ART. XXXVIII.—*Glaciation in the Finger-Lake region of New York;* by D. F. LINCOLN, M.D., Geneva, N. Y.

THE Appalachian plateau, at the line between New York and Pennsylvania, is composed of Upper Devonian sandstone and sandy shale, dipping slightly to the south, with summits 2000–2500 feet above tide level. The valleys are rather deep (400–800 feet), and resemble in a general way those of central Pennsylvania, but without the N.E.–S.W. parallelism of the latter. The elevations do not take the form of ridges; they consist of broad, clumsy masses, diminishing in steepness as they ascend, and capped with irregular rolling plains.

The Susquehanna, with its tributary the Chemung, here forms an important depression, north of which the land rises to the height of 2000 feet, again sinking to form the basin of the Finger Lakes. The lakes therefore occupy a section of the northern slope of the Appalachian plateau, which may be defined as extending 100 miles E.–W., from the Genesee Valley to Cazenovia Lake, and about 70 miles N.–S., from Lake Ontario to the curved line of high land just south of the lakes.

This line of heights corresponds in position with the "Terminal Moraine of the Second Glacial Epoch" of Chamberlin,* and is defined as a water-parting by the following high points—Bristol, 2254 ft.; Urbana, 1940; Orange, 2033; Newfield, 2095; Dryden, 1888; Virgil, 2133; Solon, 1977; Fabius, 2015; Fenner, 1862.†

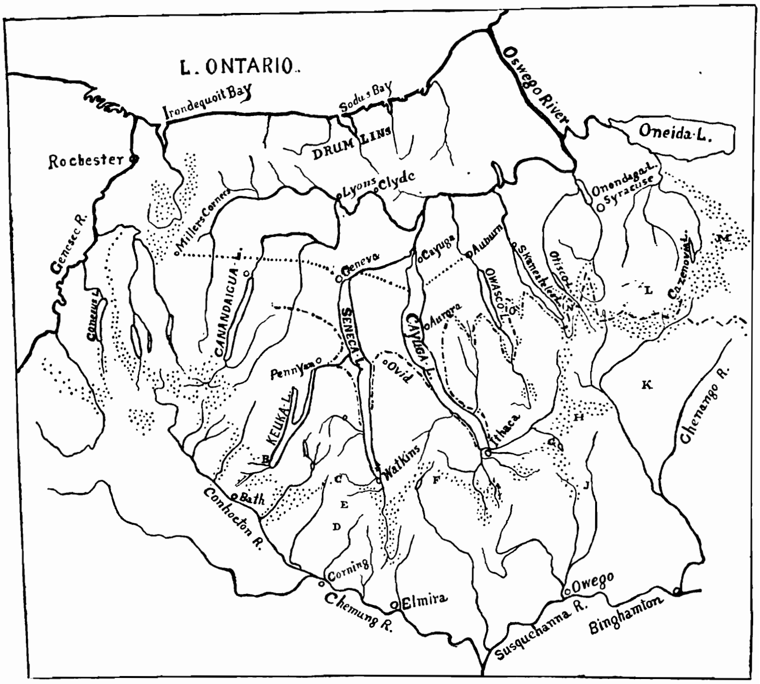
The height of land of which these are the summits is cut through by many deep straight valleys, which on the south communicate with the Chemung-Susquehanna valley, while on the north they converge toward a common imaginary center in Lake Ontario. The northerly discharge is intercepted by streams flowing eastward, which unite to form the Oswego River. Most of these north-south valleys are so blocked with drift as to form lakes.

The middle of the common basin is axially depressed, in a north–south direction; the depression is occupied by the two largest lakes, Seneca and Cayuga.

There is a considerable system of minor, preglacial valleys still traceable in the elevated tracts between the lakes. This system, however, has been so disturbed by glaciation that it no

* U. S. Geol. Survey, Third Report.
† Triangulation of N. Y. State Survey, 1883, 1887.

longer furnishes in normal fashion a series of tributaries to the lakes. The greater part of the surface water enters the lakes through torrents, running from two to four miles in a straight course, at right angles to the lake-axis, through precipitous



The Finger-lake region of New York.

Terminal moraine (from Chamberlain) is represented by dots.—Corniferous limestone, a line of dots.—Tully limestone (Prof. H. S. Williams) dots and dashes — . — .

A, Bristol;	B, Urbana;	C, Sugar Hill;	D, Hornby;
E, Orange;	F, Newfield;	G, Dryden;	H, Virgil;
J, Richford;	K, Solon;	L, Fabius;	M, Fenner.

Elevations above sea-level—Rochester, 508; Lyons, 407; Clyde, 396; Bath, 1105; Elmira, 863; Sugar Hill, 2091; Hornby, 2045; Richford, 1995.

gorges, which they are still actively deepening. Some of the finest scenery in the State is found in these gorges. Watkins and Havana glens are examples; the highest waterfall in the State occurs in the Taughannock glen, near Ithaca; its perpendicular fall is 190 feet.

