built the hills by the shifting torrential streams draining the ice-sheet.

When the ice-front lay over Henrietta and Brighton the ice probably was buoyed by the lake and wasted so steadily, by both melting and flotation, that little opportunity was given for any local or moraine accumulations south of the Pinnacle range. At the time of building the moraine the Ontario lobe of the Quebec glacier had become somewhat stagnant, and melting of the surface (ablation) had probably exposed the lower strata of the ice-sheet, which were heavily charged with drift from the north. When the balance was established between ice-flow and ice-removal the conditions were favorable for dropping the drift load rapidly and abundantly. The drift that under ordinary conditions might have been spread over a large area is concentrated in the narrow belt of the Rochester moraine.

As already stated, the form and structure of the hills suggest that they were built at a few centers of stream-work on the changing ice-front. Possibly the variable and shifting outflow from four or five principal outlets, spaced about a mile apart, could have produced the Pinnacle Hills in—shall we say, a century? The total amount of drift and detritus in the moraine is not great, comparatively, but it shows to full advantage because it rises conspicuously from a plain, instead of filling a valley or depressions in uneven ground. The Pinnacle Hills are only a minor part of the drift which has been left in the Genesee lowland and in the Irondequoit Valley.

The original slopes of the south face of the range, as made by the glacial outwash, must have been somewhat smoothed by the waves of the later waters of the lake. The slope shown in plate 53 shows the final effects.

Relation of Lake and Glacier

It is difficult to visualize the interaction of the glacier and the lake, and to know the actual conditions during the construction of the moraine. Three elements are concerned in the work: (1) the depth of the lake waters and their surface elevation; (2) the depth of the marginal ice or the elevation of the glacier surface, and the character of the frontal slope; (3), the position in the ice-front, and the manner of escape of the glacial streams which swept the gravel and sand out into the lake.

The elevation of the surface of the lake water in which the hills were built is not known with precision. It appears that the hills, with the exception of the Pinnacle, were submerged in the water, for the reason that we find no outwash delta plains or terraces, which would have been constructed if the water had been shallow, or the surface lower than the moraine deposits. As stated above, the recognized lake levels in this district are the glacial lakes Dana, here about 725 feet, and Dawson, about 480 feet. As the latter lies below the clay plain in Brighton and Henrietta, Lake Dawson was subsequent in time to the building of the moraine and therefore not concerned in that event. At full height the Dana waters would have overtopped all the range except the Pinnacle (749 feet). The base of the range is 500 feet at Brighton, about 520 feet at South Clinton Street, and 540 feet at the Genesee River. This gives a depth of water over 200 feet.

At Brighton the well-bedded sands extend up to 550 feet, but the capping of stony till suggests that considerable depth of lake deposits might have been eroded by the readvancing ice sheet. The knolls in Reservoir Park and in the Cobbs Hill area, are gravel, with bedding to high level (see plates 38–41).

At South Clinton Street the fine surface sands and gravel on the ridge west of the street show fair bedding at about 650 feet. At South Goodman Street the sands (plate 68) reach up to over 600 feet. Bowlders found in the higher sands prove sufficient depth of water to float the weighted ice-blocks which rafted the stones.

The highest peaks, the Pinnacle and the Mount Hope knolls, are either gravel or till. The coarse gravels imply strong currents to remove the sand, requiring either shallow water or land exposure.

The depth of water had buoyant effect on the glacier margin, and this probably assisted the thin ice in pushing the limestone blocks to the crest of the Pinnacle.

The earliest waters at the Pinnacle moraine were the highest, and they were certainly over 600 feet, and probably at or over 700 feet. The water level fell away when the glacier control in the Syracuse region allowed an escape for the waters lower than by the Dana pass at Marcellus. Apparently the drop was so prompt or rapid that wave erosion did not carve conspicuous or definite benches or shorelines on the south slope of the moraine. However, there is significant correspondence in height of some terraces and ridges west of the Pinnacle with elevation about 660 feet.

The vast clay plain south of the moraine carries the fine sediment which was laid in the deep water when the coarser materials were building Pinnacle range. There was no other possible source for such quantity of fine and glacial rock-flour.* West of the ridge which carries the State and County Buildings the plain fell within the area of the Genesee River, and some minor portion of the clay of the plain might have been contributed by the river. South

*A suggestion that the Pinnacle range is an interlobate moraine, with the Irondequoit lobation of the ice-sheet covering the Brighton plain west to the County Buildings and south to Ridgeland and Edgewood, has, in the opinion of the writer, no basis of fact.

of Elmwood Avenue the excavations for the University of Rochester Medical College and Hospital reveal deep silts and clay. At the surface some eight feet of silt; then some fifteen feet of chocolate colored clay, with lively reaction for carbonates. Beneath this is "quicksand," with coarse materials at the bottom, resting on the red Salina (Vernon) shale. The vertical succession of deposits gives the history, first from the ice-sheet, leaving either till or coarse outwash; then the deep lake waters and the rock-flour clays; followed by shallowing water and more sandy sediments. (See later chapter, on the Scottsville Lake.)

The intimate relation of glacier and lake is proven by the frequent occurrence of bowlders, some of great size, in the stratified sands, and even in the clays far out on the lake-bottom plain. Rafting by floating ice is the only explanation. (See plate 77.)

Ice Front Conditions and Deposition

The termination of Alaskan glaciers in the sea give some suggestion of the behavior of the Rochester ice-sheet when it was building the Pinnacle moraine in Lake Dana.

First we must recognize the peculiar structure and melting of glacier ice. Ordinary lake ice, or that produced by the freezing of water, has a massive, crystalline structure. When this ice is exposed to a melting temperature it liquefies only at the surface, while the unmelted part remains solid and firm. Glacier ice on the contrary has a coarse, granular structure, due to its origin from snowfall. When glacier ice is warmed to the melting point it melts throughout the mass, the granules separate, and the mass all breaks down. This explains the relative abrupt ending, or the bold front of glaciers.

At the position of the Pinnacle moraine the ice front was probably three or four hundred feet deep, and was faced by lake water perhaps two hundred feet or more in depth. The glacier front, therefore was not floating in the water, like the Greenland glaciers which produce the great ocean icebergs, but was resting on the land. The melting at the front of the granular ice produced, at least in the summer time, a general breaking down or rapid slumping into the lake.

The water of the lake had a singular melting action on the submerged ice. Fresh water is densest at 39 degrees, Fahrenheit. When it cools toward the freezing point of 32 degrees (under the ordinary pressure of the air) it expands, becomes lighter and rises. This property coats fresh-water bodies in winter with ice and with the colder and lighter water, and so prevents deep freezing.

When the water facing the glacier came into contact with the ice it was cooled, made lighter and rose. Such long-continued effect produced an upward flow at the ice-contact, and some melting of the submerged ice.

Probably most, or all, of the glacial drainage was subglacial, issuing from tunnels beneath the ice-sheet. This glacial outflow was probably near 32 degrees temperature, and increased the upward circulation, although reducing the melting effect.

During the winter and cold seasons, when the part of the ice mass which was exposed to the atmosphere and the sunshine was melting very little, if at all, the ice-front was probably steeper. By the continued melting under water the front might have become so steep as to overhang, and large masses might have toppled over into the lake, as small icebergs. But in the summers, when the melting above water was rapid and the ice-front was slumping, and more sloping, probably only small masses of the firm, blue ice floated out in the lake.

If the reader is to understand the conditions and geologic processes related to the moraine he must use the scientific or constructive imagination. He must see in his "mind's eye" the geographic features when the moraine was building. He must see the ice-front, irregular and drift-covered, extending east and west; westward past Albion and curving around the ice lobe in the west end of the Ontario Basin; and eastward past Syracuse and skirting the west flank of the Adirondacks. The site of Rochester is buried under, perhaps, 500 feet of ice. Over Brighton and Henrietta is a lake, with outlet through the valley at Victor, the waters of which lave the ice-front.

Will the reader now imagine himself as standing, at that not-far-distant time (speaking geologically) on some commanding point in Henrietta, with a field-glass in hand? Southward the hills rise into the till-covered upland, as today. East and west he sees a few islands rising from the shallow waters. But looking northward he sees the muddy waters ending against a slope of dark-gray color, the débris-covered ice-front. Further back the higher slope shows, in places beneath the rock-rubbish, the blue ice of the glacier; while the far-north horizon is an elevated surface of snowy whiteness, glittering in the pseudo-arctic sunshine or half obscured in cloud and mist. It is the same sort of view which may be seen today, in all essential features, in Alaska or in some Polar regions.

Examining the ice margin and moraine, with his field-glass, he would see that the muddy lake waters are greatly agitated at some points, where subglacial streams, under hydraulic pressure, emerge from beneath the glacier, contributing great quantities of detritus to be spread out beneath the waters as sand and silt. Other streams pouring out of the ice, or perhaps rushing down the surface of the ice-front, are building the higher gravel knolls. But even the latter may be submerged in the lake.

Now, will the reader imagine that he tired of the somber view, and went away; but returned years later? In general the appearance is much the same, but the glacier has expanded slightly and the ice margin has pushed southward so that the gravel knolls which at the time of his former visit were building at the ice edge or in the reentrant angles of the margin, beneath the muddy waters, are now half buried, or even wholly covered by the readvanced ice sheet. Without leveling the knolls or greatly removing the old deposits the plastic ice is overriding them, and capping them with massive, stony till; while huge blocks of rock, including the limestone of the Rochester plain, are being shoved up and left on the very summits of the highest hills. What he cannot see is that the overridden deposits are being mashed and crumpled by the push and weight of the ice.

In western Europe and Great Britain our ancestors saw similar spectacles, for perhaps many thousands of years. It is possible that the scene here imagined was actually observed by the original American. But geologists have not credited any "finds" of glacial man in America.

Detailed Description

Explanation

The more systematic and special study of the Pinnacle range was made by the writer during the years 1893–1900; and the following descriptive details of form and structure are largely from notes made during those years. But the hills have been continuously under personal observation, as they are a very important and exceedingly interesting subject of geologic study by the classes in the University.

With the constant excavation for sand and gravel many of the features noted below have been destroyed. In other parts of the range, where exploitation has ceased, the structure is now concealed by the slumping of the steep slopes, and by the growth of vegetation; while other and very interesting areas have been occupied for residences, or utilized for rubbish-dumps, instead of being included in the public park system, as should have been done.

The photographs here reproduced are the best description, and they will be the permanent record of the remarkable morainic phenomena.

Brighton Area

Plates 24–37

This division extends from Brighton village westward to the Cobbs Hill reservoir, including the knolls at the Steel reservoir of the Lake Ontario Water Company, and the forested part of the city park.

The eastern end has been deeply excavated for sand and gravel, and will eventually be filled and graded for building sites. Then the accompanying photographs will be the only record of very interesting glacial structures. With an abundance of building materials about the city, and with boundless area available in all directions for residences it would appear that an enlightened public policy would have preserved the hills with their glacial topography and commanding view, as part of the public park system, for the pleasure and education of later generations. By the geologist and the nature-lover this sort of real-estate "improvement" is described in uncomplimentary terms.

The most easterly excavation, and one of the oldest, was on the east side of Winton Road, now partly graded and filled. It was mostly coarse gravel, largely Medina sandstone, with great masses cemented by lime to stony hardness. The latter fact was probably one reason for the abandonment of the pit (plate 24).

The later and more interesting exposures are west of Winton Road. This area consisted of two ridges, similar to Cobbs Hill. The northern and main ridge, in direction west, 15 degrees south, connected with the high knolls in the north side of the wooded park, culminating at the steel reservoir. The Rochester sheet of the topographic map (figure 3) does not contour this area correctly. The lesser ridge, along the south side of the area, trends about southwest. Nunda Boulevard lies on its southern flank.

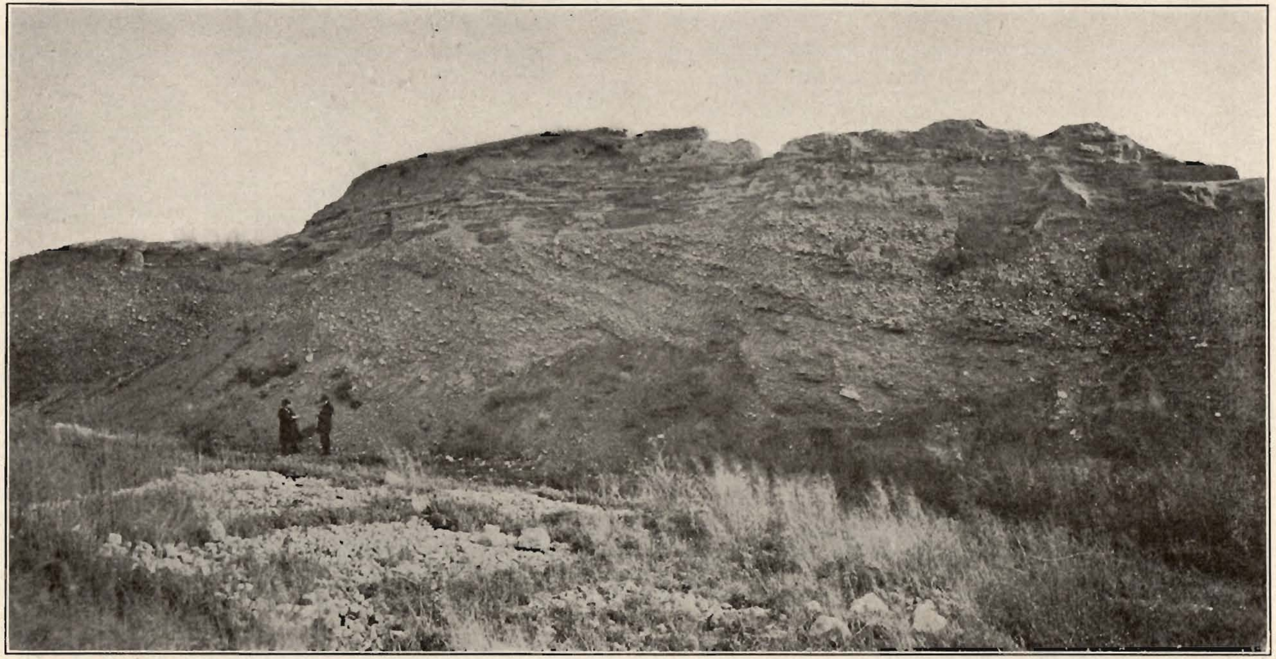
The large gravel pit in the east end of the area, close to Winton Road on the west side, the Sheehan pit, has for over 30 years been cutting back (southwestward) and giving excellent exposures with constantly changing detail of structures. This cutting has given us a cross-section in the heart of the east end of the range, with a vertical face of 30 to 50 feet. Plates 25–30 are from photographs of the face of this one excavation, and all taken on the same day They show the primitive and the induced structures, and the remarkable variation of the aqueo-glacial deposits, or the variable conditions during the depositional process, even within the short distances of a few score feet. The marks of tools, pick and shovel, should not be confused with the sand structures.

All the bedding here, beneath the till capping, is water-laid, sand and gravel, deposited in standing water under variable outflow from the near-by front of the ice-sheet. The fine-grained or silty layers represent the weaker flow, which could transport only the finest detritus. The coarser, sandy layers were deposited during more vigorous flow. Plate 31 shows the alternating coarse and fine layers when etched out by the wind. The sand layers are friable and are eroded by the wind, while the more compact and adhesive clayey layers resist the wind action.

This alternation of coarse and fine layers, very common in glacial deposits, certainly indicates some periodicity in the glacial outflow. The only periodic factor to which such thin layers can reasonably be attributed is the variation of flow between day and night. We may suppose that the weaker flow, with the lighter and silty burden, occurred late at night and in the morning, while melting of the glacier front was at the minimum; and that the copious flow, bearing sand and gravel, took place in the afternoon and evening when the melting was at maximum. This may give a time-gauge for such deposits of limited thickness.

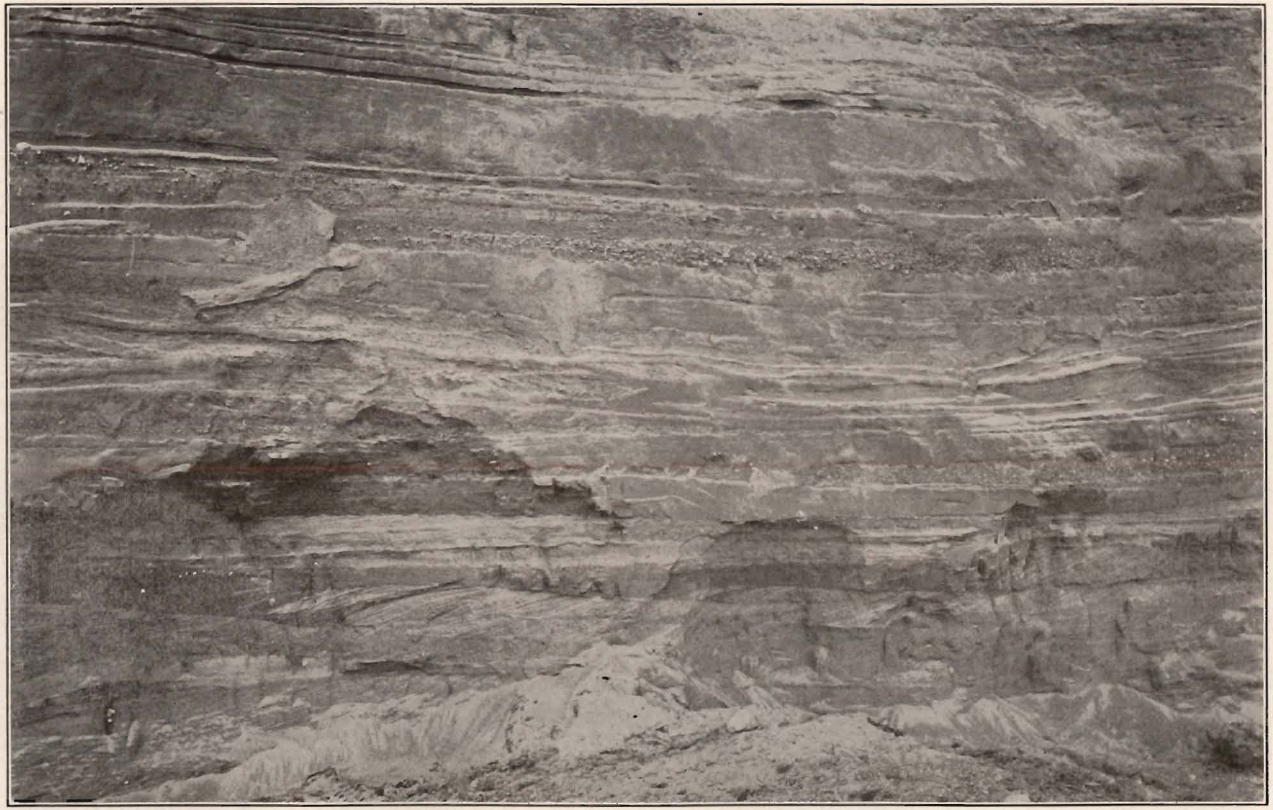
The more southerly beds in the Sheehan pit, and the deeper beds in both this pit and the Elam pit on the west, were quite horizontal (plates 33–37). The north side of the pit generally showed considerable dip or southward slant (plates 29–30), which might be partly due to the original inclination, and partly to the up-tilting by the push of the readvancing ice-front.

At one place in the north side of the ridge a number of large blocks of limestone were imbedded in fine sand. Such anomalous



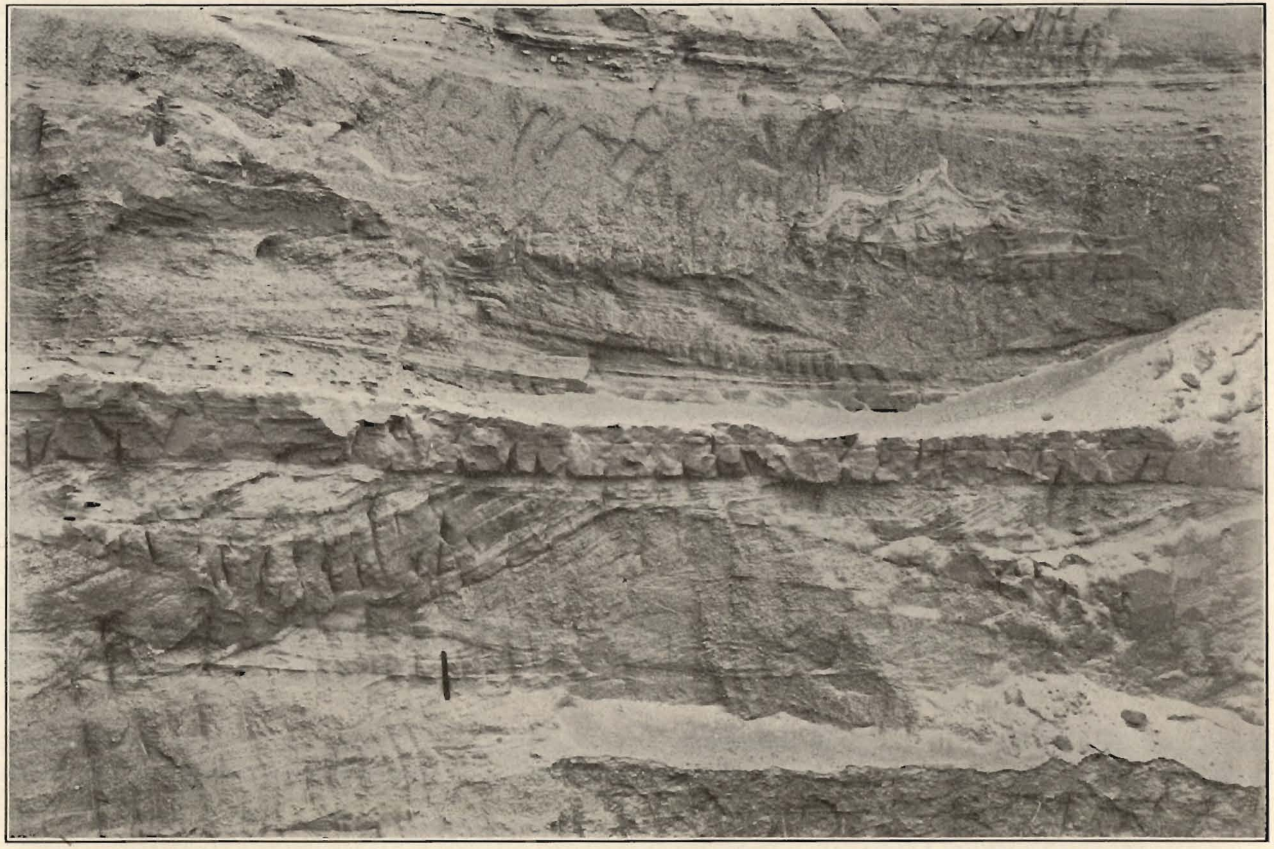
GRAVEL EXCAVATION SOUTH OF BRIGHTON
East side of Winton Road. Duffy pit. Looking southeast

October 1894



BRIGHTON EXCAVATION
West side of Winton Road. Sheehan pit. Looking west 20 degrees south

October 17, 1894



BRIGHTON EXCAVATION

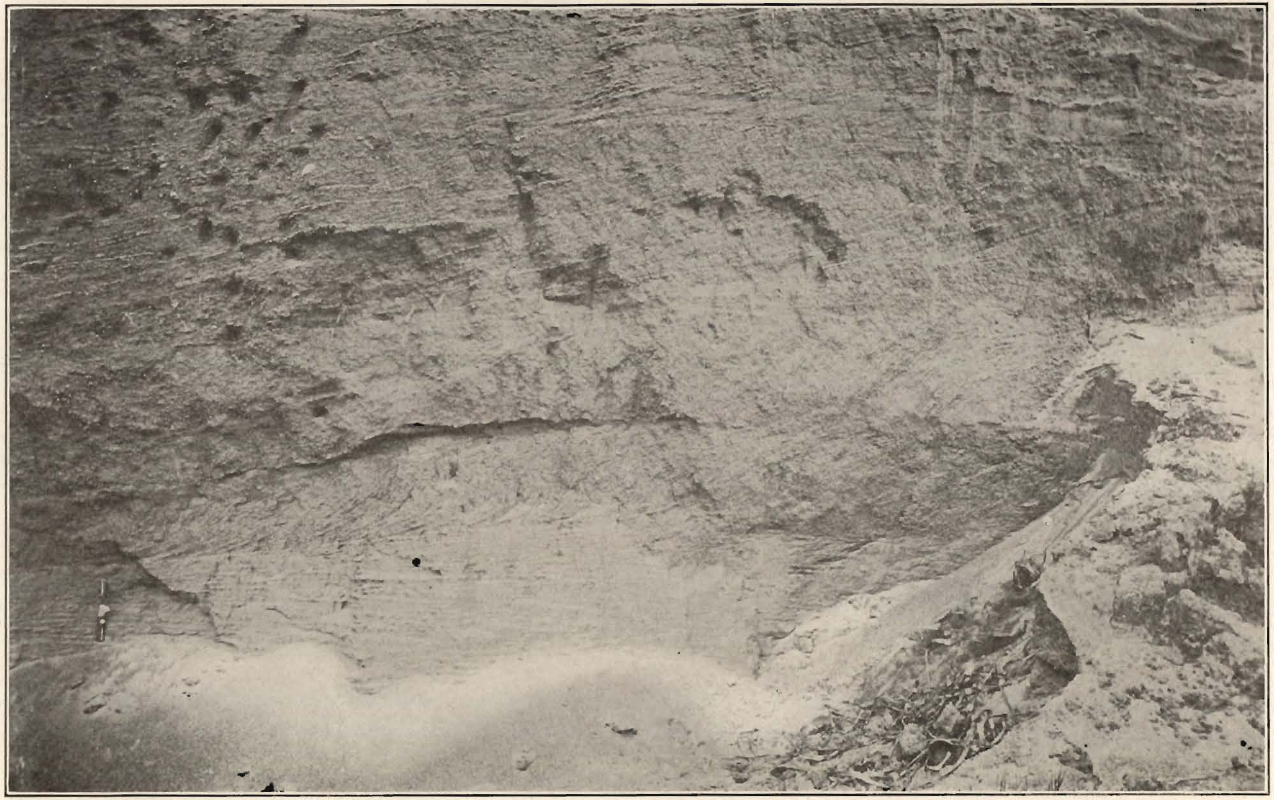
West side of Winton Road. Sheehan pit. Near south end of pit. Looking west 15 degrees south

October 17, 1894

BRIGHTON EXCAVATION

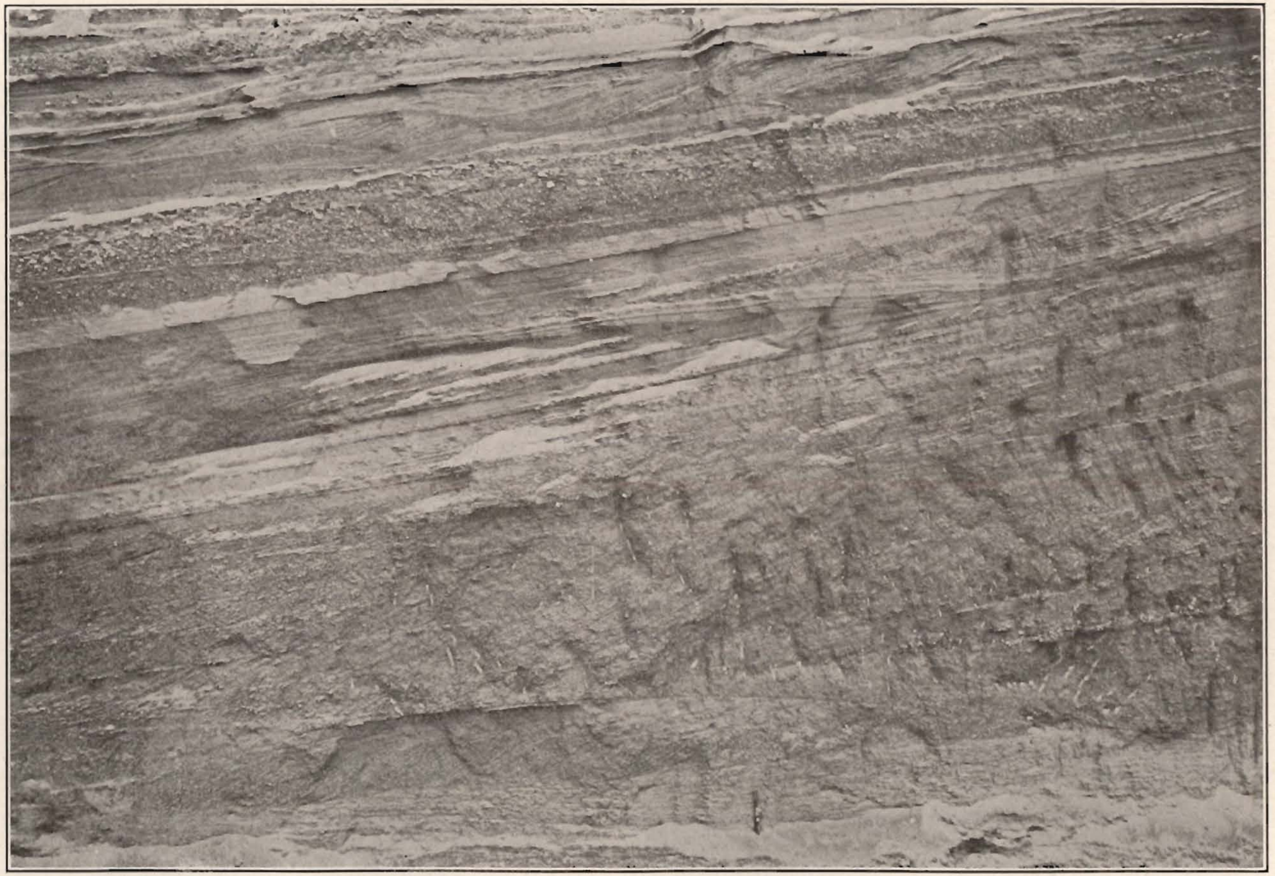
West side of Winton Road. Sheehan pit. Looking west 10 degrees south

October 17, 1894



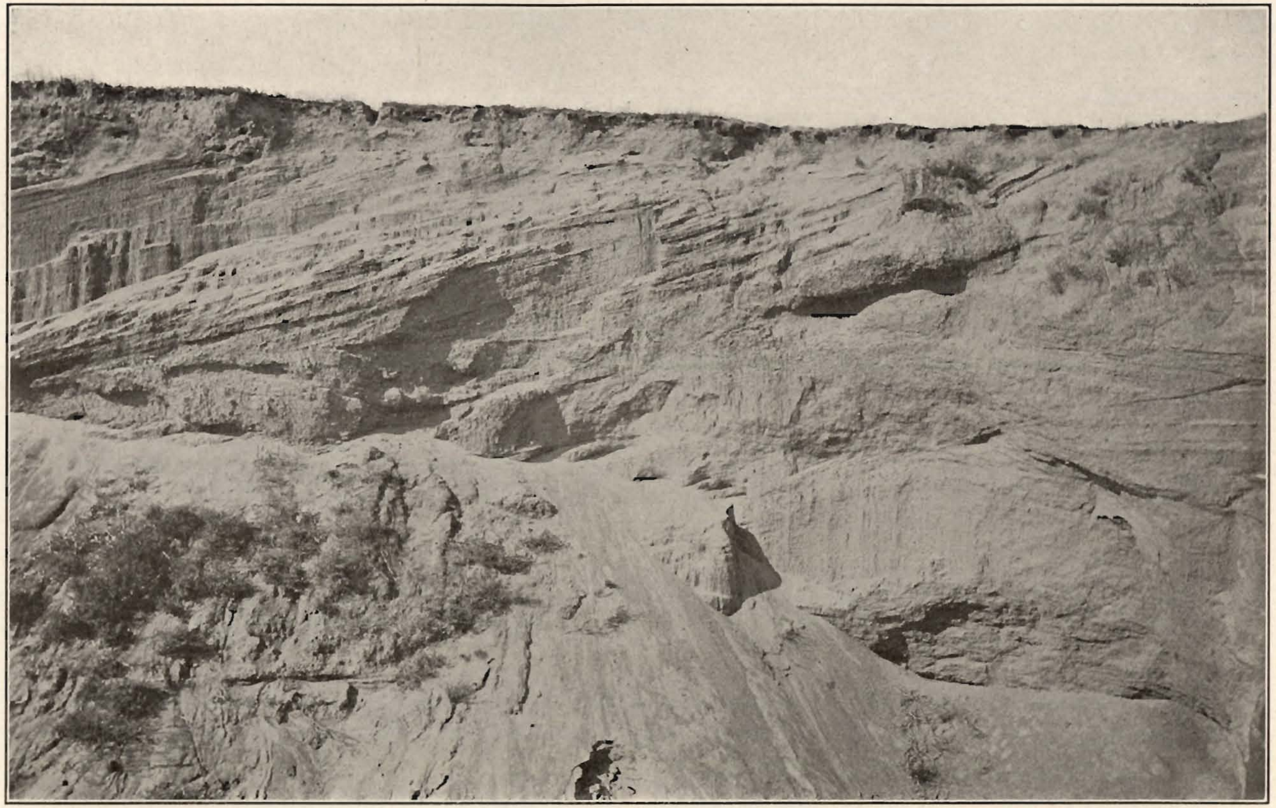
BRIGHTON EXCAVATION
West side of Winton Road. Sheehan pit. Looking west

October 17, 1894



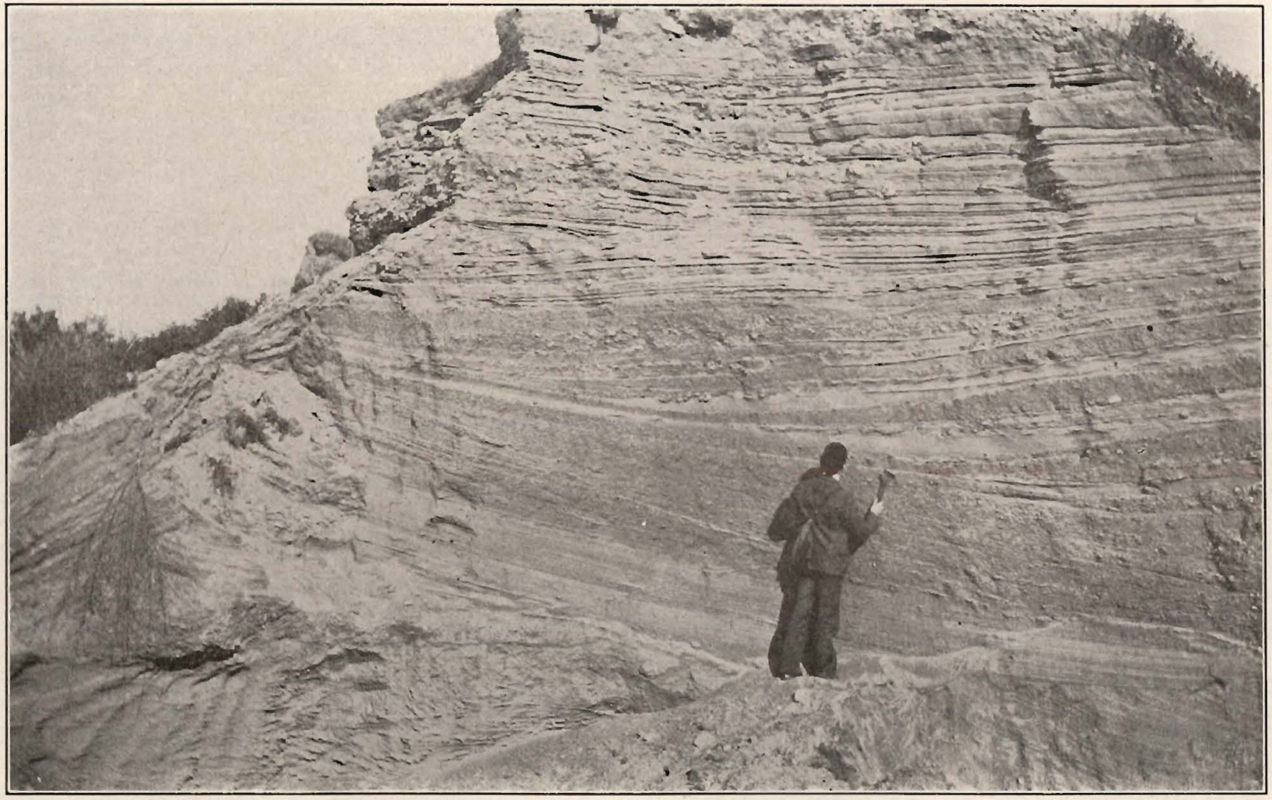
BRIGHTON EXCAVATION
West side of Winton Road. Sheehan pit. Looking west

October 17. 1894



BRIGHTON EXCAVATION
West side of Winton Road. Sheehan pit. Looking west

October 17, 1894

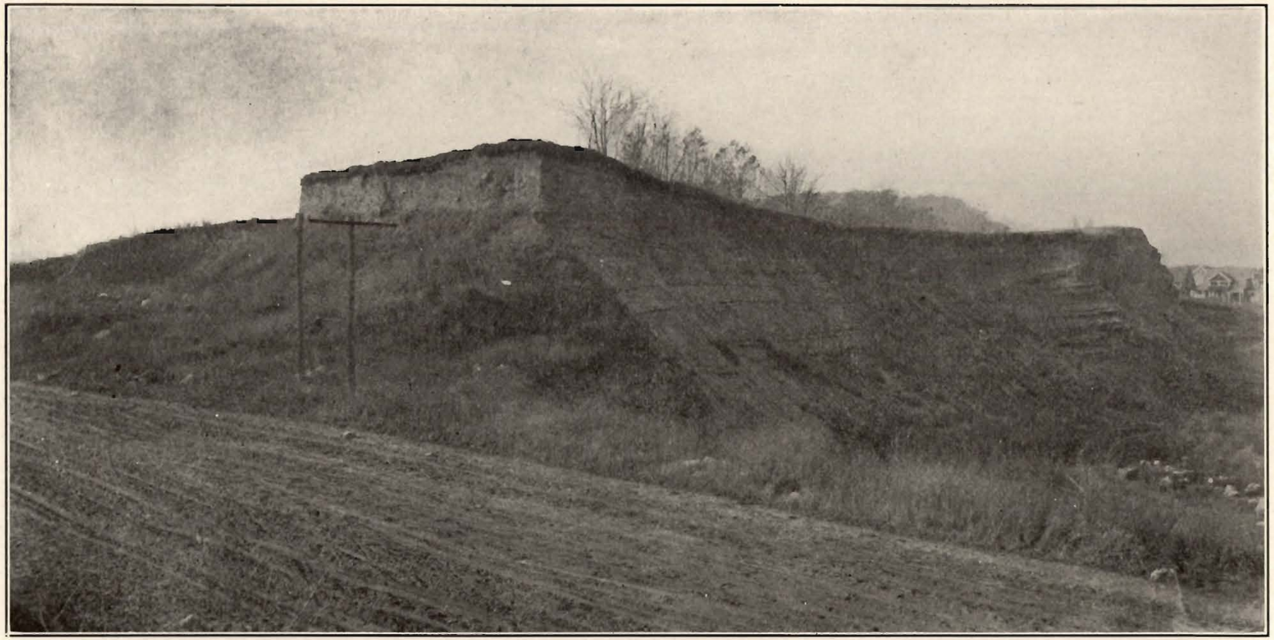


BRIGHTON EXCAVATION
Sheehan pit. Alternation of fine and coarse layers

October 21, 1901

BRIGHTON EXCAVATION
Showing crumpling and faulting. Sheehan pit.

October 21, 1901



BRIGHTON EXCAVATION

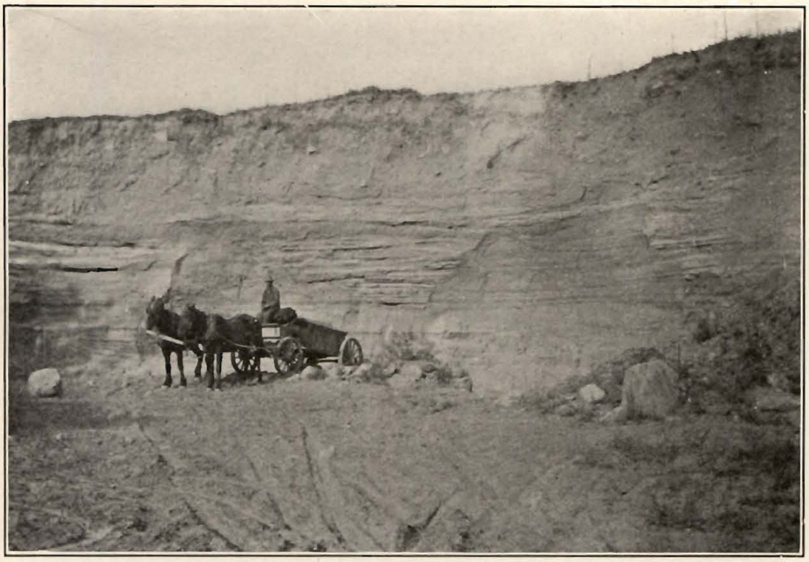
West side of Winton Road. Sheehan pit. Till capping. Looking west from Winton Road

November 11, 1917

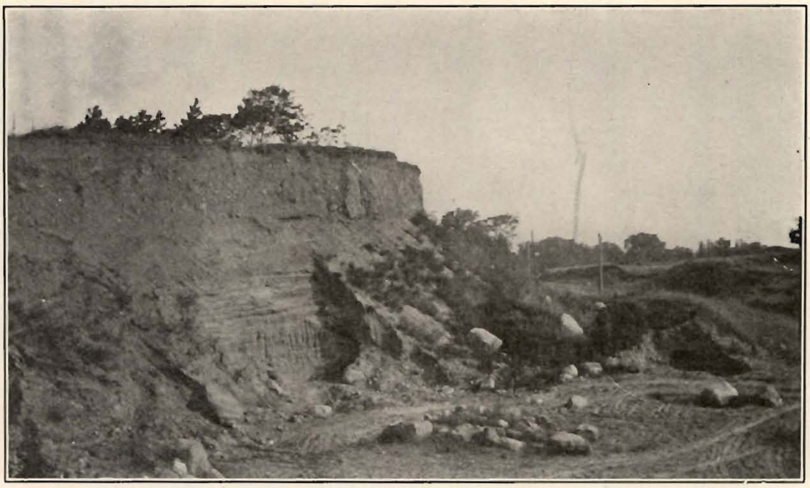
TILL, CAPPING LAKE SAND

Small pit by Winton Road (Charles Elam) south of the Sheehan pit. Looking west. Compare plate 35