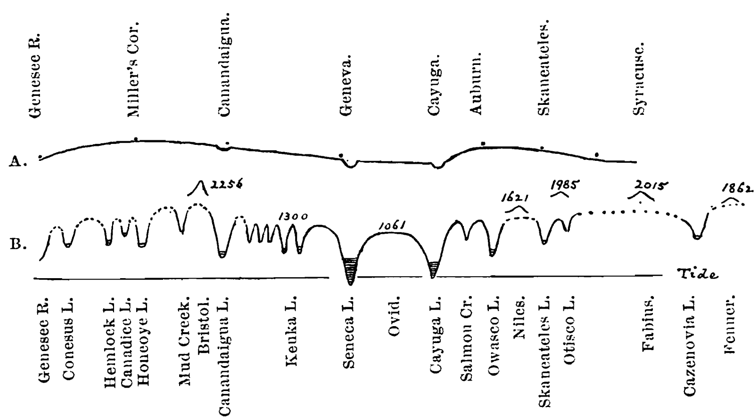
Altitudes and Depths of Lakes.

	Elevation above tide.		Greatest depth.
Erie	572·9	L	210 G
Chautauqua	1291	G	
Conesus	821	R	70 G
Hemlock	898	R	87 G
Canadice	1099	R	87 G
Honeoye	less than Hemlock		25 G
Canandaigua	668	G	
Keuka (Crooked)	718′ 10″	G	
Seneca	441	C	618 M
Cayuga	378	C	435 M
Owasco	670	G	
Skaneateles	860	G	
	864′ 12″		
	861	C	
Otisco	no data		
Cazenovia	900	G	
Schuyler	1200	G	
Otsego	1193	G	
Onondaga	361	G	
Oneida	369	G	
	367·71		
	368	C	
Ontario	246	L	738

L = U. S. Lake Survey. C = Resurvey of N. Y. Canals. R = Rochester Water Works Surveys. P = Penn. & N. Y. R. R. G = French's Gazetteer of N. Y., 1860 (comparatively poor authority.) M = Soundings given on map published by Engineering Department of Cornell University.

The entire basin may conveniently be divided into three regions or zones, nearly corresponding with certain geological formations. The northern zone (Silurian) is nearly *level*, with a heavy mantle of drift; it extends from the Ontario coast to the northerly escarpment of the Corniferous limestone, which is skirted by the line of railroad passing through Auburn, Geneva, Canandaigua, and Miller's Corners. The middle zone comprises the *moderate ascent* of the lower Devonian, extending south from 6 to 20 miles from the railroad. The southern zone, with *steep slopes* and deep valleys, comprises the Upper Devonian (Chemung and Portage rocks), including on the east the lower Devonian to Skaneateles. The zigzag dotted line of the Tully limestone partially indicates the demarcation between the two latter zones. The terminal moraine bounds the whole on the south.

The northern zone comprises the Medina, Clinton, Niagara, and Salina formations, dipping south at a low angle. The Clinton and Niagara limestones form escarpments facing north, which are inconspicuous in large part. It is traversed by the



A. Vertical section nearly E.-W. along N. Y. Central R. R., nearly on Corniferous outcrop.

B. Vertical section near the middle of each lake; dotted lines show deficiency of exact data, partially supplied by a few adjacent known points.

N. Y. Central R. R. and the Erie Canal at very easy grades. A portion along the southern edge of this belt is level and free from drift-hills: north of which the surface is diversified by an extraordinary series of drumlins, already described by Hall (New York State Geological Report for 4th Dist., 1842) and Johnson ("Parallel Drift Hills of Western New York;" Annals of N. Y. Acad. of Sci., Nov. 9, 1882). These are stated by Hall to be bounded northerly by the beach of the ancient Lake Iroquois—the "Ridge Road"—which runs a few miles from the shore of Lake Ontario.

As compared with the drumlins of New England, these are of much greater length, are relatively much narrower, much sharper at their ridges and steeper in their side-slope. Their northern ends are very bluff, their southern ends gently inclined. Their axes lie nearly north and south, on the whole, with marked local differences.

The width of these hills at top is often sufficient to receive a country road without much leveling, but some would not (in their original state) admit the passage of a single cart along the ridge; while in exceptional cases there are flat tops some hundreds of feet in width.

The inclination to the south is often so gentle as to have no definite ending; thus many hills which begin northwardly with well-marked drumlin-outlines sink and broaden southwardly into plains of till. Some, however, are well-defined at both ends, and in length fall within one-half or two-thirds of a mile. Johnson states that the best developed ones run two or three miles, and reach the height of 100–200 feet above the plain; that they are highest and longest chiefly just south of the Niagara escarpment, though there are a few very high ones more to the south.