September 27, 1922



View looking west

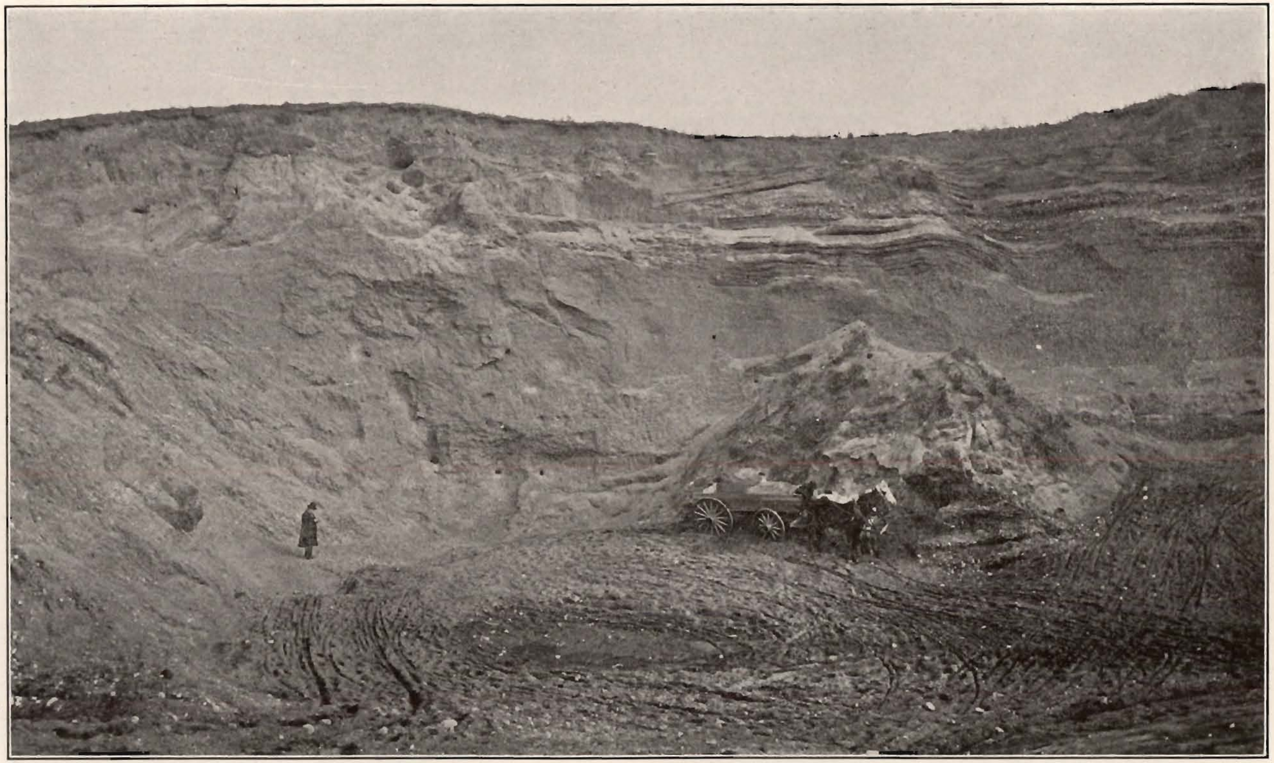


Looking north at east end of cliff

TILL, CAPPING LAKE SAND

Same excavation as in plate 34

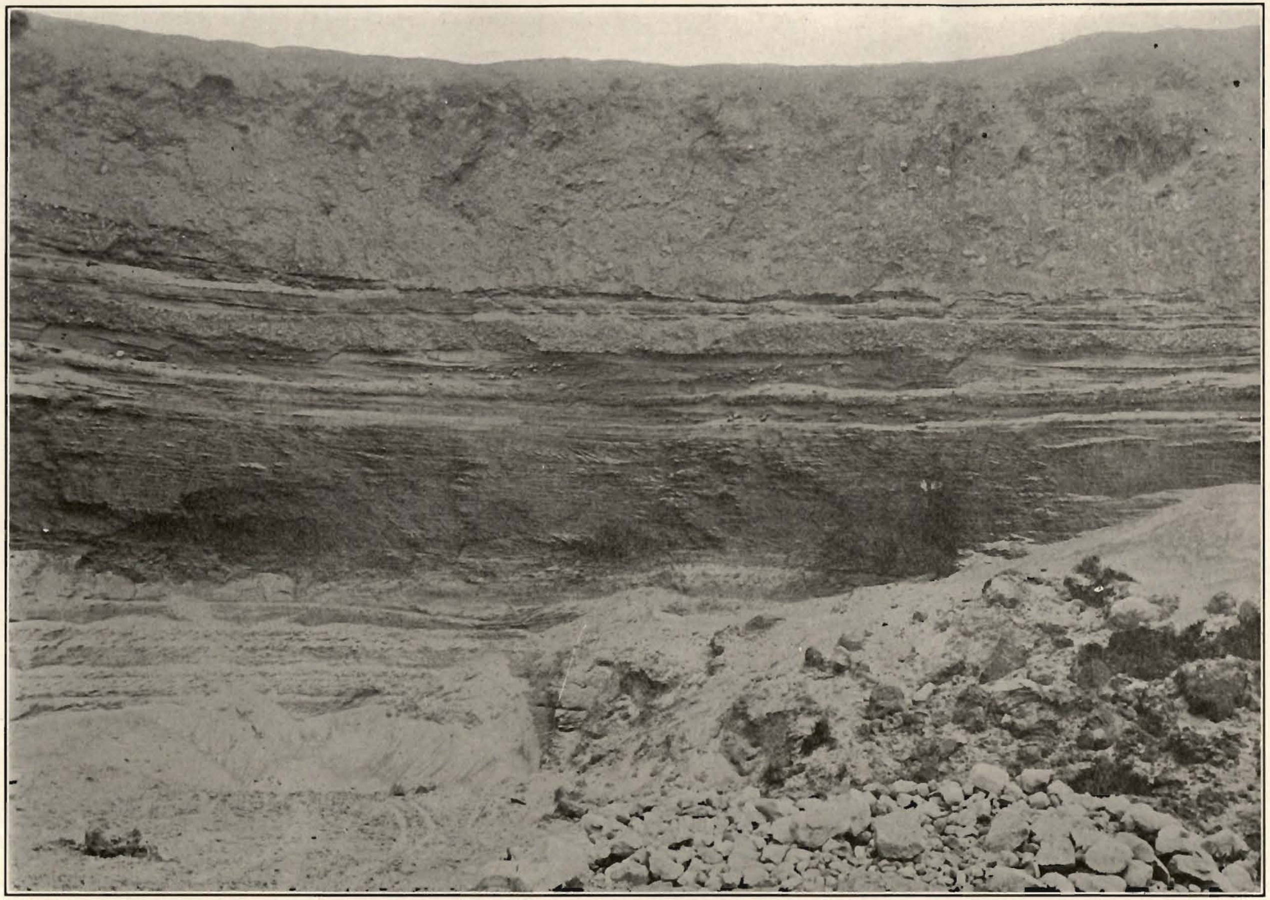
October 1914



ELAM PIT, NORTH SIDE OF BRIGHTON HILL

West of Sheehan pit. Looking southeast. Compare later view, plate 37

October 15, 1894



WATER-LAID DEPOSIT CAPPED WITH TILL

Elam pit, north side of Brighton hill, west of the Sheehan pit. Looking east. Compare earlier stage, plate 36. November 15, 1918

relationship is impossible by water action alone. It is attributed to the rafting work of ice blocks, diminutive icebergs, detached from the ragged ice-front. Ice-rafted bowlders are not uncommon in fine-grained and stratified deposits laid in waters which bathed the fronts of glaciers, and they are regarded as proof of glaciation. They suggest, of course, sufficient depth of water to float the bowlder-weighted icebergs. Bowlders held in sand or gravel may be seen in plates 47, 65. In most excavations huge bowlders may be found which must have been imbedded in the excavated sands or gravels.

The horizontal water-laid beds in the Brighton area indicate lake water to at least the present height of 550 feet, while the western part of the range shows positive work of standing water to over 600 feet.

Many of the beds, especially the deeper ones in the Sheehan pit, (plates 26–28) show much discordance from the normal uniformity of quiet-water deposition. Some of this is probably due to variation during deposition in both the velocity and direction of flow. Irregular structure is to be expected in deposits laid at the margin of a rapidly changing ice-front. The common current ripples or flow-laminae show the direction of water flow. Here the general direction was southeastward or across the range. But the folded, crumpled, unconformed and faulted structures are certainly "induced," or formed subsequent to the deposition. Yet where such disturbed structures are local, and buried under undisturbed layers, as in plate 26, the disturbance must have occurred immediately after deposition, and may be attributed to the grounding and scraping and ploughing of floating ice-blocks, or little icebergs. These glacial-water structures have many curious forms, interesting but often inexplicable.

Much of the east end of the Brighton area is capped with massive till, 10 to 15 feet thick, seen in plates 33–37. In the early photographs of the Sheehan pit, and at the east end of the Elam pit at the present writing (1923) this was unstratified, gravelly sand. But in the center of the Elam pit (plates 36–37) and by Winton Road the topping bed is very stony and bowldery till. This cap of stony till was laid directly by the ice itself, and has already been noted as proof of the readvance of the ice-front, overriding, disturbing and burying the previous lake deposits.

The southeast slope of the Brighton area, as of the entire range in general, was laved by the lake waters, and probably somewhat eroded. This accounts for the smooth surface which grades off into the low plain, under 480 feet, the Dawson lake-bottom.

Passing westward along the north side of the range we find another pit, the old Elam pit, which forms the abrupt north side of the wooded park and of the Ontario Water Company's property. The material was coarse, bowldery gravel, with pronounced southerly dip.

The west end of the Brighton area is very fortunately preserved as city park, and left in natural forest. It contains a number of excellent kettles, and is a fine example of kame topography, or mound-and-basin structure; surpassed only by the Mt. Hope cemetery area. The south side of the forest tract is occupied by residences, known as Highland Heights.

The steel reservoir stands on the highest point of the Brighton area, with ground altitude of 620 feet. Very deep kettles lie both east and west of the reservoir. The north slope of the hills at this point is natural, and shows the steep and irregular surface produced by the ice-contact. The knolls here appear to be all gravel. The material was banked against the ragged ice-front, and when the latter melted away the gravel crumbled down to repose. The steep reentrants or hollows may have been somewhat deepened by later erosion. The kettles represent the places where detached ice masses were buried in the glacial outwash.

From the above description the reader will be able to prove the morainal origin of the deposits, and to interpret the history.

Cobbs Hill Area

Plates 38–52

This part of the Pinnacle range lies between the Brighton area and Monroe Avenue. It is now wholly occupied by the city reservoir and the surrounding park, and the geologic features are entirely obscured. Plate 44 is a general view from the west of the hill as it appeared in 1895, and plate 45 is a similar view of today.

Like the Brighton area the Cobbs Hill had two ridges, shown in plates 44, 46. The north and main ridge had trend west 15 degrees south, while the south crest was east and west. These ridges were morainal, composed of very bowldery till, especially the south ridge, as shown in plates 48, 49. The structures were revealed by an extensive excavation on the north side, near the Canal "widewaters," and the pits which encircled the west end, by Monroe Avenue. The original excavation was made in the cutting for the highway, Monroe Avenue, some time previous to 1838. Plate 47 shows the extension of this cut as it appeared in 1894. The many hundreds of bowlders show the stony character of the till at this point; yet Mr. Cobb said that these were only a part of the great numbers found. Most of the blocks were the local Niagara limestone; some of them with diameter to eight or ten feet. A few bowlders were Medina sandstone, and a very few were foreign or far-travelled. Excluding 25 larger blocks, it was estimated that the remainder would average two feet in diameter. Many bowlders were handsomely glaciated. All the excavations about the west end of the hill had been abandoned, evidently because of the very heavy capping of bowldery till, and because the lower beds were sand of texture too fine for use as building material. Yet in the condemnation for the reservoir the price was computed on the basis of good gravel.

The widewaters pit, on the north side of the hill, owned by Mr. Cobb, is now filled and buried under the retaining bank of the reservoir. In 1894, 60 to 80 feet of coarse material was exposed, with little if any original bedding preserved, except at the east end. Plates 38–40 show the beds dipping about 18 degrees from the horizontal, in direction somewhat west of south. The vertical section was as follows:

20 feet unstratified material, at the top.

15 feet coarse sand, grading into

10 feet of gravel.

40 feet of reddish sand, remarkably veined and faulted.

Throughout the pit there was much faulting and veining, with the veins cemented and lying in various directions. Medina sandstone formed the bulk of the sand and smaller cobbles. The larger bowlders were Niagara limestone, which is the case throughout the entire range. At the west end of the pit the whole depth was till-like and stony, while the top was true till.

Plate 43 shows a small pit east of the widewaters pit, opened in 1904 on the land of W. P. Davis (whose residence appears in plate 44, on the south slope of the hill) to prove that his part of the hill was gravel. The contention was verified, for the enormous volume of gravel and coarse sand required for the concrete floor and walls of the reservoir was supplied, with much to spare, from the Davis end of the hill.

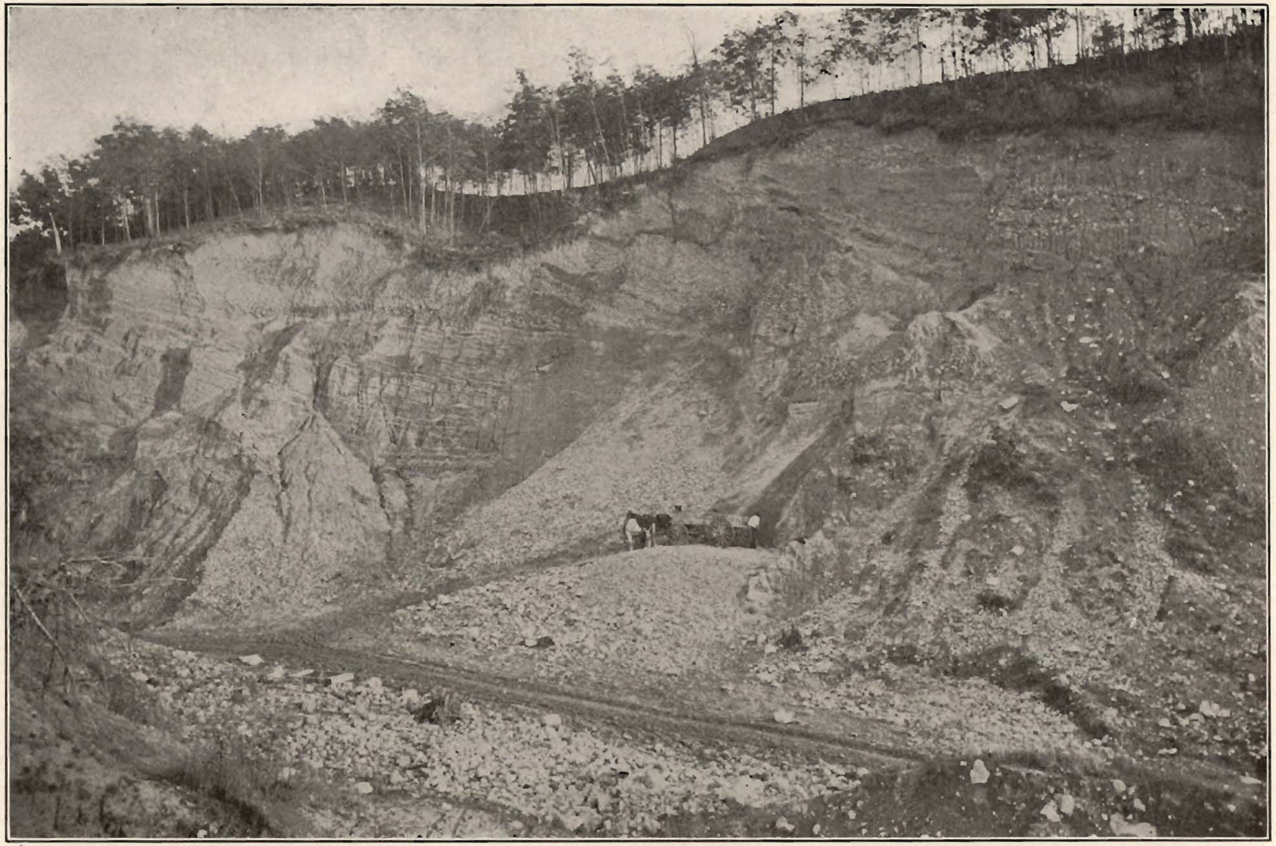
The steep dip of the beds shown in plates 40, 43 may not be wholly the initial dip or original slope. It may be due in part to sinkage on the south, and to the push from the north of the re-advancing ice-front. These views also show the rapid alternation of coarse and fine layers, representing periodicity in the deposition.

North of the widewaters pit and opposite the lock in the old Canal is a distinct moraine ridge, some 30 to 40 feet in height above the canal, with trend west 15 degrees south. This was a retreatal moraine built during a brief pause of the ice-front, in its removal northward. It probably correlates in time with similar moraine ridges west of Clinton Street, and west of Goodman Street.

Plates 51, 52, 54 show the Northrup pit, by Monroe Avenue, on the north side of the Cobbs Hill. At the east end of this excavation the material was unstratified, having been shoved and crushed by the ice. It held some bowlders, two of immense size. Westward this structureless mass was bounded by a nearly vertical fault, the whole thickness of about 30 feet lying against the fine sand which formed the walls of the remainder of the pit, as seen in plates 51, 52. Here a face of 60 to 70 feet of mostly fine reddish sand was exposed, with some lenses of sand and masses of till near the top. The downward curve, without much faulting, in the middle of the pit might be due to unequal settling, especially of unfrozen beds; or perhaps to the melting of buried ice. Probably great masses of morainal deposits were buried in a frozen and saturated condition. These sands were greatly faulted and veined. The veins had been channels for seepage, and being cemented by lime, they formed conspicuous projections on the crumbling walls. The largest vein was near the fault above noted, at the junction of the gravel on the east; the vein having nearly vertical position and with thickness of eight inches.

The old pit on the south side of Cobb's Hill, by Highland Avenue, had reached the crest of the south ridge, and showed a topping till of about 15 feet in thickness (plates 47–49). It appears that the south ridge was very stony till. Large blocks of limestone lay over the surface of the fields on the ridge, and in the hollow between the two ridges. Also piles of bowlders had been accumulated along the fences.

At the east end of this pit the lower beds were sand, quite horizontal and undisturbed, in contrast to the crushed and crumpled north side of the hill. Mr. Cobb said that ridges of sand originally extended away from the south slope, across what is now Highland



COBB'S HILL

North side of hill, near Erie canal widewaters. East end of pit. Looking southeast. Compare plates 39, 40.
October 15, 1894

COBB'S HILL

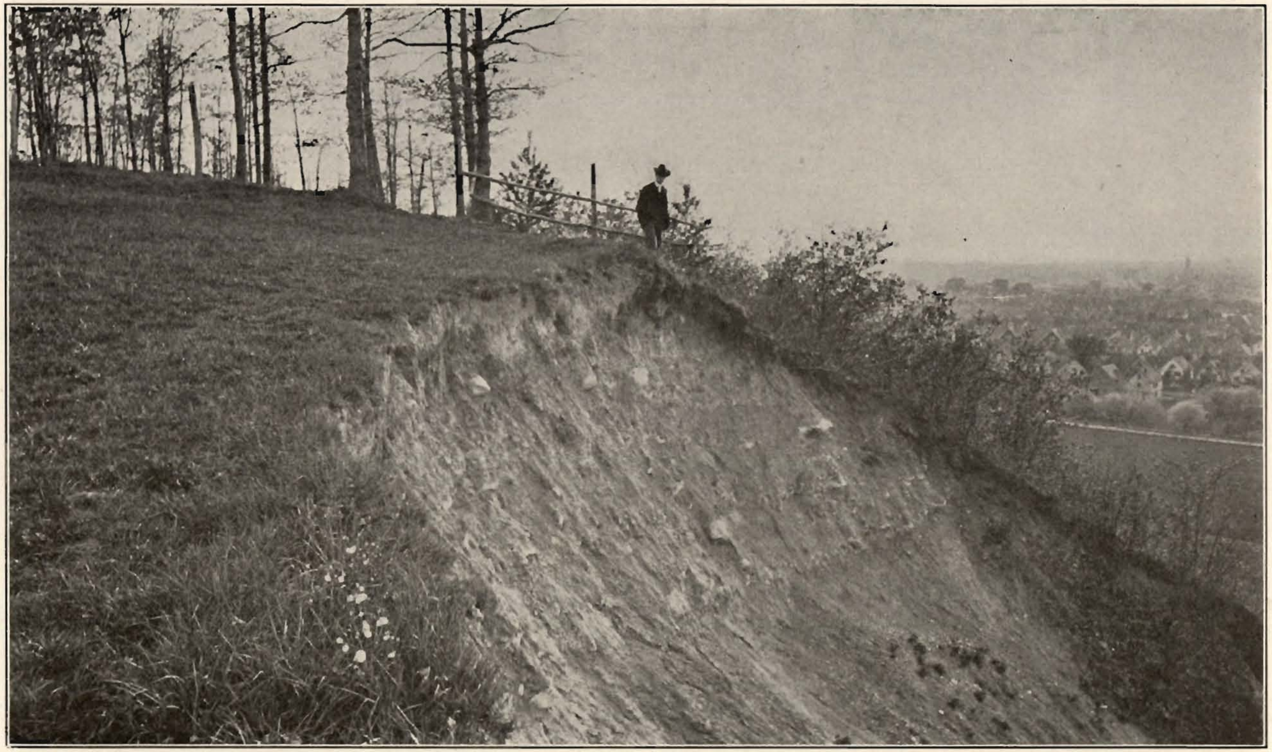
North side of hill, near Erie canal widewaters. East end of pit. Looking south 15 degrees east. Compare plates 38, 40

April 17, 1895

COBB'S HILL

North side of hill, near Erie canal widewaters. East end of pit. Looking southeast. Compare plates 38, 39

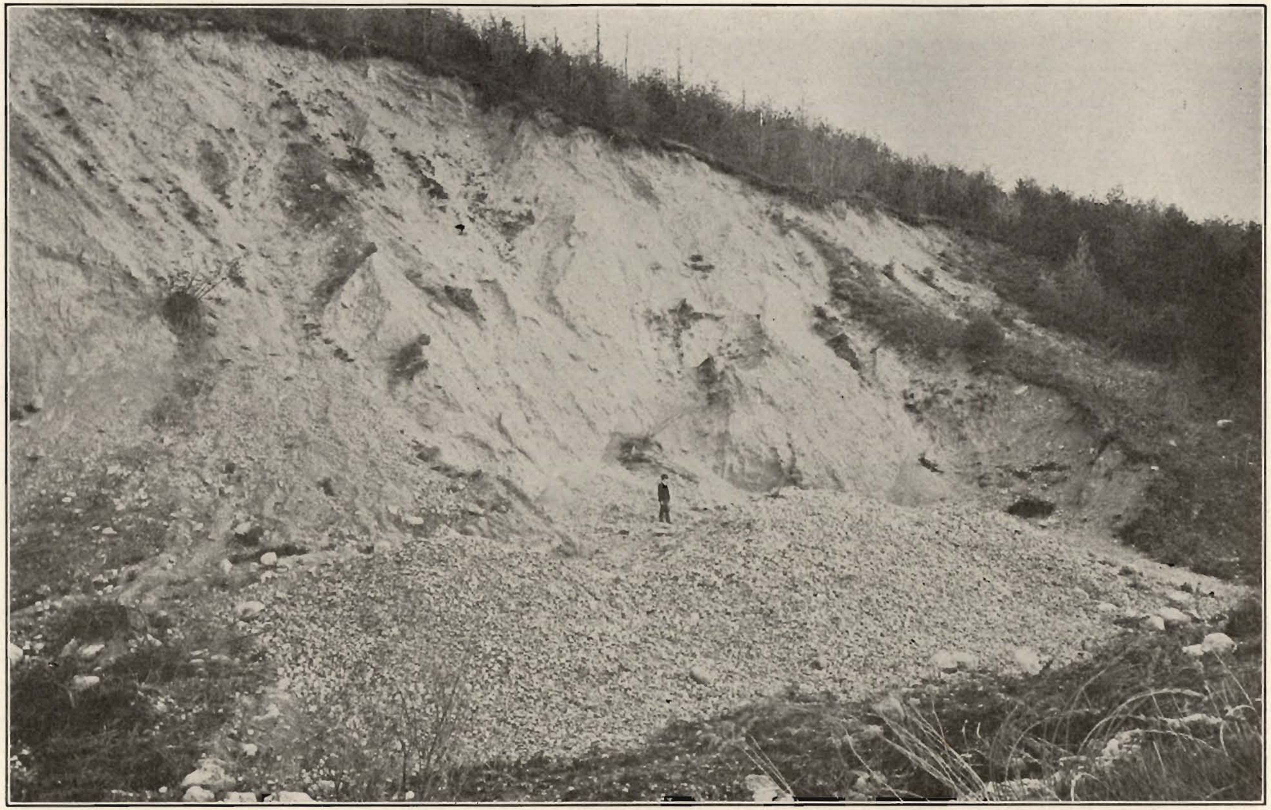
May 15, 1903



COBB'S HILL

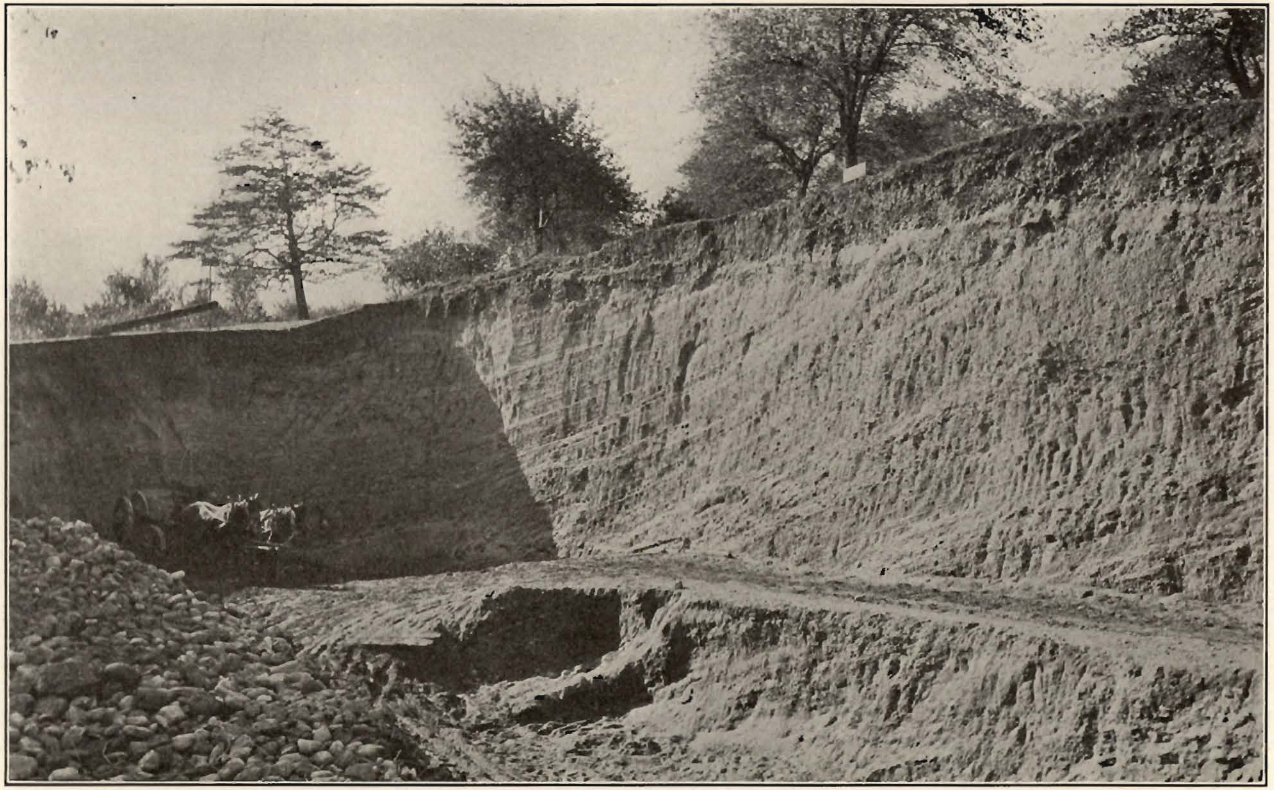
North side. Top of pit by Erie canal widewaters. Looking west

May 15, 1903

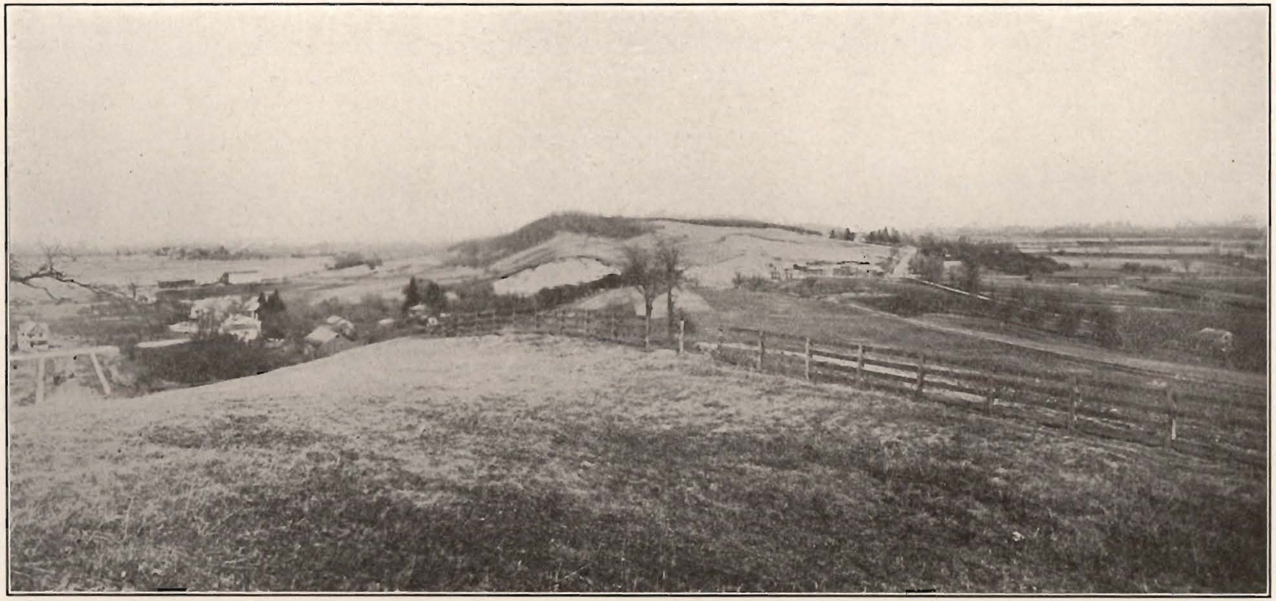


COBB'S HILL
West end of pit near Erie canal widewaters. Looking south

May 15, 1903

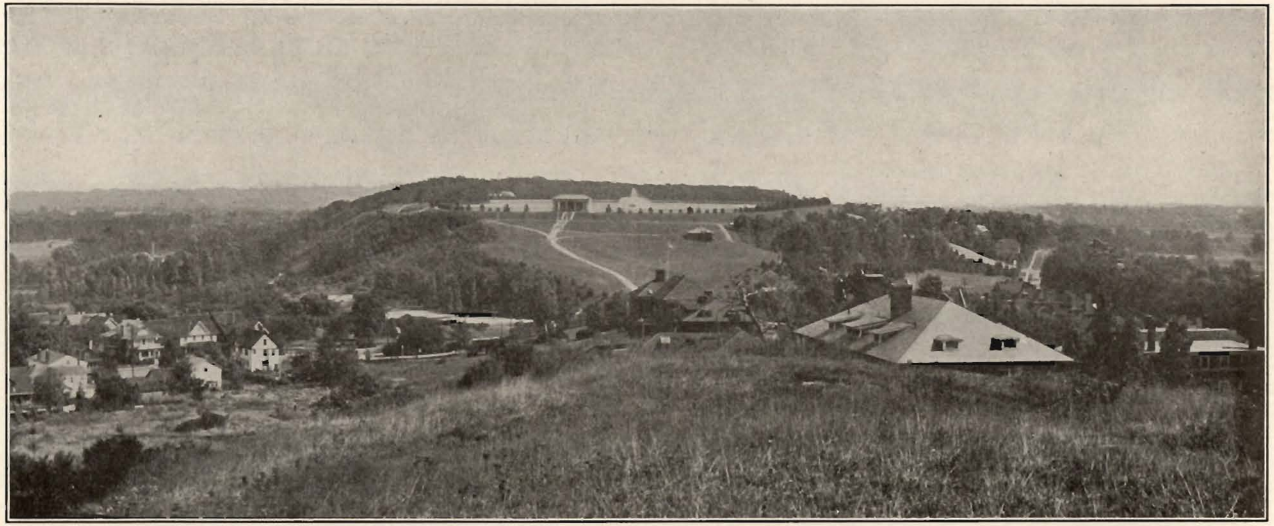


DAVIS GRAVEL PIT
Northeast slope of "Cobb's Hill." (W. P. Davis pit.) Looking south 30 degrees east
October 15, 1904



COBB'S HILL
View looking east from Klinck knoll. Compare plate 45

April 18, 1895

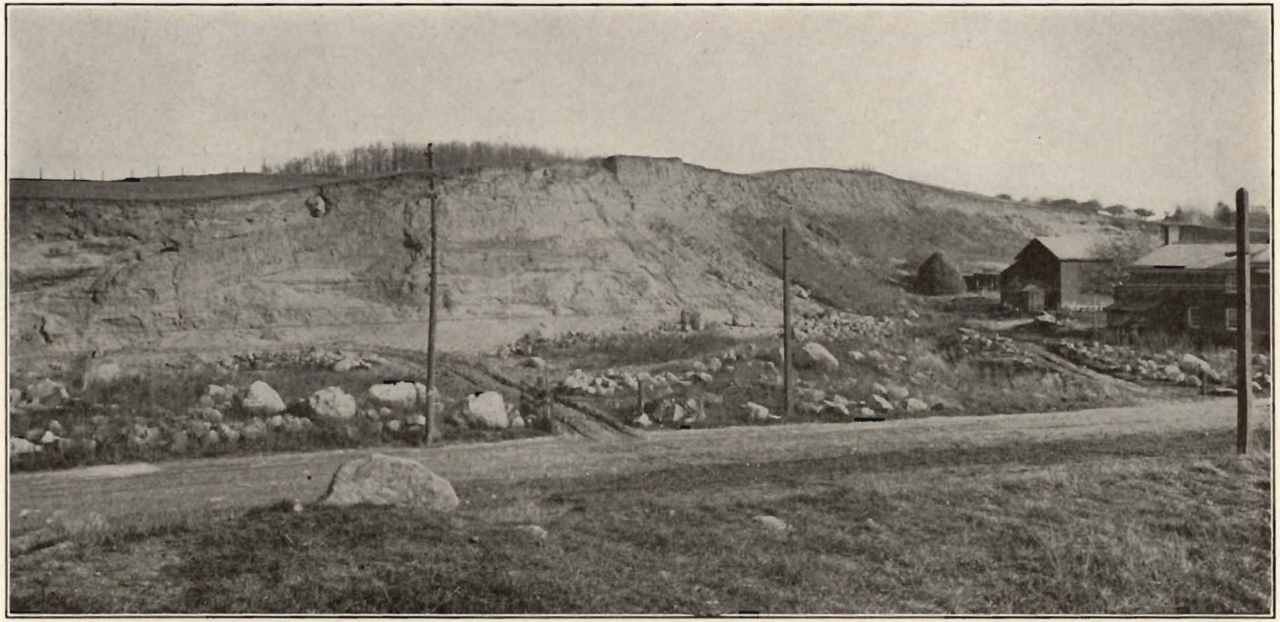


COBB'S HILL
View looking east from flank of Klinck knoll. Compare plate 44

September 27, 1922

COBB'S HILL
North ridge. Looking northwest from the south ridge

May 16, 1903



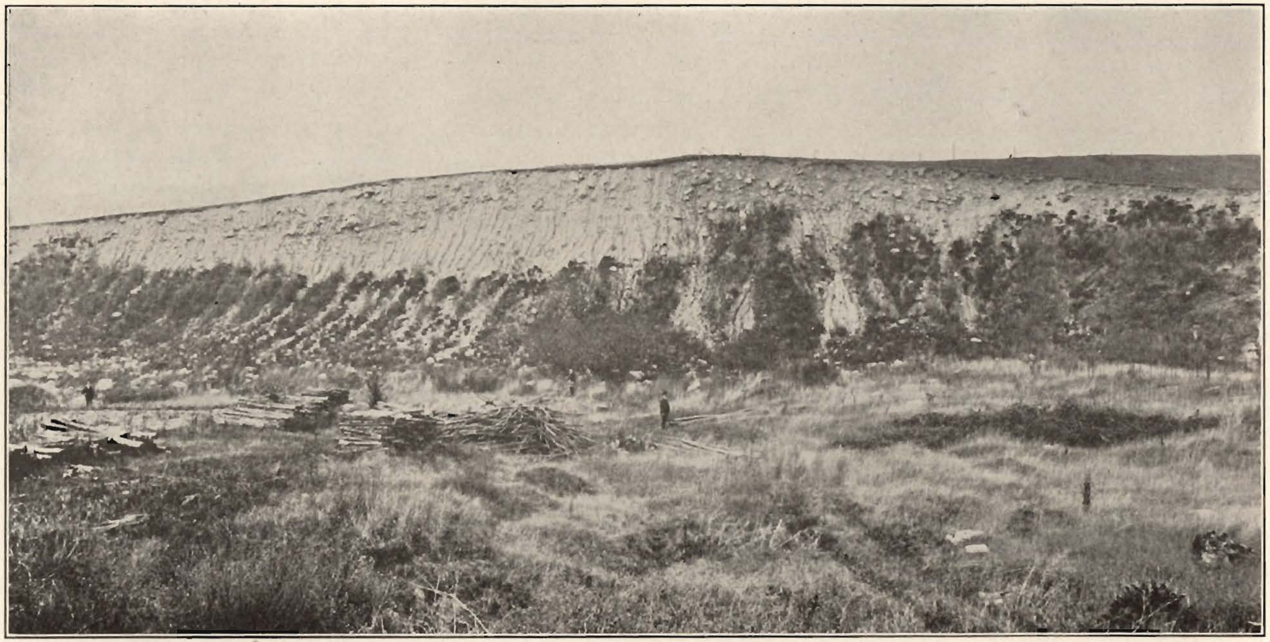
COBB'S HILL
Old excavation by Monroe Avenue. Looking east, across the Avenue

November 22, 1894

COBB'S HILL

Old pit facing Highland Avenue. Looking northeast. Compare plate 49

April 17, 1895



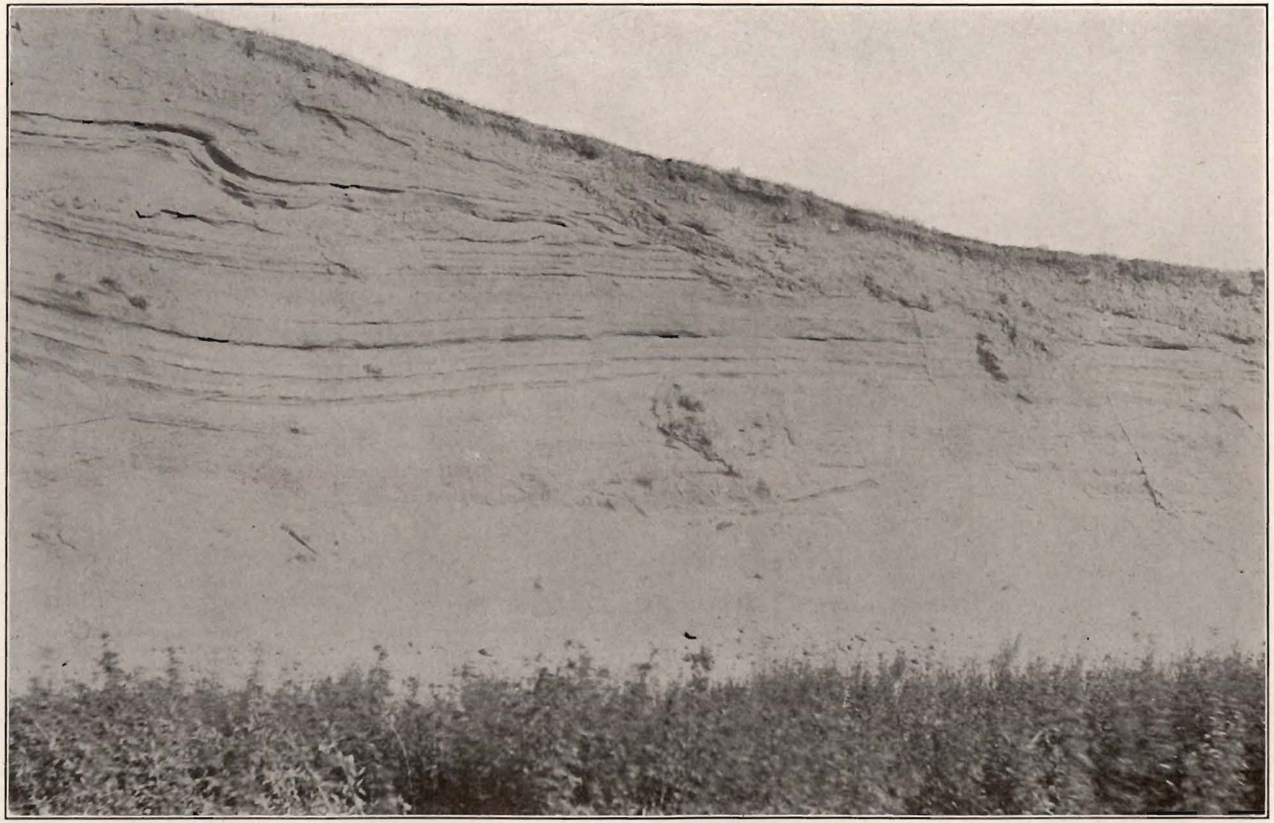
COBB'S HILL

Old pit facing Highland Avenue. Looking north. Compare plate 48

October 19, 1899

COBB'S HILL
By Monroe Avenue, back of Toll-house

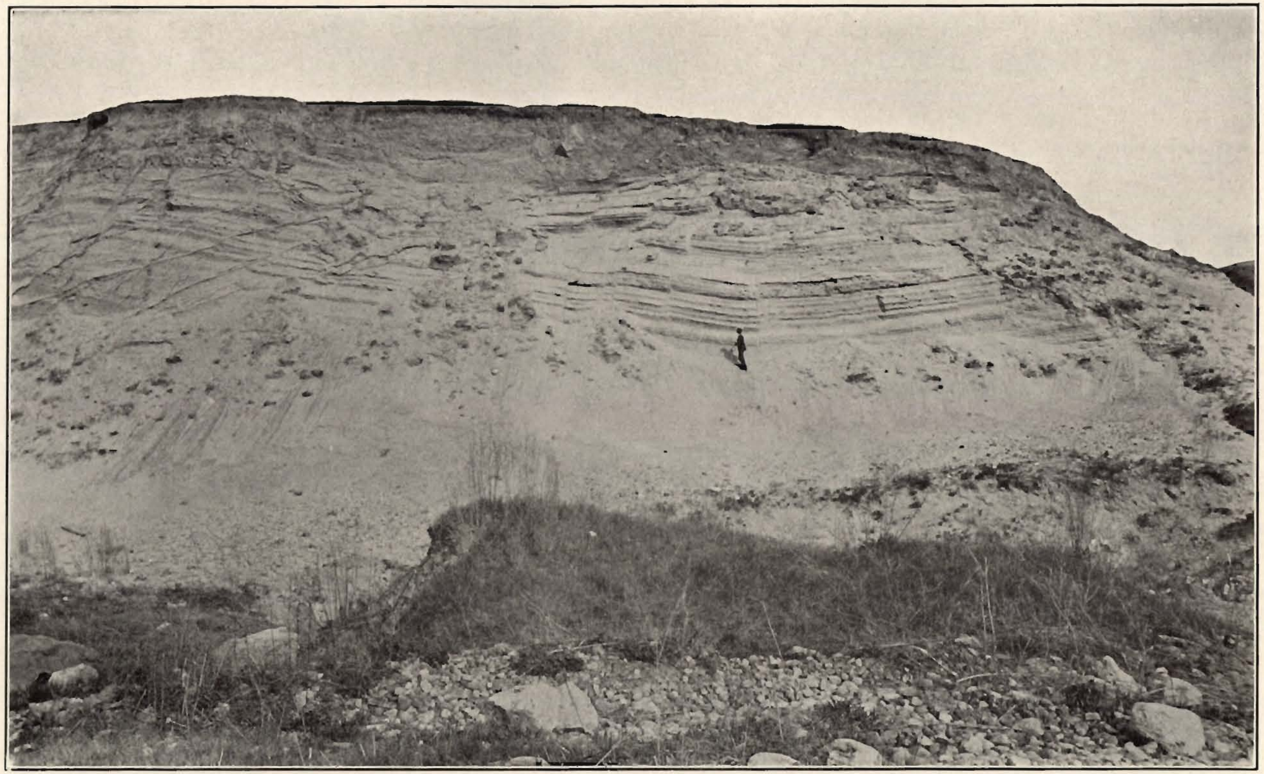
June, 1891



COBB'S HILL

North side, near Monroe Avenue. Old Northrup pit. Looking southwest. Compare plate 52

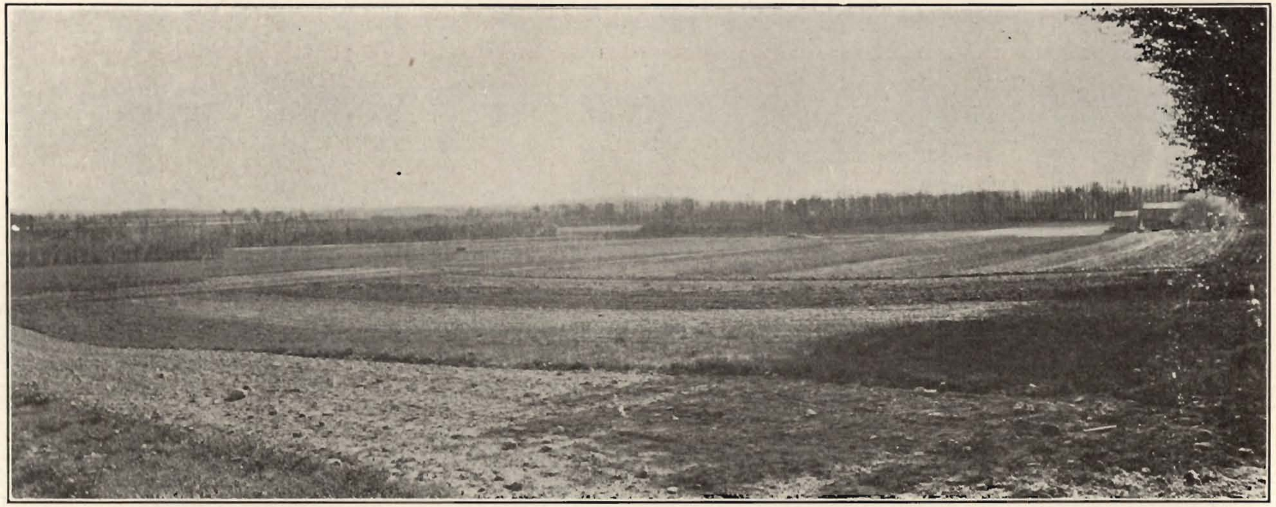
June 25, 1891



COBB'S HILL

North side, old Northrup pit, near Monroe Avenue. Looking southeast. Compare plate 51

May 15, 1903



OUTWASH PLAIN AND LAKE BOTTOM

View looking southwest from intersection of Monroe and Highland Avenues. The tract now called "Home Acres."