Measurements of a few of the steeper ones (kindly communicated by Mr. George H. Barton) show the inclination of the sides to be about 23°, and only exceptionally 25°.

The material of these hills is a till, possessing the usual characteristics—unless a tendency to the formation of very deep gullies (5–15 feet deep) on the sides be considered exceptional. Some are covered very thickly with good-sized traveled stones; some with sand or gravel of varying depth. In the neighborhood of Rochester are some of which the nucleus is sand, till forming the upper part. Considerable kame-deposits are associated with the drumlin-belt at some points, and near Rochester a portion of the moraine traverses it.

The writer's personal study of this region is limited to five localities, and the above statements are in part drawn from other sources. An excellent cursory view can be had from the car windows as the traveler passes east from Rochester on the main line of the N. Y. Central R. R. via Lyons and Clyde to Syracuse.

This belt of *large* drumlins practically comes to an end at the distance of twenty miles from Lake Ontario. Then come low lands, partly sandy, partly marshy. Still farther south, within the middle zone, the drumlin-formation is resumed, in ridges of much smaller height, but in considerable numbers. As this point has not met the writer's eye in print, attention is here called to it, and some special observations are offered.

Among the drumlins of the second range (in the middle belt) there are some which resemble the typical "lenticular hill" of New England. More, however, are of the ridge variety. And of the latter there are many grades, from the very well marked ridge with rather steep banks to very low ridges which are often so low and flat as to simulate terraces. The face of this part of the country is laid out in shallow grooves, often producing the strong impression of "fluting."

An instructive group of these ridges occurs in and around the town of Geneva. They are very nearly parallel, their axes lying between 10° and 15° west of north. The easternmost skirts the lake, and is somewhat eroded by the waters, displaying sections of till, with limited beds of blue clay and "quicksand." Its crest, on which Main street is built, reaches a height of 90 feet above the lake. The other ridges increase in absolute elevation, but not in size, having an apparent height of 20–50 feet above the ascending slope which they cover. At somewhat over a mile from the shore they attain a height of 300 feet above the surface of the lake, which corresponds with the verge of the higher levels of land. Similar ridges are found for several miles farther west; sometimes crossing the road at pretty regular intervals of $\frac{1}{4}$ to $\frac{1}{8}$ mile, with elevations of only a few feet; at other times forming hills with a rather bold northern descent.

A distinct termination north and south can generally be traced in the ridges of the Geneva group, although the ordinary observer is inclined to overlook the fact. Their general outline, their material, and their tendency to steepness at the north end, ally them with the drumlins of the northern belt. The long ridge running west from the end of the lake is of typical till, with some large bowlders, overlaid in part by stratified sandy clay.

In this locality, the till evidently forms a continuous sheet, of which the ridges are merely a surface irregularity.

The slope of the sides of the ridges is about from 2° to 10° at Geneva, and their crests are occasionally from 100 to 300 feet wide.

The direction of the ridges of till as a whole is probably similar to that of the glacial striations, that is, convergent to a northerly point. At Clyde and Lyons (on the central axis of the region) they run a degree or two west of north. Near Cayuga, about N. 8° W.; and still further east, about 20° west of north.

The till at Geneva is a firm "hard-pan," containing a great number of subangular striated stones of all sizes up to three feet in length. The greater part of the stones are from the Corniferous limestone, which is exposed just north of the village. Of those representing more northern formations, many are water-rolled. The limestone fragments give a bluish tint to the otherwise reddish brown mass.

About three feet of the upper part of this till appears thoroughly oxidized and leached. This portion is a red clay, distinctly contrasted with the gray-blue till, and rather well demarcated. It is of a deep shade, unstratified, very tenacious, nearly free from sand; at times flaky, at times tending to split when dry into rectangular forms. It cuts with a slight grittiness; the surface is dotted with occasional specks of material not fully decomposed, which may represent some of the myriads of little bits of limestone found in the till. The stones are few, chiefly such as resist oxidation (quartzites); these correspond in appearance and amount with a simliar ingredient of the till. Gneisses and schists are absent, or badly rotted. The forms are characteristic of till, and in some cases striation is observed. A part of the stones react feebly to HCl; the clay does not react.

Midway of the Cayuga lake shore, on the east side, there are fine till sections which give a similar result on analysis.

The same leaching of the upper part has been observed in stoneless sedimentary clay of Geneva. Absence of the lime-reaction is stated to be characteristic of the soil at the State Agricultural Station in the same town.