May 17, 1908

Avenue, toward the plain on the south. Also that patches and knolls of sand were found on the flat plain one-fourth to one-half mile away. These features had been removed in the grading for Highland Avenue and the long cultivation of the slopes and plain

The low plain south of the range carried a veneer of clay, streaked with sand, which for years supplied the brick factory on the extension of Monroe Avenue. The lake-bottom plain west of Monroe Avenue and south of Highland Avenue, now the Home Acres tract, is shown in plate 53.

The Pinnacle

Plates 54–60

This is the central area of the range of hills, and the culminating point in altitude. It includes the stretch between Monroe Avenue and South Clinton Street.

The east slope of the hill, facing Monroe Avenue, is now occupied by the Hillside Home (formerly the Rochester Orphan Asylum).

The northwest and west slopes, reaching to the apex of the hill, carry the old St. Patrick's (Catholic) Cemetery. Peck's History of Rochester states that it was established in 1838, and known as the "Pinnacle Burying Ground." In 1871 it was supplanted by the Holy Sepulcher Cemetery, on Lake Avenue, but, judging from dates on monuments, interments were made here as late as 1889. The main entrance on Pinnacle Avenue (now South Clinton Street) was left inaccessible by the cutting for the street, but the three stone columns of the gateway are yet in position, some 15 feet over the street, and appear in plate 62.

The "Pinnacle" has interesting relation to the scientific surveys of the region. As part of the geodetic surveys of the Great Lakes (1841–1881) the basin of Lake Ontario was surveyed by the Engineer Corps of the United States Army, and the Pinnacle was one of the stations for primary triangulation, occupied in 1875–1877.* The other stations of the district were Turks (Baker's Hill) south of Fairport, and Scottsville and Brockport on the west.

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*Primary Triangulation of the U. S. Lake Survey; Professional Papers of the Corps of Engineers, U. S. Army, No. 24. Washington 1882.

The technical description of the Pinnacle station is found on page 515 of the report, as follows:

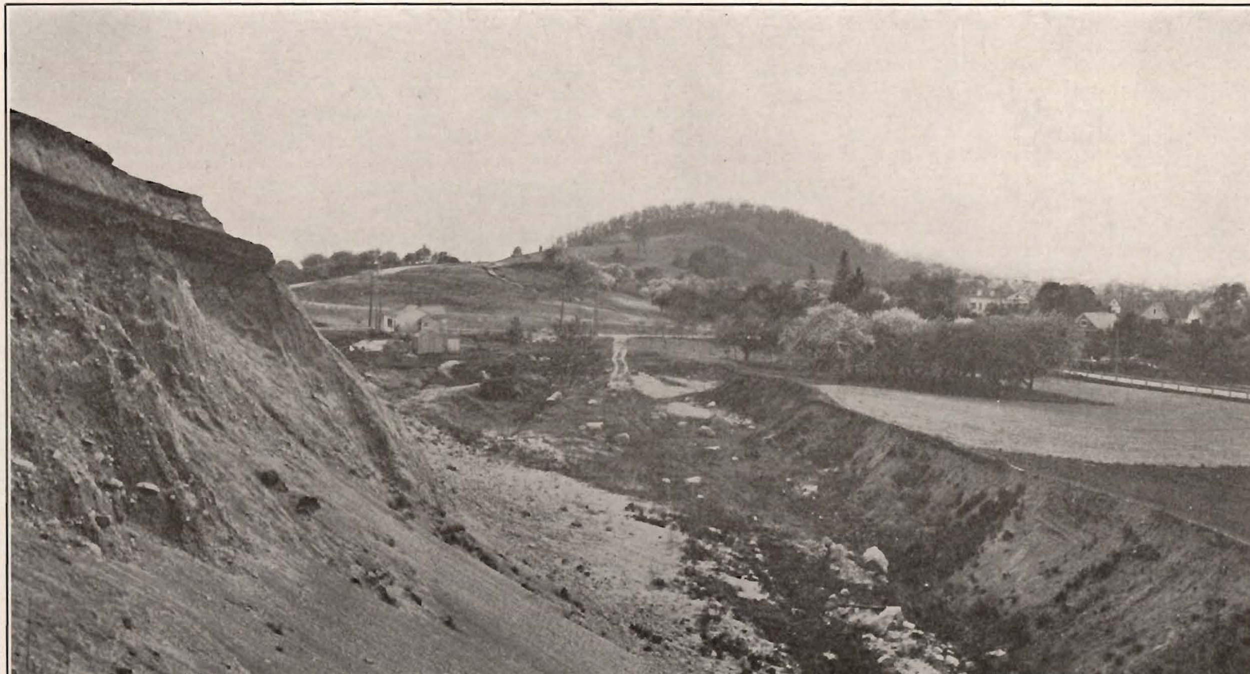
" . . . in a Catholic Cemetery, on the summit of a hill known as Pinnacle Hill, about two miles southeast of the center of the city of Rochester. The geodetic point is marked by a cross and the letters U. S. cut in a bowlder 3 feet below the surface, with an ordinary marking stone set directly over it, rising to the surface of the ground. Two stone reference posts are set as follows: one bearing north 15° 23′ west, distant 22.56 meters, and one bearing south 13° 12′ east, distant 31.73 meters from the geodetic point. A large marble monument marked Mahon on the base, bears S. 80° 55′ W., distant 87.97 meters, and a large granite monument, with Cummings on the base bears S. 70° 26′ W., distant 117.75 meters A black oak tree bears N. 82° W., distant 25.54 meters.

The height of the ground is given as 502.1 feet over Lake Ontario, which makes the altitude 748.7 feet above tide. A square tower, 33 feet high, was erected on the hill, and the four holes for the corner posts are yet conspicuous, with a depression over the geodetic point. When the U. S. Geological Survey made the topographic survey for the Rochester quadrangle, in 1893–1894, the Pinnacle station was reoccupied for the secondary triangulation. Close south of the tower site is a smooth level space which was the site of the house used by the engineers.

On the northeast slope of the hill is a conspicuous bald knob, known as Klinck knoll, (690 feet) which is a favorite view point. Blocks of Niagara limestone are imbedded in the top. An excavation, plate 56, lies in the hollow south of the Klinck knoll, opened more than 30 years ago, and abandoned probably because it revealed only gravelly and stony till. The material is largely waterworn, Medina sandstone predominating. The cobbles include many crystallines and some of the bowlders are granitoid and quartzite.

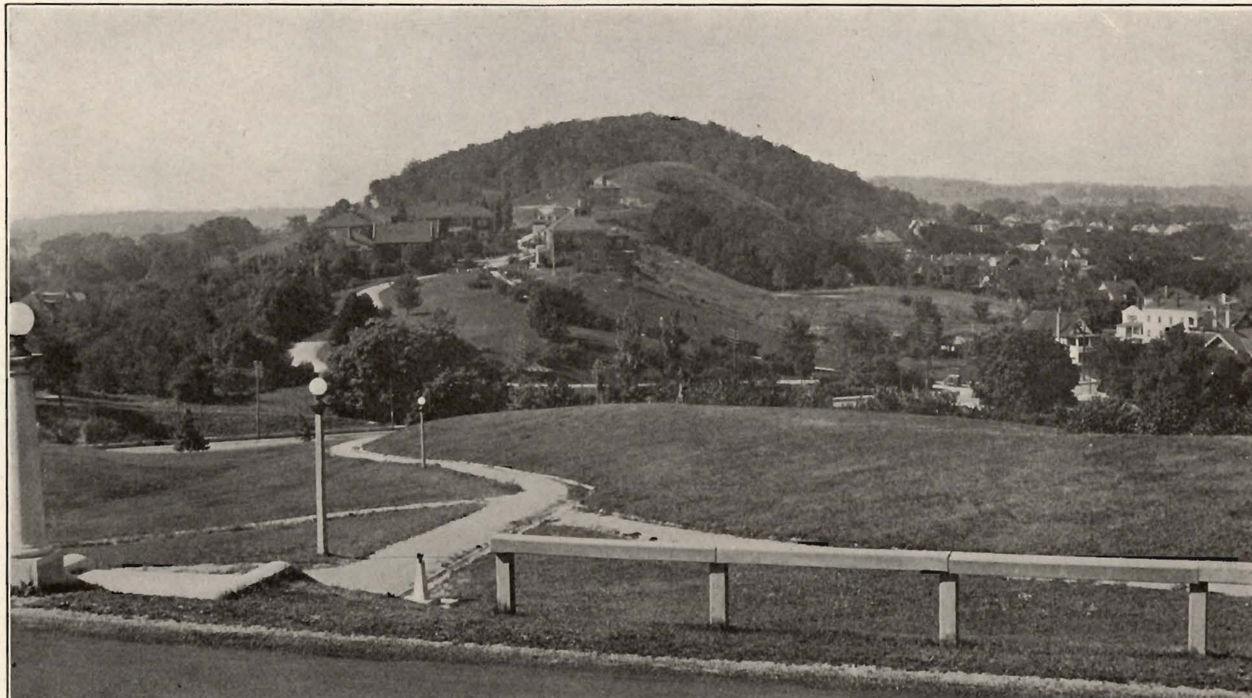
The north slope of the Pinnacle is very irregular, with gullies and knobs, partly due to the ice-contact and partly to late deposition by the ice edge. Some old diggings above the street named Pinnacle Road show ice-laid stuff or till, crowded with unworn blocks of Niagara limestone up to six feet in diameter. Such sand and gravel masses as appear have been mashed in the till.

Climbing the Pinnacle from the Hillside Home, the path up the steep east slope shows angular bowlders in the massive gravels. On the very crest of the Pinnacle are huge blocks of Niagara limestone imbedded in the deposit. The occurrence of these blocks at such



THE PINNACLE
View from Northrup pit, looking west toward the Pinnacle

May 15, 1903



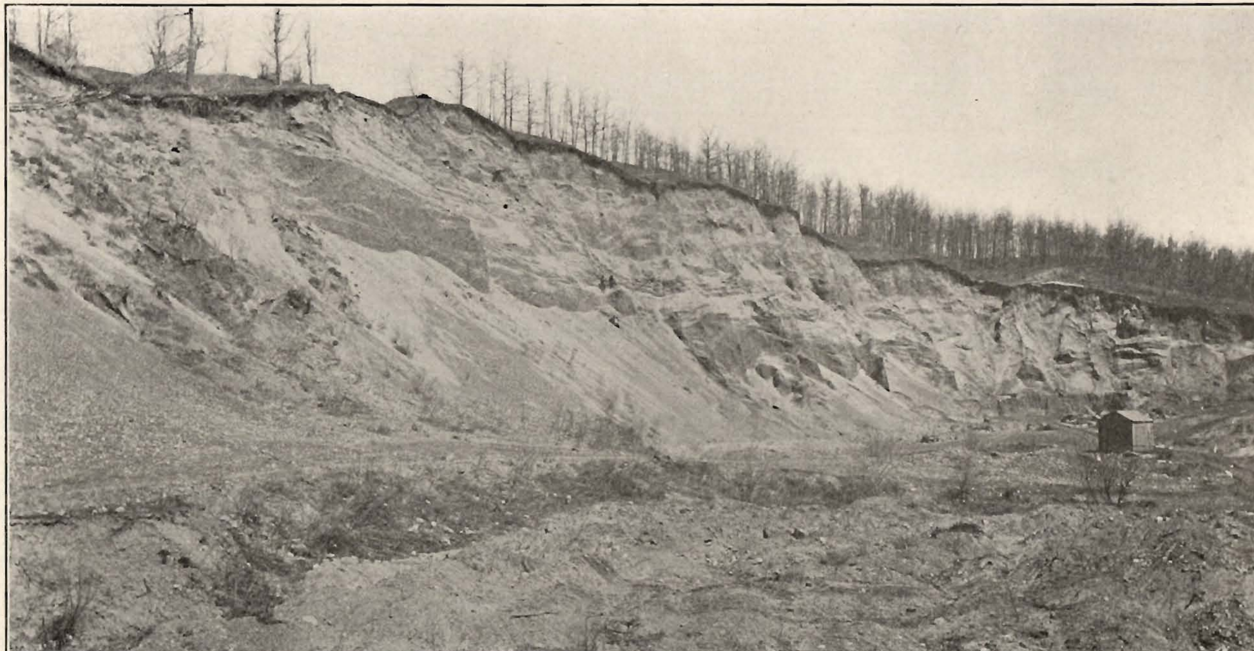
THE PINNACLE

View from the Cobb's Hill reservoir. Looking south of west. Compare plate 54

September 27, 1922

THE PINNACLE
Old pit on east slope, south of Klinck knoll. Looking southwest

November 22, 1894



THE PINNACLE
Excavation (Schwalbach) on southwest slope. Looking northeast

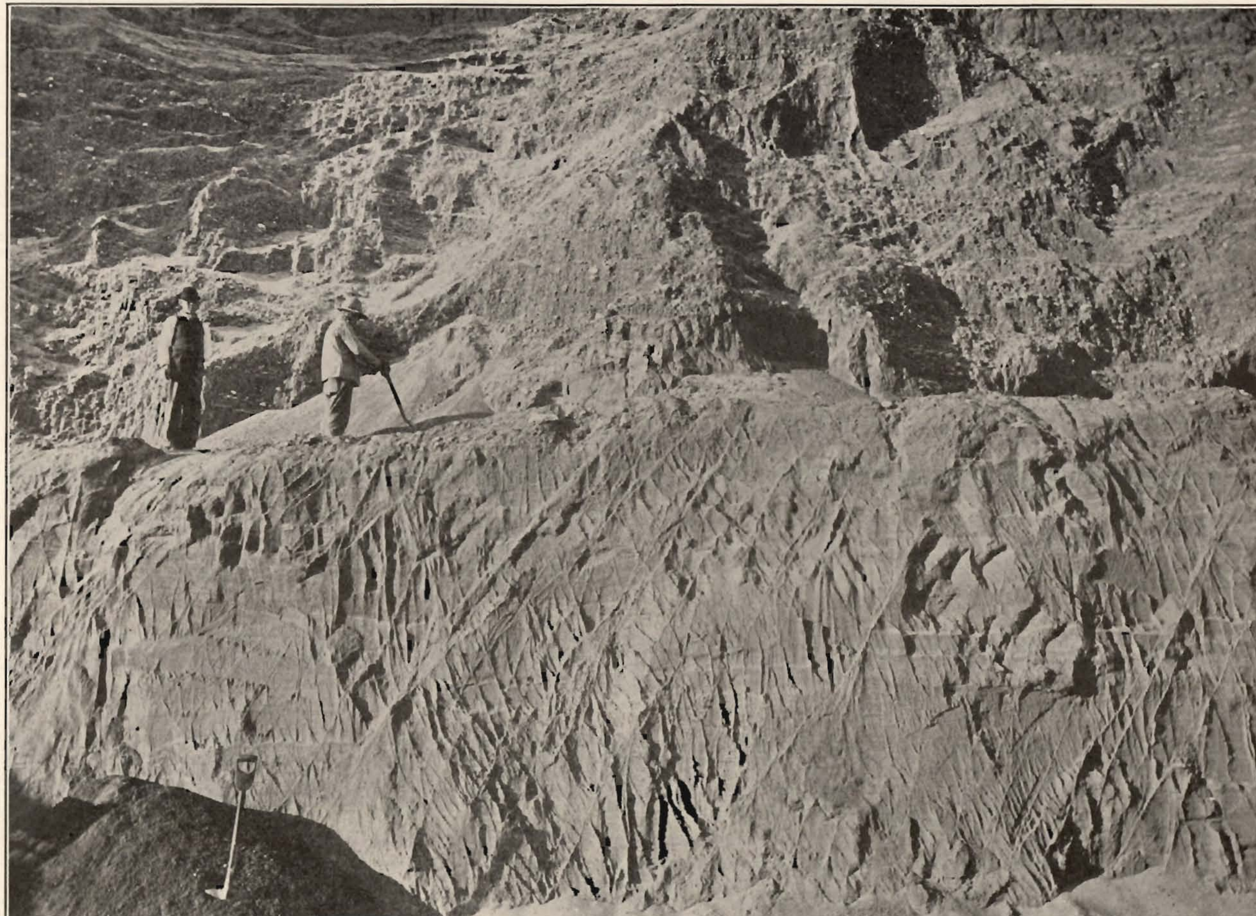
April 18, 1895

THE PINNACLE
Middle of Schwalbach pit. Looking north

April 18, 1895

THE PINNACLE
Schwalbach pit, southwest slope of hill. Looking north. Compare plate 58

October 17, 1894



THE PINNACLE
Schwalbach pit, southwest slope of hill. Minute faults in fine gravel

October 17, 1894

height suggests interesting questions relating to the mechanics of glacier work. The northern outcrop of the Niagara (Lockport) limestone lies through the center of the city. The limestone blocks must have been plucked from their original positions by the bottom ice. Hence within a maximum distance of about two miles the ice sheet lifted the bowlders about 275 feet (460–480 feet up to 749 feet). It is inferred that the relatively thin edge of the plastic ice sheet, charged with its rock burden, was pushed up the north slope of its own morainic deposit by the impulse of the thicker ice on the north, perhaps assisted by the buoyant effect of the lake waters.

One of the largest excavations in the entire range, and the one with the highest face, is the Schwalbach pit on the southwest side of the hill, shown in plates 57–60. The exposure was over 100 feet in height. In recent years this pit is abandoned and the crumbling walls have buried the interesting glacial records, partially preserved in the old photographs.

This excavation encroached on the cemetery, and at one time the irreverent work exposed the contents of neglected graves. Unlike modern exploration and desecration of Egyptian and other ancient tombs this could not be excused as in the interest of history and archeology. The top of the slumping bank of the excavation is now (1923) about 734 feet elevation.

Like other exposures in the range the materials here were varied and changed character as the excavation extended. The upper portion, perhaps one-third of the vertical face, showed no bedding but was tumultuous, apparently crushed by the advancing and overriding ice sheet. Below this the bedding was clear, but in some places exceedingly faulted and veined, as shown in plate 60. Some masses were firmly cemented. There was a general dip of the beds 10 to 15 degrees in direction southeast, or even eastward. In the center of the pit a stratum of fine sand, much distorted, about 15 feet thick, lay beneath the non-bedded upper deposit. This stratum shows in plates 58, 59. It declined eastward about 50 feet in a distance of 400 feet.

Few bowlders occurred in this pit, but two large Medina blocks were noted and several granitic bowlders. A count of the pebbles made by the students showed that up to egg size 50 per cent were Medina, and above that size about 35 per cent. Near Clinton Street uptilted strata and remarkable sand concretions occur (plate 65).

The Schwalbach pit has deeply cut the south slope of the hill westward to, and beyond, South Clinton Street, which street is here made the limit of the Pinnacle area.

Along Highland Avenue, south of the Pinnacle, and near the east end of the great Schwalbach pit, cutting has been made in the south side of the range, on lands of J. L. Schrader, C. A. Schrader and Frank Crouch. The exposure here is heavy, gravelly till at the top, with many stones, and very large bowlders (plates 65, 77). Below are gravels which grade down into sand. This is one of the two localities where till has been found on the south side of the range.

On the west slope of the Pinnacle four terraces, or benches, are seen. The highest one carries the Cummings burial plot and monument referred to in the description by the U. S. Lake Survey engineers. The elevation is about 725 feet, which corresponds to the summit plane of Lake Dana on this parallel. It is possible that this small terrace is artificial.

A larger terrace is probably natural. A level space, some 50 feet wide and 150 feet across the ridge, has elevation about 700 feet. At the east end this carries a drive and the enclosed Hughes burial plot. The steep bank on the east has the appearance of a wave-eroded cliff. Toward the west end of the larger terrace the enclosed burial plot of Brennan is about three feet higher, and the original surface there is about six feet over the smooth lower area next to the cliff.

A lower bench of rolling surface, at about 660 feet, carries the monuments of John McCambridge and Bernard Lennon.

The lowest and strongest terrace is quite certainly natural, with elevation about 648 feet. It is about 50 by 250 feet in area, covering the top of the ridge, near Clinton Street, and carries a number of plots, the tall Cochrane monument standing at the east end. The old drive entering from Clinton (old Pinnacle Avenue) curves around the east end of this terrace. This terrace is the same elevation as the level-topped ridge west of Clinton Street.

Clinton Street and the Lowland Westward

Plates 61–67

The natural geographic division between the Pinnacle mass and the Highland Park area is the sag in the range, half-way between

Clinton and Goodman Streets. But the lowland, with some special features, is included, for description with the Clinton Street area.

At Clinton Street, S. the main ridge has been deeply excavated by westward extension of the Schwalbach cutting, as shown in the photographs, and some work is yet in progress (plate 61).

Here the material is mostly sand, and much of it so fine or with so much silt that the excavation has been irregular. Cementation of the sand, by deposition of lime, has also interfered with the work.

All of the original bedding here has been disturbed, and much of it has been obliterated. Some sections show much faulting, with production of interesting reticulated structure (plates 64, 60, 32). Probably the movements which produced these structures occurred when the sands were solid by freezing. Plate 65 shows a spire close to the street in which the sand strata have nearly vertical position. At the time of writing (April, 1923) this locality is the best exposure in the range for the study of disturbed and distortion structures.

Relatively few bowlders are seen in the Clinton Street cuttings, but they do occur, and several are noted in position, imbedded in sand at both high and low levels. (Plate 65.) Some gravel appears in plate 63, but the masses in plate 64 are only firm blocks of the partially cemented and reticulated silty sand. Considerable color is noted here, greenish, yellowish and pink layers. Some of the reddish and clayey sand is indurated into "stone."

As elsewhere in the range the lowest exposed beds are stratified sand. East of Clinton Street, perhaps one-eighth of a mile, in the bottom of the old Schwalbach pit, where perhaps 100 feet of overlying gravel has been removed, 15 feet of clean, fine sand is exposed in an active operation. The elevation at the bottom is about 580 feet, somewhat below the summit of the street.

West of Clinton Street the remnant of the main ridge has a level crest, at about 648 feet; the same height as the lower, strong terrace east of the street in the cemetery.

North of the main ridge, and west of the street, is a minor, very stony morainic ridge, which carries a small cemetery, the St. Boniface Church Cemetery. Between this later ridge and the main ridge is a deep sand excavation, now partly filled and leveled for a baseball ground. It had reached perhaps 30 feet below the street, with the face of the pit rising 40 feet, more or less, above the street. No original bedding was shown here. A new street, Highland

Parkway, in line with Field Street, is planned to occupy the hollow between the ridges.

The decided sag or depression in the range between Clinton and Goodman Streets represents deficiency in the moraine building; and this has been increased by the production of kettles, due to the melting away of ice-blocks which had been more or less buried in the drift deposits. Three large and handsome kettles lay here, two of which are shown in plates 66, 67. The one with the geology class "in a hole" was in the very axis of the range and at the lowest point in the sag.

Another large kettle, and scientifically the most interesting of the three, was situated between the two basins noted above. It lay in a deep embayment in the north side of the high ridge, and was known as the "peat-bog kettle," and was described in a paper, number 9 of the appended list of writings.

This kettle had evidently been a deep lakelet but had become filled with decomposed vegetal matter, or peat, by the drifting in of forest materials and by the growth of swamp vegetation. In wet seasons the marsh was wet, but in the summer it was dry. The level floor of the basin, oval in form and about 140 by 300 feet in dimensions, was occupied by a growth of yellow birch which had developed "knees" so as to lift the trunks above the water. The peat was used by Ellwanger & Barry, who owned the area, for packing the roots of nursery stock for shipment, and it was probed to a depth of 25 feet.

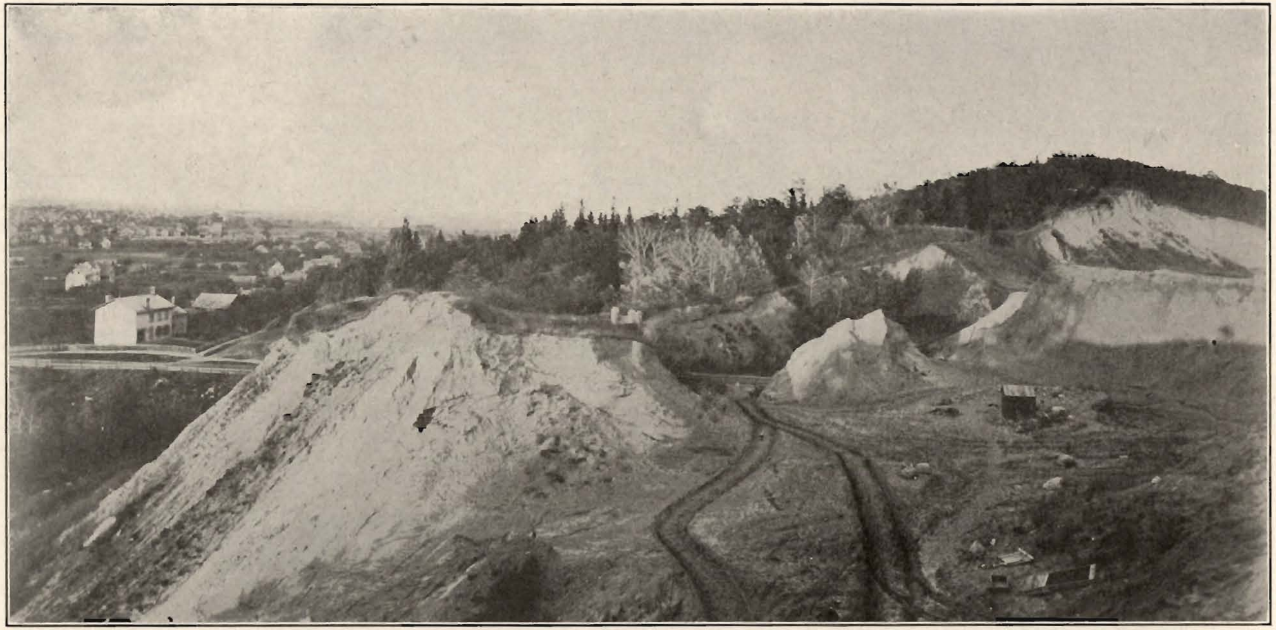
The presence of standing water in these kettles for considerable part of the year implies an impervious bottom, but whether till or rock is unknown. Directly north of the peat bog was another small kettle with a wet-weather lakelet.

All of these beautiful topographic features, of scenic and scientific interest, have been destroyed. The kettle shown in plate 66, with adjacent basins, has been made a city dumping-ground for ashes and rubbish, and the peat-bog kettle is suffering the same shameful fate. The charming lakelet, plate 67, lay only a short distance east of Goodman Street, and is now obliterated by real estate development. It has been filled and the site traversed by a new street lying south of Rockingham Street, the Highland Parkway.

SECTION AT SOUTH CLINTON STREET

View from west slope of the Pinnacle, looking west. Extension of the Schwalbach working

April 18, 1895



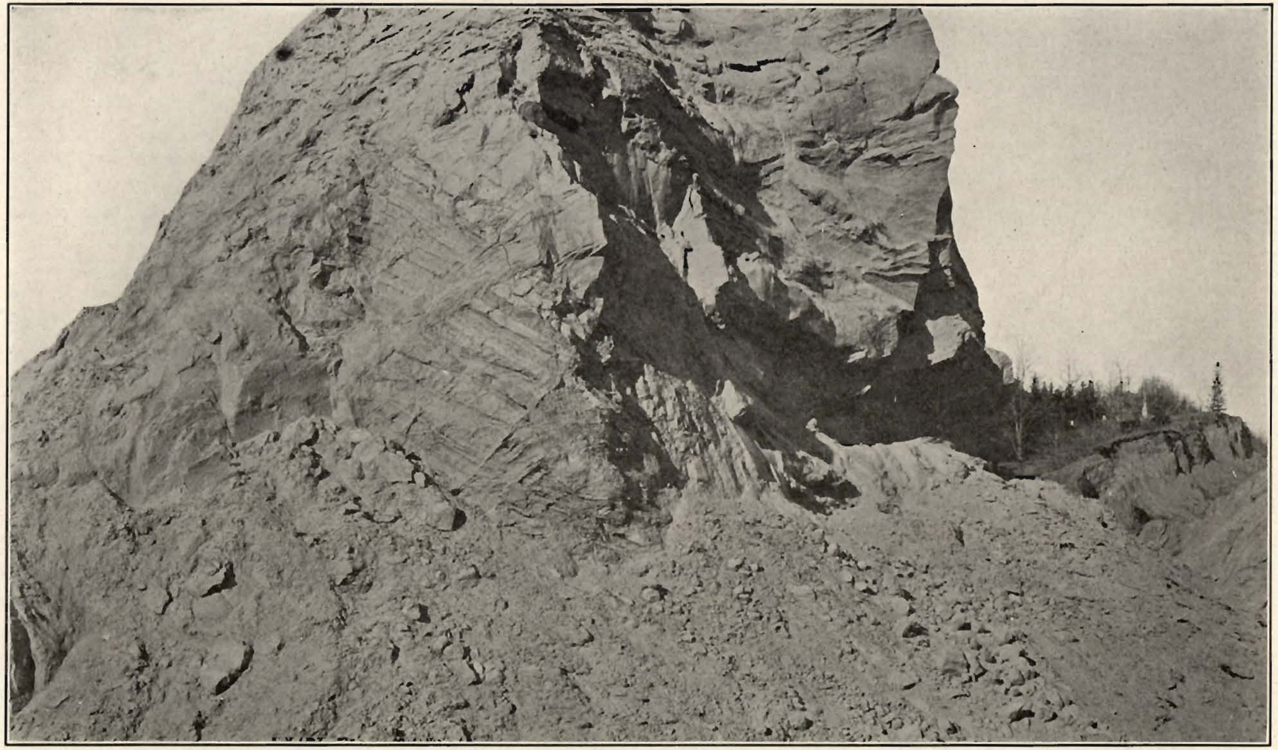
SECTION AT SOUTH CLINTON STREET

View looking north of east, toward the Pinnacle. Clinton street crosses the picture, left to right

October 17, 1894

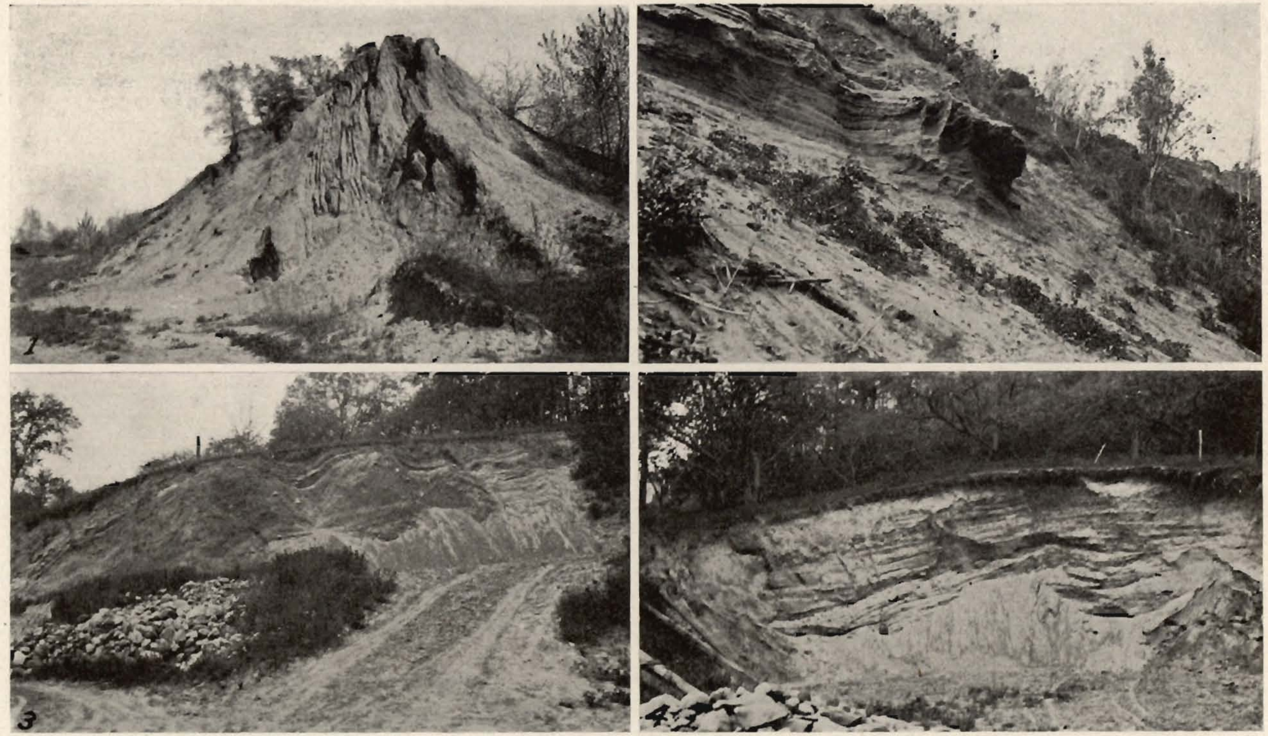
SECTION AT SOUTH CLINTON STREET
Excavation west of the street. Looking southeast. Sands highly crumpled

April 18, 1895



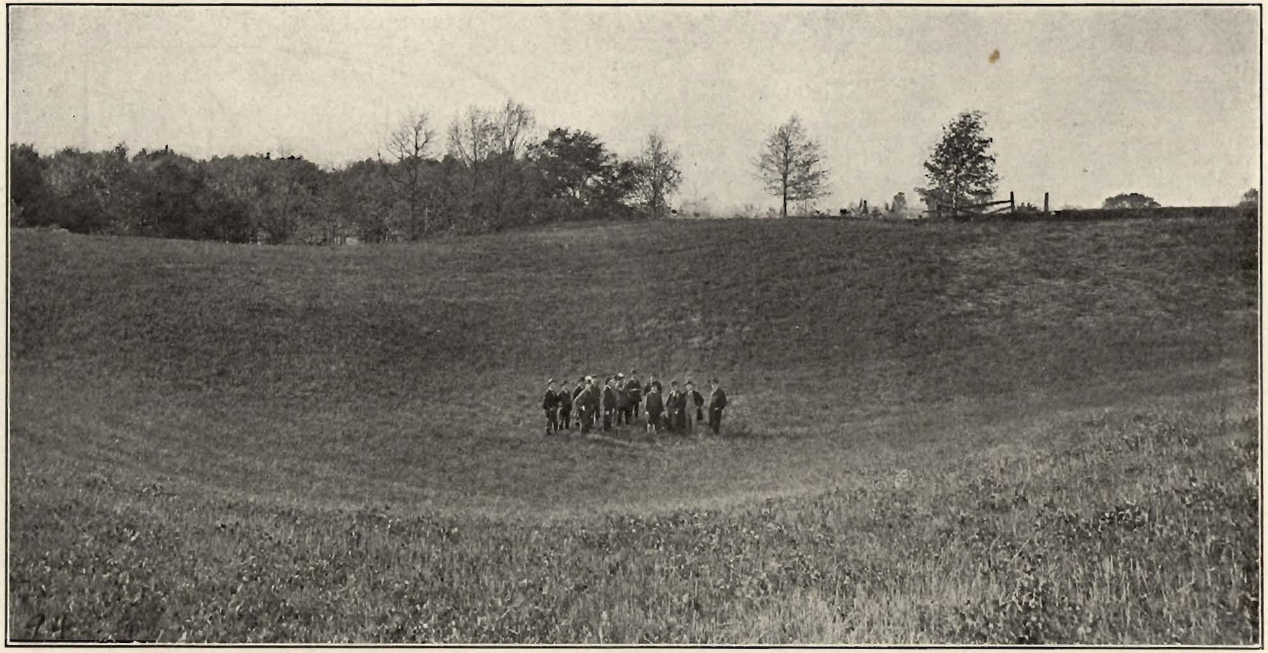
SECTION AT SOUTH CLINTON STREET
Rectangular structure produced by complex fautling, in sandy silt

April 18, 1895



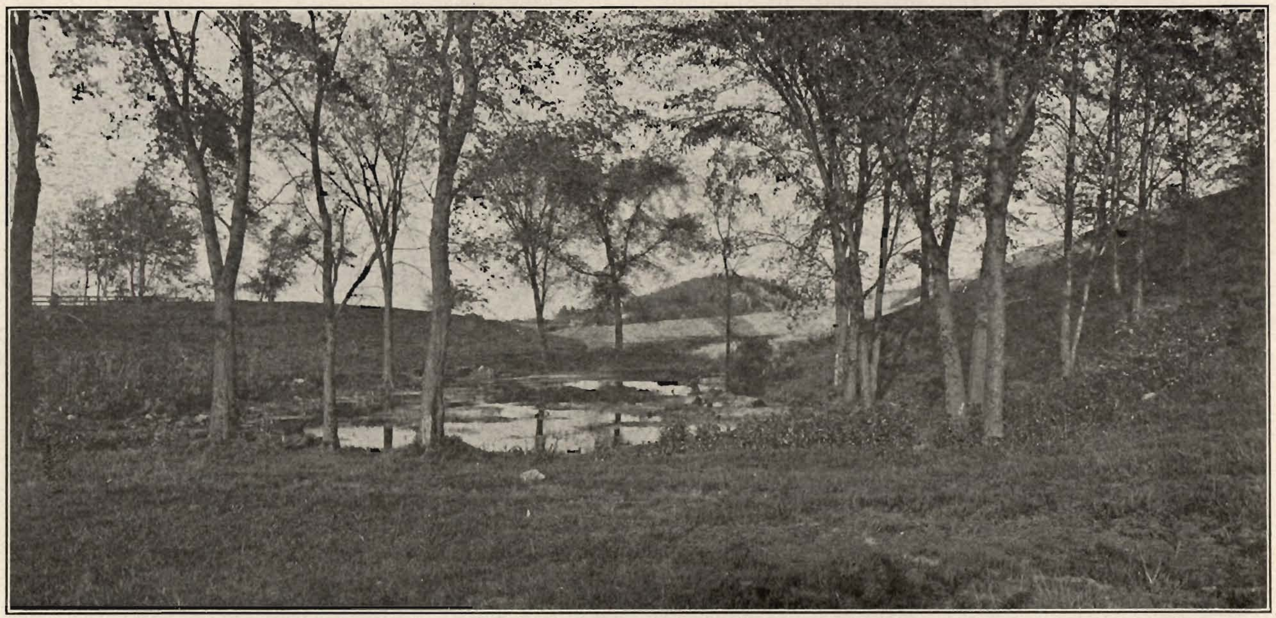
STRUCTURES ON THE SOUTH SLOPE OF THE PINNACLE

1. Upturned beds of fine sand, east side of Clinton Street. Looking southeast
2. Indurated (lime-cemented) sand, east of Clinton Street. Looking northeast
3. Contorted gravel beds, south of the Pinnacle. In the Schrader pit. Looking west
4. Gravel beds back of No. 3. Looking north



LOWLAND WEST OF CLINTON STREET
Kettle in low point of the range. Looking north

May 16, 1895



KETTLE-LAKE EAST OF SOUTH GOODMAN STREET

View looking north of east. The Pinnacle in the distance

April 18, 1895

South Goodman Street Section

Plates 68–72

In the year 1894 South Goodman Street was extended across the Pinnacle range by a cutting over 40 feet deep. And our information reaches deeper, because at the same time a large sewer, connecting the County buildings on Mt. Hope Avenue, was constructed in a tunnel 35 feet below the present summit of the highway. The City Engineer's elevations are as follows:

Original crest of the ridge	623.24	feet
High point in the street	580.94	"
Elevation of sewer	545.84	"
Depth of sewer below street	35.10	"

The entire exposed section was in sand, and the tunnel was wholly in fine, reddish sand. The tunnel contractor stated that five large bowlders were encountered. The smaller ones, 150 to 200 pounds, were found in the course of the trunnel, but the largest, about one ton in weight, lay over the tunnel and fell in. The presence of bowlders in fine, bedded sand proves a rafting process, and here it implies the work of floating ice-blocks or miniature icebergs, detached from the rough ice-front, which was faced by lake waters of some depth.

Through the south slope of the ridge the sewer excavation was an open cut, showing the same fine, reddish sand with some clay layers; and near the top some thin layers of fine gravel. The top and south slope of the ridge showed red Medina gravel, collected by the removal of the sand by wind erosion.

A smaller ridge south of the main ridge was trenched for a conduit leading to the Mt. Hope Reservoir, ascending the ridge obliquely, and which revealed mainly fine sand, with thin streaks of gravel and frequent bowlders. At a later date a pit on the south side of the south ridge, on the west side of the street and near Highland Avenue, showed distinctly bedded sand and gravel in thin and rapid alternations. Many angular stones and glaciated blocks were scattered through the deposit, with some till-like masses. The latter could have been dropped in a frozen state. No faulting or other disturbance was observed here. Opposite this pit and on the east side of the roadway the material appeared as true till, heavy and compact, with angular and striated stones.

These details are given to emphasize the varied composition of the moraine and the fickle character of the geologic agents. The remarkable cross-bedding and erosion structures shown in plate 71 indicate a history, or succession of deposition and erosion, which challenge any attempt at translation.

Between the main ridge and the smaller one on the south some large granite bowlders lay on the surface, and a few others were seen in the nursery on the main ridge east of the street.

This Goodman Street section is remarkable for the great depth and breadth, practically the entire range, of bedded sand, the gravel being insignificant. This section is in striking contrast with the coarse material of the Pinnacle, only three-fourths of a mile away. The sand was too fine for concrete. Much of it was so silty and adhesive that it resisted removal by the wind. The structure and flow-laminae, and the periodic variation in conditions of deposition, were elegantly revealed by the autumn winds (plates 69–72). The general direction of water-flow, as shown by the ripples, was south 15 degrees west.

Some very conspicuous and handsome faults are shown in plates 69, 70. The two faults in plate 70, on the east side of the cut, become broken into compound faulting on the other side of the cut, as shown in plate 69.

North of the main ridge at Goodman Street is a lesser but strong ridge, from which the picture in plate 68 was taken. This morainic ridge extends west to the Highland Hospital. It is separated from the main ridge by a distinct hollow, perhaps 300 feet across. The grading for the street cut about 15 feet, vertically, into this till ridge, and the sewer trench, 14 feet deep, showed six feet of till beneath which was sand of unknown depth, as in the main ridge. Two square pits for sewer inlets excavated seven feet below the curb gave good sections of the lowest till. The complete section of the pit at the east curb is as follows:

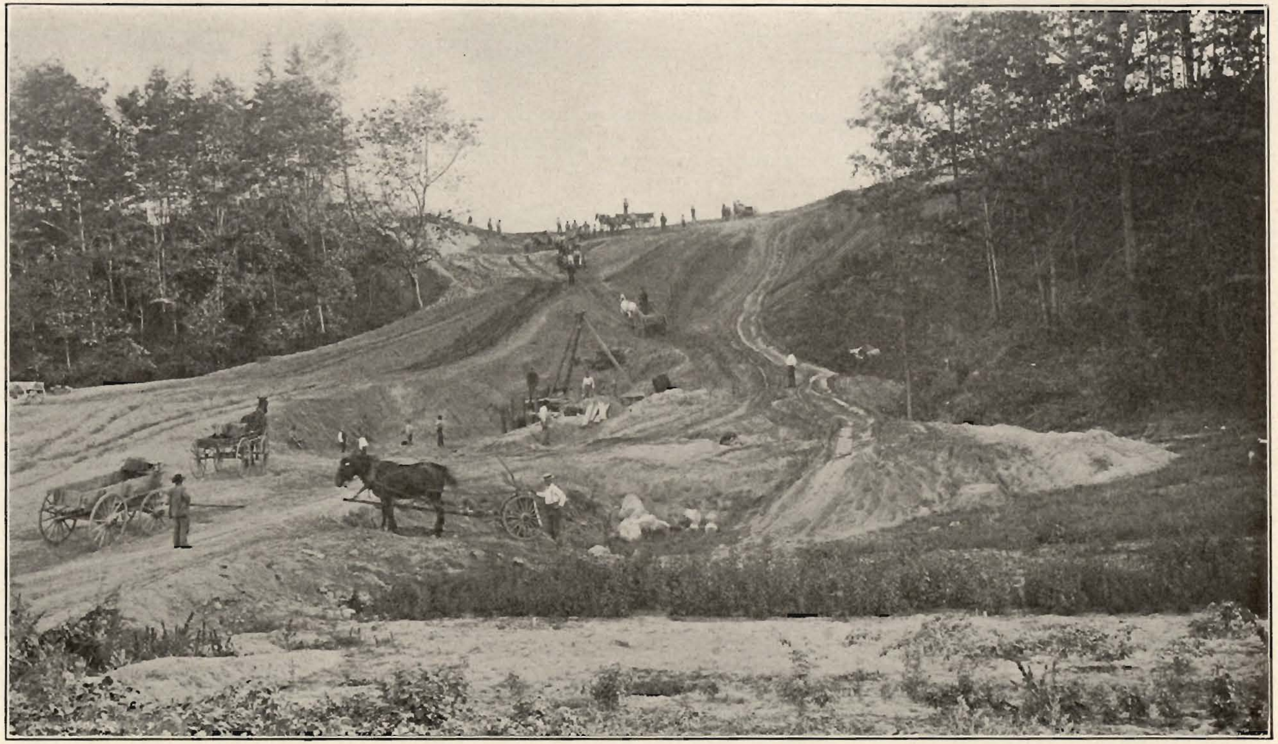
A. Surface of ridge, yellow sand.

B. Reddish till, 10 to 15 feet.

C. Brick-red till, two feet. Containing angular stones of limestone and crystallines. The lower limit sharply defined.

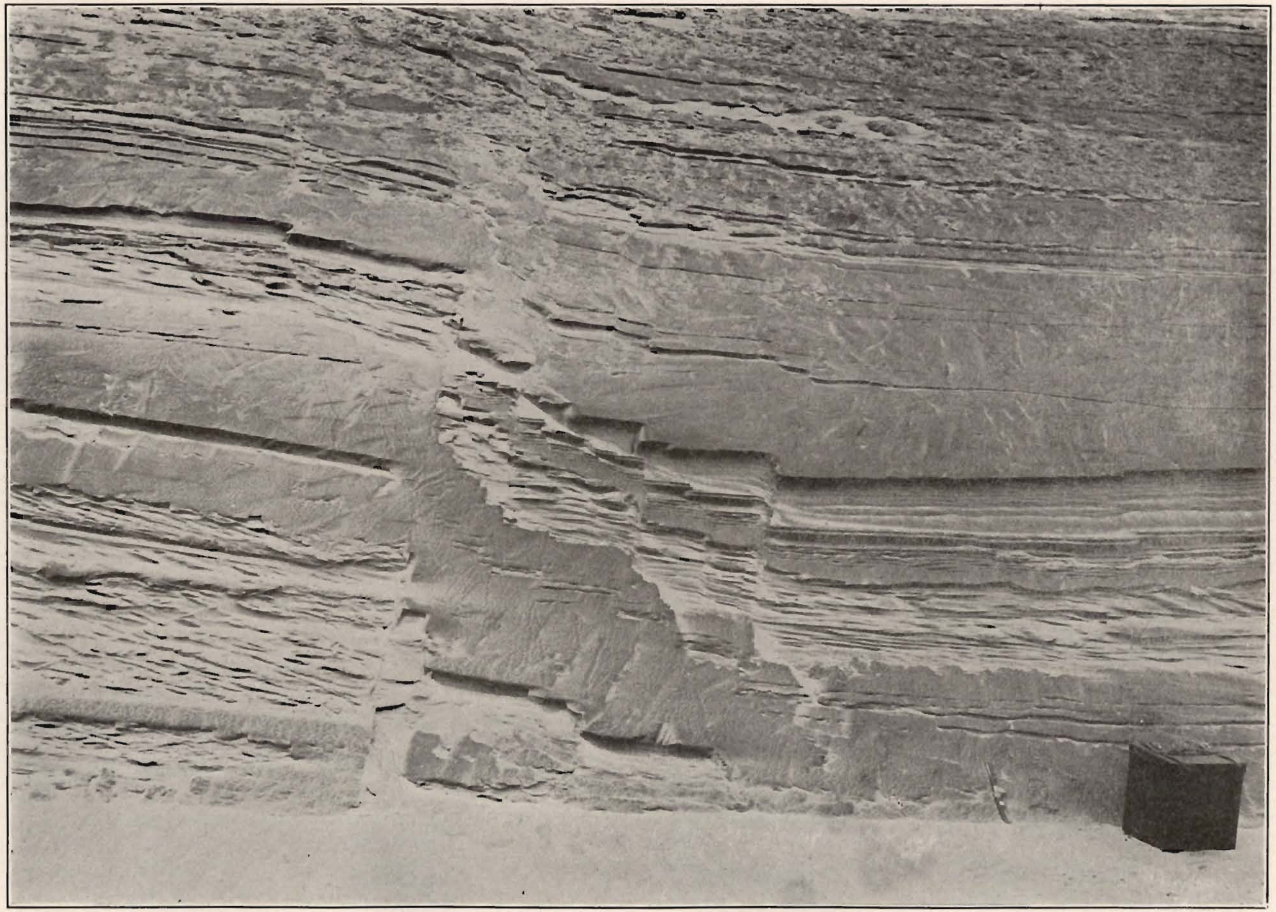
D. Yellow till, 18 inches. Streaked with thin sand layers, and holding Medina and limestone pebbles. Reddish at bottom.

E. Red, laminated clay. Crumpled and distorted. About one inch.



SOUTH GOODMAN STREET SECTION
Cutting for street extension. View looking south

September 27, 1894



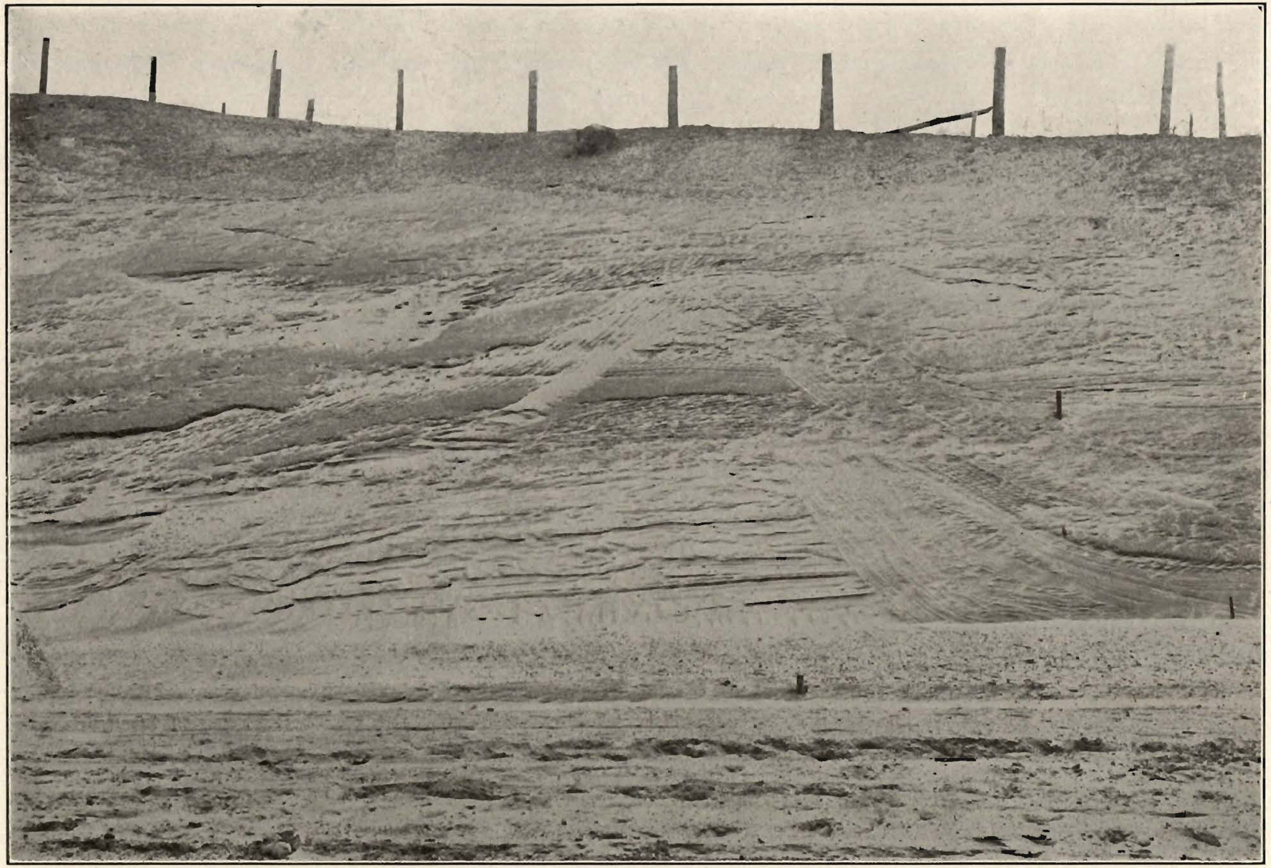
SOUTH GOODMAN STREET SECTION

Faulting in sand strata. Compare plate 70. Looking northwest

November 18, 1894

SOUTH GOODMAN STREET SECTION
Double fault in sand beds. Compare plate 69. Looking east

November 18, 1894



SOUTH GOODMAN STREET SECTION

South end of cut; looking east. Erosion and unconformity in fine sand

November 18, 1894

SOUTH GOODMAN STREET SECTION
Alternation of coarse and fine sand layers. Looking northwest

November 18, 1894

F. Gray till, 20 inches. With no stratification; some gravel, and few pebbles.

G. Fine sand, for at least seven feet. Clean, sharp, well stratified, with some gravel.

This is a record of at least seven changes in the process of deposition. The thick basal sand indicates open water. The overlying till represents overriding by the ice-sheet, with considerable variation in its action.

West of Goodman Street a great excavation between the Highland Park mass and this northern ridge has exposed a section of the latter where it is much higher than at Goodman Street. Here 10–15 feet of till caps the sands and gravel. (See next chapter.)

This northern moraine ridge appears to represent the latest pause of the thin ice-front before it made its final and more rapid retreat. It correlates with the St. Boniface Church Cemetery ridge, west of Clinton Street; and with the till ridge by the "eastern widewaters" (now converted into a public skating rink).

Highland Park Area

Plates 73–76

This area extends from South Goodman Street west to Mt. Hope Avenue, being bisected by South Avenue. Excepting a large excavation, by Ellwanger & Barry, on the north slope, it is fortunately preserved as city park or residential tracts. The surfaces have been somewhat modified, but not sufficiently to destroy its morainic aspect.

The eastern portion, between Goodman Street and South Avenue, consists of two ridges, like the Brighton and Cobb Hill areas. But here the ridges are larger, more distinctly separated, and of higher relief. The intervening hollow is 50 feet or more in depth, and the knolls rise 120 feet over the Rochester plain. The south ridge carries the Memorial Pavilion and the Mt. Hope Reservoir. The main park driveway between South Avenue and Goodman Street lies in the hollow between the ridges. Plates 73, 74 show this depression as it was in 1894; but the grading and artificializing has somewhat changed the appearance.

The largest kettle in the area is close to South Avenue on the west, in the northeast corner of the city property west of the avenue, in what was the "Warner tract." The swampy bottom is now an artificial pond, surrounded by pleasure and tennis grounds.

The till ridge on the north, mentioned in the preceding chapter, appears in plate 74. Plates 75, 76 were photographs of the large excavation north of the main ridge as it was in 1895. It then showed a vertical face of nearly 100 feet, with the usual variation of sand and gravel, with the structures due to original deposition and the subsequent disturbances by the ice push. The excavation had reached into the minor till ridge on the north, and showed about 15 feet of till capping. One huge block of Niagara limestone was seen beneath the till, and many smaller bowlders. This excavation is now (1923) in use for making cement block, and some of the structures may be seen. A deeper pit in the east end of the large excavation showed clean fine sand, as might be expected so near to Goodman Street, with the layers slanting in different directions.

Trenches for water mains in connection with the reservoir revealed variations in the water-laid materials and their structure, which would be tedious to describe.

The cutting for South Avenue showed two or three feet of fine, yellow sand, so frequently found as the surface deposit. Beneath this was 15 feet of pinkish or yellow sandy till, or what might be called a stony sand.

It may be noted that the north-and-south line across Highland Park area shows three distinct moraine ridges.

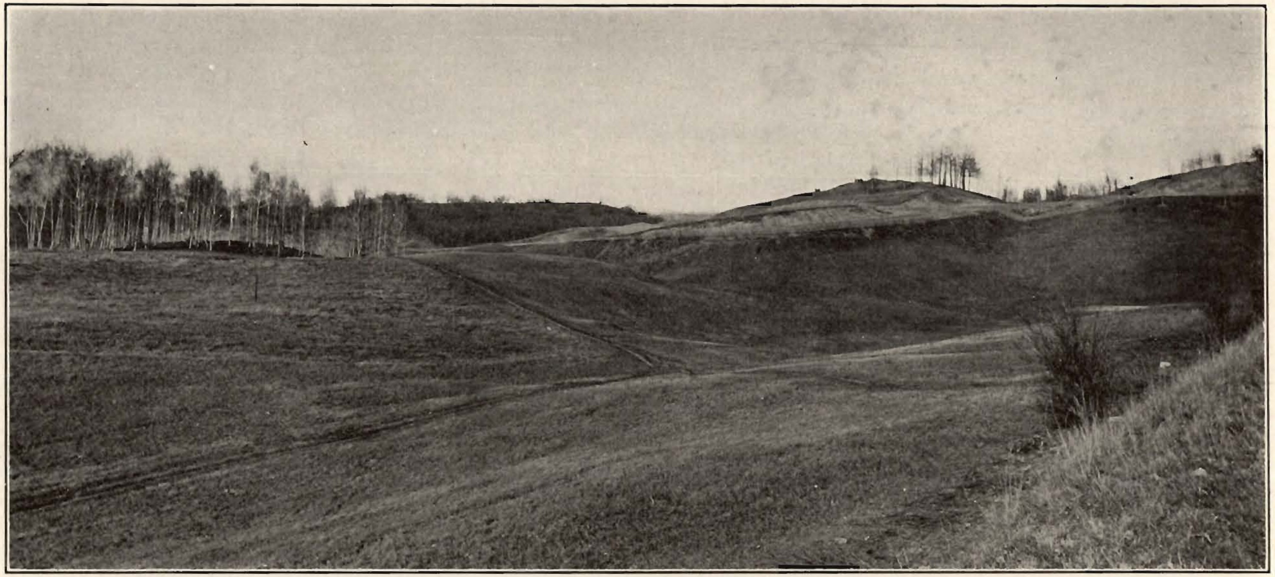
Mt. Hope Cemetery Area

This area extends from Mt. Hope Avenue west to the Genesee River and to the cut across the moraine for the Erie and the Lehigh Valley railroads. The northern part of the area, which is the older portion of the cemetery, is an unsurpassed example of kame topography. The knob-and-basin forms give high and sharp relief. Deep kettles lie among tall, steep-sided, conical gravel mounds, producing an unusual land surface. It is very difficult to obtain satisfactory photographs of the kettle-basins, but the failure here to include pictures is not serious, because the features are preserved and open to easy observation.

Where so much of sentiment and reverence are demanded of the visitor to this most beautiful of cemeteries the natural geologic features may be unnoticed or unappreciated. But it will not de-

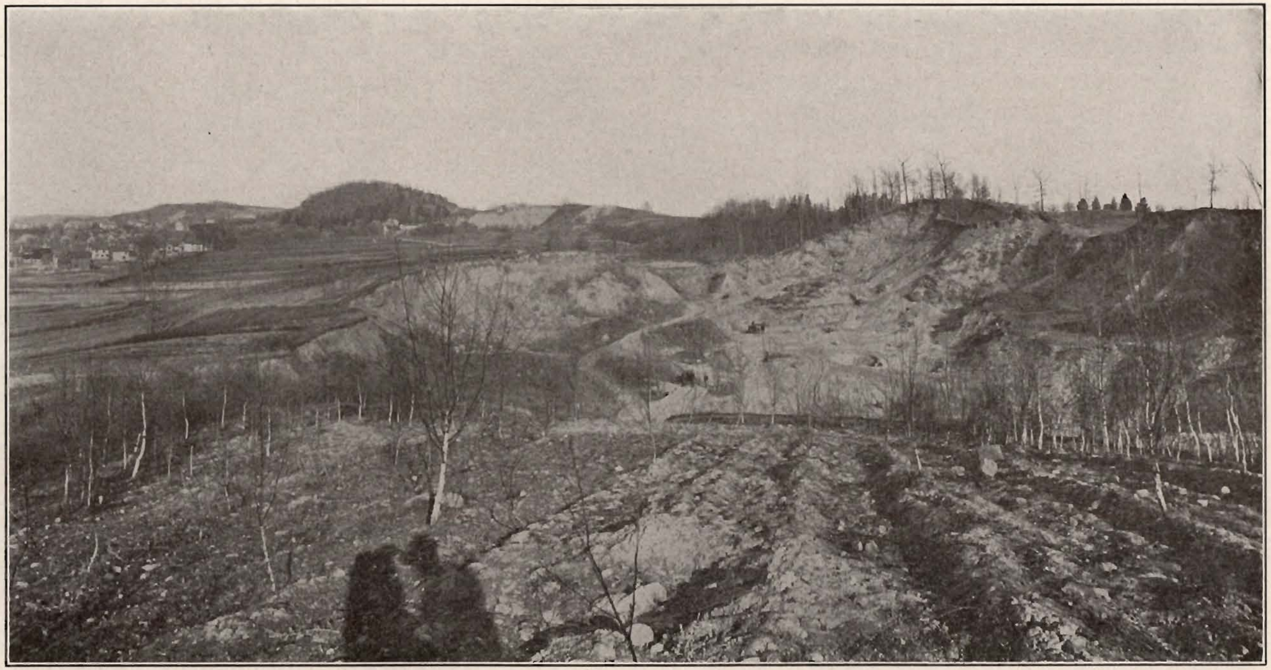
HIGHLAND PARK AREA
View looking southeast

September 1894



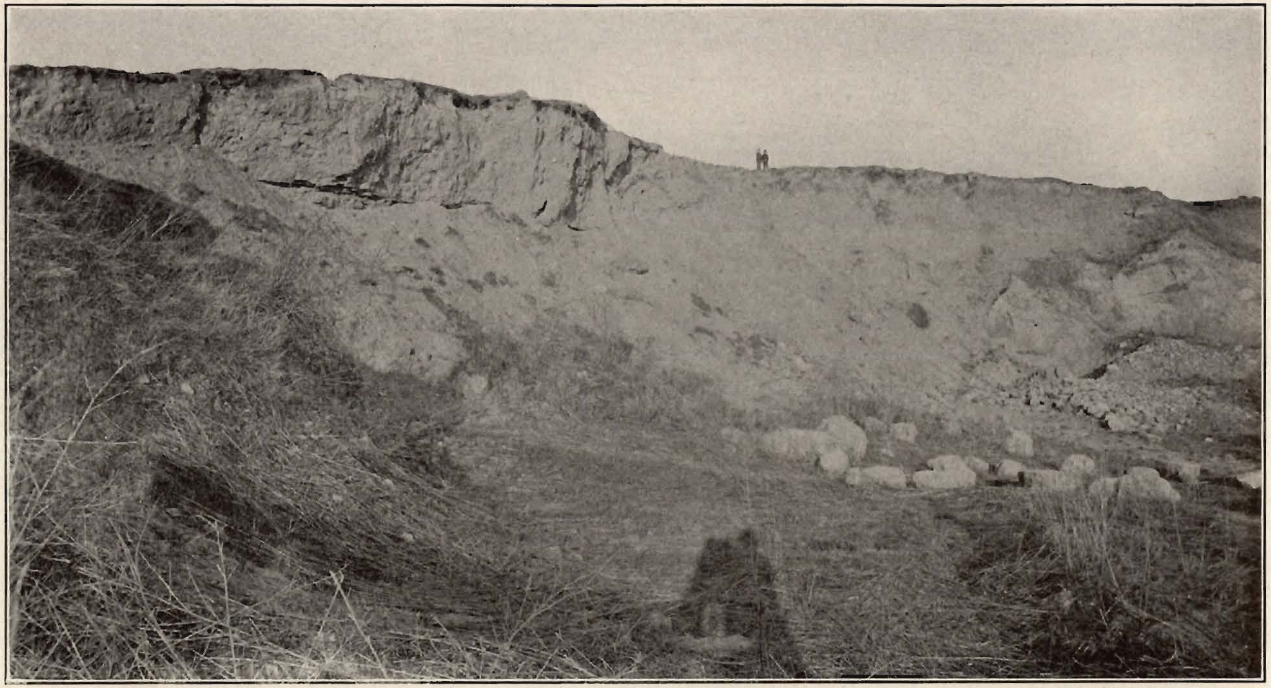
HIGHLAND PARK AREA
View looking northeast from near gatehouse of reservoir

April 20, 1895



HIGHLAND PARK AREA

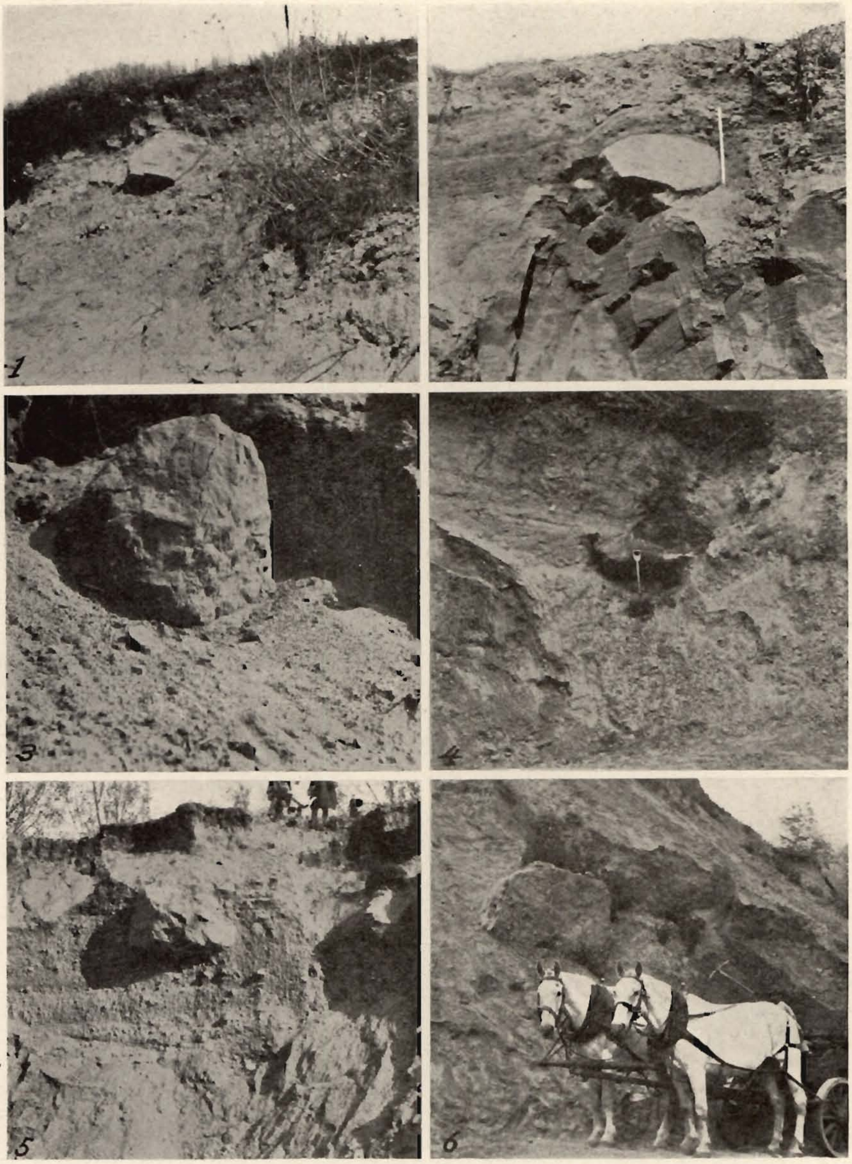
Excavation (Ellwanger & Barry) north of park. Looking south of east, toward the Pinnacle, from the northern moraine ridge April 20, 1895



HIGHLAND PARK AREA

Ellwanger & Barry pit, east end. Looking south of east. Compare plate 75

April 20, 1895



ICE-RAFTED BOWLDERS IN WATER-LAID DEPOSITS

1–3. In sands east of Clinton Street S. 4–6. In gravels south of the Pinnacle
From over No. 2, a granite bowlder, 80 feet of gravel have been removed

tract from the honor due the departed for the visitor to realize that they repose in the midst of the finest display, in a small area, of the singular earth-forms produced during a romantic episode of the geologic history of the Rochester region.

The drive called Indian Trail leads around over the higher ground, among the higher knolls and deeper basins. The four kettles which have not been greatly altered lie in the area circled by the Indian Trail and Dell Avenue. The two larger basins are the one holding the pond, called Sylvan Water, and the one on the west side of Dell Avenue, which formerly held a water tower. Three basins have been partially filled. Elevations are given in a later chapter.

The only other part of the Pinnacle range which is comparable with Mt. Hope for kame-and-kettle structure is the eastern part of Cobbs Hill Reservoir Park, and about the steel reservoir.

The composition of the knolls is mostly gravel, or gravelly sand, becoming finer southward. Many years ago a tunnel for drainage was run from the swampy basin near the main entrance westward toward the river, which is reported to have encountered chiefly sand.

The newer part of the cemetery includes the smooth plateau-ridge, which carries the Firemen's and Soldiers' monuments, having elevation about 585 feet. The railroad cut across this ridge exposes some 30–35 feet of sandy till, or of sand charged with stones and limestone bowlders. The southward slope of the ridge declines to the clay plain at Elmwood Avenue.

The highest knob in the cemetery is at the east side, near Mt. Hope Avenue, with elevation about 676 feet. The bottom of the deep kettles is about 605–610 feet elevation. The altitude of the ridge at the railroad cut is about 585 feet. The contouring on the Rochester sheet of the cemetery area, as well as all the Pinnacle range, is unreliable for detail.

The cemetery area is the widest part of the entire range, being about three-fourths of a mile, from McLean Street on the north to near Elmwood Avenue on the south. But north of McLean Street, and lying between Mt. Hope Avenue and the Harbor Boulevard, is a high knoll and gravel ridge extending northward, with declining elevation, to near Clarissa Street. An old excavation on the river side exposes bedded sand up to 40 or 50 feet above the river plain. Regarding this mass as a part of the moraine gives a total width of the Cemetery area of about one mile.

Oak Hill; University of Rochester Site

This area is the westward extension of the ridge in the west side of Mt. Hope Cemetery. The cut for the railroads makes the artificial division. The area lies in a meander or sharp westward bend of the Genesee River, which is the reflex of the eastward meander in Genesee Valley Park.

Doubtless the moraine extended as a continuous ridge westward from the cemetery kames to and along Brooks Avenue, west of the river. The river has breached the moraine, and the Oak Hill area lies between the artificial railroad cut and the natural river trench.

The surface of Oak Hill has been somewhat smoothed, for the golf ground and the drives, but it yet shows the rolling morainal surface. The altitude is somewhat under the cemetery ridge. The highest point is close to the railroad cut, being 584 feet. The central ridge has elevation by the railroad cut of 580 feet, declining westward to 565 feet at the Club House.

The Moraine as River Barrier: the Scottsville Lake

The relation of valley, river and moraine indicates that the latter must have been, at a late stage in the history, a barrier to the river. The reader will recall that the moraine was built in the waters of Lake Dana, or the sub-Dana. Eventually this lake was drained down, by eastward escape toward the Mohawk-Hudson, so that the moraine at Oak Hill appeared above the water surface. Then the waters south of the moraine and west of the South Avenue (West Brighton-Ridgeland) ridge must have been a shallow, local, morainal lake, with outlet northward, across the ridge where the river has made its cutting. Of course this point of original overflow must have been the lowest point on the crest of the ridge which the waters touched. Judging by the map contours, the altitude of the original overflow could not have been much over 540 feet (present elevation), or the river would have made its cut somewhere on the west, across the line of Brooks Avenue. With an initial elevation of 540 feet the lake waters would have extended far south up the valley past Scottsville toward Avon. We may name the waters the Scottsville Lake.*

Lake Dana was connected eastward through the pass at Victor, where the eroded channel has elevation of 600 feet. Recognizing the differential land uplift of about two feet per mile, the plane of the Victor pass, and the lowest Dana waters in this district, is about 620 feet. Consequently, when the waters were lowered below 620 feet at Rochester and Fairport they could escape only through the Fairport valley. They then ceased to be Lake Dana and became Hyper-Dawson. It follows that the establishment of the Scottsville Lake was after the Hyper-Dawson waters had fallen about 80 feet (620–540).

The overflow of the Scottsville Lake was into the subsiding Hyper-Dawson waters north of the moraine. As the latter lake eroded the drift-filling east of Fairport and lowered its level at Rochester, the Scottsville Lake outlet (we may not as yet call it Genesee River) was encouraged to correspondingly erode its channel across the moraine, thus lowering the lake level.

During the life of the Scottsville Lake it was a catchment basin for the detritus brought down by the Genesee River, and the broad valley plains from Rochester to Avon are partly the lake sediments, topped by the silts left by the river floods.

When the river in its downcutting found the limestone rock at the "Rapids," at about 500 feet elevation, its rapid cutting ended.

The outflow of the Scottsville Lake into Lake Dawson could not build any heavy delta deposits in the latter waters, because the Scottsville Lake was holding the sediment of the upper river; and the detritus for delta building was only that supplied by the erosion of the outlet channel across the moraine.

The theoretic succession of deposits in the Genesee Valley above the moraine are as follows, numbering from the bottom upward:

1. Any Preglacial materials which the ice sheet did not brush away.

2. Glacial drift; till, bowlders, gravel.

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*These waters were recognized in 1895, in a paper on "Glacial Genesee Lakes," Bull. Geol. Soc. Amer., Vol. 7, 1896, pp. 445 and 450. The name "Scottsville" was used in 1907, in N. Y. State Museum Bulletin, No. 118, page 81.

3. Glacial lake sediments, in lakes Warren and Dana. Partly from the glacial outwash and partly by the Genesee River.

4. Accumulation in the shallow Scottsville Lake.

5. Floodplain silt from the overflow of the present river.

The rolling plain between Elmwood Avenue and Crittenden Boulevard, occupied by the University of Rochester Medical College and Hospitals, illustrates the Scottsville Lake deposits. In examination of the area with reference to foundations for the buildings, nineteen test holes, by wash-boring, were distributed over the tract of about four acres. These borings gave an average depth to "rock or bowlders" of about 34 feet; the shallowest hole being 26.6 feet, and the deepest 49.0 feet. The greater depth was along the east side of the tract, which has a surface elevation of 540–545 feet.

The most definite and uniform stratum found by the exploration is the surficial deposit of fine, sandy, pinkish-yellow silt, called "yellow clay" by the drillers. This averages 8.4 feet in thickness, with a minimum of 6 feet and maximum of 9.6 feet. Beneath the yellow silt is a variable deposit of chocolate-colored or purplish clay and silt, called by the drillers "brown clay and sand." This varies in thickness from seven to 25 feet, with average about 15 feet, the greater thickness being on the east side of the area. This stratum is highly calcareous, and appears to be chiefly the rock-flour of the glacial mill, swept into the lake by the glacial outwash. Large bowlders were encountered in the clays.

Beneath the dominant deposit of clay is coarse material, sand, gravel and bowlders. The borings did not discriminate the water-laid material from the till or ice-laid material.

When the borings were made, in the winter of 1922–23, groundwater was reached at 15–17 feet from the surface of the plain, beneath which the fine materials behaved as "quicksand," necessitating that the buildings be set on concrete-pile foundations.

It will be seen that the succession and the character of the deposits agree with the theoretic succession for Lake Scottsville beds, as noted above. The coarse bottom stuff represents the glacial drift, along with the coarser stream outwash dropped close to the receding edge of the submerged ice. The thick brownish clay and silt is the finer material of the glacial outwash, carried out into the lake by the gentle currents, and in suspension, while the coarser sand and gravel were building the moraine of Mt.

Hope Cemetery and Oak Hill. The topping yellow silts are too thick to be attributed to the post-lacustrine oxidation and weathering, and must be referred to the river-borne sediments dropped in the shallow lake waters during the closing phase. This river detritus had been long exposed to atmospheric agencies previous to the time of its final deposition.

Elevations on the Range

All the figures for altitudes given in this paper refer to mean ocean level, and are based on the figures of the Barge Canal Survey. The local reference bench mark (B. M.) in Rochester is a bolt set in the coping of the old canal aqueduct, at the curve east of Exchange Street. The elevation of this bench is 511.240 feet. This is a fraction of a foot higher than the value used by the U. S. Lake Survey, and the U. S. Geological Survey, and 1.428 feet higher than the elevation originally used by the Erie Canal.

The precise figures given below are from the data of the City Department of Engineering. The benches are located between the sidewalk and curb, and the iron cover-plate is marked R.T.S. This plate should not be confused with similar benches of the Rochester City Survey, which lie in the sidewalks, and are designated R.C.S. The other figures are mostly by aneroid and are subject to a small correction.

B. M., Winton Road and Hillside Ave., northwest corner,	511.581
Summit of Winton Road, pavement	515.
Crest of ridge west of Winton Road (south edge of Elam gravel pit)	560.
Northeast corner of Reservoir Park	600.
Top of knoll east of the steel reservoir (Lake Ontario Water Company)	625.
Bottom of kettle close east of steel reservoir	585.
Base of the steel reservoir	620.
Top of high knoll west of the steel reservoir	640.
Bottom of kettle northeast of Cobbs Hill reservoir	525.
Cobbs Hill Reservoir, water surface	636.
Cobbs Hill Reservoir, coping of wall (under fence)	641.
Cobbs Hill Reservoir, cement walk, close to coping	640.5
B. M., Monroe and Highland Avenues, northeast corner	544.753
Summit of Monroe Avenue, near gate-house	546.
Top of Klinck Knoll, above Hillside Home	685.

The Pinnacle; ground at the geodetic station	748.7
West of the Pinnacle; terrace in cemetery (Brennan and Hughes plots)	700.
Terrace in cemetery, east of Clinton Street, by Cochrane monument	648.
B. M., Clinton, S. and Field Streets, northwest corner	565.889
Summit of Clinton Street S.	586.
Crest of ridge west of Clinton Street	648.
B. M., Goodman Street and Highland Ave., northwest corner	545.285
Summit of Goodman Street S.	581.
Top of ridge, Goodman Street cut	623.
Highland Park; ground at Memorial Pavilion	652.
Highland Reservoir, water surface	636.
Highland Reservoir, coping of wall	640.
B. M., South Ave. and Alpine Street, northeast corner ...	598.180
South and Reservoir Avenues, pavement	610.
B. M., South and Highland Avenues, southwest corner ...	595.141
B. M., Mt. Hope Avenue and Bonivard Street, southeast corner	565.842
B. M., Mt. Hope and Reservoir Avenues, southeast corner	614,232
Mt. Hope Cemetery; summit of Indian Trail drive, by Henry A. Ward monument	644.
Mt. Hope Cemetery; surface of "Sylvan Water"	610.
Mt. Hope Cemetery; top of highest knoll, by Mt. Hope Avenue	676.
Mt. Hope Cemetery; plauteau-ridge at Firemen's Monument	585.
Oak Hill; highest point in golf ground	575.
Oak Hill; highest point, by R. R. cut	584.
Ground at Medical College	540–545
B. M., Elmwood Avenue and Park Road, southwest corner	527.365
Genesee River, Barge Canal Harbor	513.
B. M., Elmwood and Plymouth Avenues, Av. Ext. northwest corner	522.772
B. M., Brooks Avenue and Thurston Road, southwest corner	568.009

Comparison with Neighboring Moraines

The distinguishing feature of the Pinnacle Hills moraine is its extended or linear form, with narrow breadth. From Brighton westward to the Genesee River, and west of the river for six miles, it marks a fairly definite stand of the ice-front. All the other conspicuous moraine deposits in the region are irregular and scattering, indicating variable and receding positions of the ice margin. Figure 5 shows the near by and most striking example.

The westward extension of the Rochester moraine is depicted in figüres 2 and 3; and the stretch past Spencerport and Brockport, to the western limit of Monroe County, is shown in figure 4. Here the moraine is very unlike the Pinnacle range, being scattered in more or less detached masses over a belt three miles wide.

North of the Pinnacle moraine, and therefore later in time, a few morainic masses have survived the leveling action of lake waters, but they will not resist human destruction, and should be put on record.

In the west edge of the city a group of sand knolls occupied the space between West and Chili Avenues, west of Lincoln Park. Four lines of railroad tracks, the barge Canal and Buell Avenue, have dissected the knolls. At the present time (1923) a large and deep sand pit is open on the west side of Buell Avenue, between the two railroad freight lines. The area appears in figure 2. About one-half mile north of the Lincoln Park kame area is a prominent moraine ridge, which carries two contours on the topographic map. It is indicated in figures 2 and 3. The Charlotte branch of the Buffalo, Rochester & Pittsburgh Railroad cuts the east end of the ridge, and the Barge Canal passes the west end.

East of South Greece a group of knolls lies in the embayment in the Niagara limestone scarp, and faintly indicated in figure 2. The shore line of Lake Dawson passes through this tract and wave-work has had some smoothing effect.

The level and smooth surfaces west of the city, with silted stretches and swampy areas, were produced by the waters of sub-Dana and Dawson Lakes.

In the eastern part of the city a conspicuous mound lies north of Blossom Road and east of the Central Railroad. The streets Hampden, Middlesex and Marion have been graded through this kame. Another small area of low sand knolls lies on Blossom Road, east of Winton.

Probably other mounds of gravel or sand could have been recognized in former years, but are obliterated in the growth of the city

Passing south of the Pinnacle range, we find an area of sand north and south of Mortimer Station on the West Shore Railroad, and traversed by the Erie and Lehigh Valley railroads. The sand knolls are low, detached and inconspicuous, having been softened in relief by the waves of the Scottsville waters. They are spread over an area a mile wide and two miles long, northeast by southwest.

South of the Spencerport-Brockport moraine only occasional and detached masses of drift are found in the town of Ogden. In Riga, moraine drift is seen along the N. Y. Central main line from Chili Junction to Churchville.

In the town of Chili, and south of Coldwater Station is a conspicuous and singular group of kames, indicated in figures 2 and 3. They lie in a belt about a mile wide and two miles long, northeast by southwest. They stand 20 to 40 feet high above the plain. They have no orderly arrangement, but individually they have an east-and-west elongation. Two drumlins lie along the east side of the kame belt. Upon the highest summits, 600 to 620 feet, are numerous granitoid bowlders. They appear to represent gentle outwash into quiet waters of Lake Dana. Like the other moraine areas they have no correlating land valley to direct the glacial drainage, and no feeding esker. The outwash was probably englacial or superglacial.

Before the front of the Quebec ice-sheet had receded to the arcuate line of the Rochester-Albion moraine it had built massive moraines, some of which exceed the Pinnacle Hills in height and in volume. These were briefly described in paper No. 3 (and in the Journal of Geology, Vol. 4, 1896, pages 129–159), and they deserve more detailed description than can here be given; and especially should be correlated with lines of the ice-front recession.

The Mendon Hills kame area, in Mendon and Pittsford towns, is shown in figure 5. This is the most massive and isolated moraine group wholly within Monroe County, and forms some of the highest ground, rising to 840 feet. The hills have an irregualr grouping, with an area of four square miles. They lie in two series of gravel kames, and kettles, with high relief and striking topography. An intervening valley holds four lakes, the only lakes of note in the county. Each series of kames has a massive ridge or esker, mapped by Giles in paper No. 12.

The remarkable Mendon kames are surrounded by drumlins, which are strong on the northeast, in the direction of the ice movement. The isolation of the area is striking, with no relation to any valley or apparent line of glacial drainage. The deposit probably correlates in time with the belt of drift westward toward Scottsville, and eastward with the Irondequoit Valley kames, and the high Baker-Turk Hills mass.

Between Allen Creek corners and Pittsford, and lying between the N. Y. Central main line and the Auburn branch, in an area of some four square miles of drift with singular topography. This was deposited in Lake Dawson. It has the aspect of an eroded or much broken plain, with main level at 440 feet. Some areas are 460 and 480 feet.

The valley of Irondequoit was naturally the catchment basin for the heavy drift from the glacial outwash. An area south of Bushnells Basin has a remarkable display of kettles, among the gravel knolls. Bullhead Pond occupies a deep kettle.

The elevated tract between Fairport and Victor, commonly known as Turk and Baker Hills, is the largest drift deposit and the highest in the county, rising to 935 feet. The highway over Baker Hill, 928 feet, is the highest road in the county. The mass is complex in origin. The north flank, toward Fairport, is distinctly drumlin. The south part has morainal surface, but this may cover drumlins, or possibly conceal a core of rock. The southwest flank carries excellent delta plains, built in Lake Dana, at 700–715 feet. The Baker Hill was swept by Lake Warren waters, at 920 feet.

The more southerly of the two southeast corners of Monroe County touches the west slope of the largest kame-moraine area, known as the Victor area. Lying mostly in Ontario County, it is mapped on the Honeoye and Canandaigua sheets. The kames rise to 1.100 feet, and the County corners on the ridge north of Ionia Station known as the Hopper Hills, at 1.020 feet, the highest point in the County.

Acknowledgment

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