At many points on the surface of the lower-till (Drumlin) deposits just described, there is little or none of the englacial material defined by Upham.* But where the stones lie thickly in the fields it is necessary to suppose that they are chiefly of englacial origin.; for the proportion of limestone fragments in such cases is quite too small to permit us to refer them to the lower-till. This is easily seen in the piles of stones which the farmers draw from the fields—sometimes 12–20 feet in diameter from a 100-acre lot—consisting mostly of gneissoids, schists, and quartzites, with perhaps one-fifth corniferous limestone, the lumps varying from 2 to 200 pounds in weight. The larger stones (bowlders) carry out this statement; they are almost all far-traveled stones. Large bowlders are not very frequent. The largest within observation are one of labradorite (7×7 feet), and one of an argillaceous rock from the Salina beds (6×11) which is exceptional in having traveled only 5 or 6 miles.

Stratified deposits are not infrequent, however, upon the drumlin formation. Rolled gravel is not rare, and the kames and osars deserve a fuller description than can here be given.

On reaching the higher levels, west of Geneva or east of Aurora, we often find the surface sandy. The sand even takes the form of low hills and ridges. The deposit of tough lower-till, however, is still found beneath the light top-soil.

The thickness of the till-sheet at Geneva is reported at several points as 20–30 feet. Sand lies beneath this, and still lower, till again. At one well, there was 14 feet of sand, and 13 feet or more of the deeper till bed. Layers of vegetable matter, and blue clay, are also found.

In passing south from the soft shales of the Hamilton group to the sandy shales and hard fissile sandstones of the upper Devonian beds, we are informed of the change of bed-rock by the alteration in the character of the lower-till. The latter, in recent exposures, may be very tough, but is sandy rather than clayey. The enclosed stones are sandstone, rarely limestone. Fragments handsomely glaciated occur as large as three feet

* Amer. Geologist, vol. viii, No. 6.

long. The field-stones in this region split, losing their likeness to till-stones. Hence the "flat gravel," characteristic of the soil of the hilly districts.

The deltas of the lake sides are among the most conspicuous accumulations of drift material. Rising at intervals along the sides of the lakes and the southern continuations of their valleys, they attain by a series of steps the height of (?) 400 feet above the lakes. Their strata contain many stones which still show half obliterated glacial striæ.

The remainder of this paper will be devoted to certain points of preglacial topography and drainage, and the associated questions of amount of glacial corrasion, and bulk of drift-deposit. The northern zone, except as specially designated, will be omitted from consideration.

The deposits of the terminal moraine are very heavy; for a description of this feature the reader is referred to the paper on this subject by Thomas C. Chamberlin.

From considerable examination of the country included between the four larger lakes, the writer has been led to set a moderate estimate upon the amount of drift, and a very high estimate upon the amount of erosion in certain parts.

The lakes are to a great extent bordered by vertical cliffs of rock, with little or no beach at their foot. Owing to the greater prevalence of westerly winds the cliffs are best developed on the east side. In the case of Cayuga Lake this natural facility is aided by the presence of a railroad at the water's edge, for which in many places the cliffs have had to be cut. From Aurora southward for nearly 20 miles the top of the cliff is visible most of the way, undulating in very moderate curves, occasionally rising 50 feet or more, and at several points sinking below the level of the lake for short distances. In the latter case the rock is exposed in brooks a few rods inland. Till overlies this rock, varying in thickness from 2 to 40 feet. The till deposits along the east shore of Seneca lake are apparently not much in excess of the above.

It is probable that the rock-sections thus displayed correctly represent the general surface of the region as it would appear if the drift were removed. In some tracts, at all events, this is demonstrably the case. In the northern reaches of the lakes, hills of rock with a very flat curve correspond with these cliffs. A few examples may be worth describing. At the foot of Seneca Lake on the east side there is a line of cliff (Marcellus shale), which rises gradually to a height of 25–30 feet and extends more than a mile. A hill-side rises directly from the brow of this cliff to the height of about 90 feet; mainly rock with 2–20 feet of till. Three miles to the southward is another long shore-cliff of rather greater height, the land behind which rises for 1½ miles eastward, reaching a height of 150 (?) feet, and forming a broad-backed N–S ridge of Hamilton shale covered with a couple of feet of drift. A third ridge 250 feet high, at a similar interval to the S.E., slopes very evenly to the lake (2½ miles distant) over rock covered with a very few feet of drift; in this case no cliff is formed, the rock not quite reaching the lake. The axis of this hill points N. 20°–30° W. On Cayuga lake, south of Aurora, there is a hill 300 feet in height, forming a cliff at the lake-side, two miles long and one mile across, with its long axis directed N.W.–S.E., composed of Hamilton shale. The top of this hill, for the length of a mile, forms a plateau. A smaller hill of Marcellus shale lies 4 miles to the north of this.

In the present state of the question it is admissible to suppose that these hills may be remnants of preglacial hills of bolder outline. The fact that they lie parallel to the lake need not militate against this view, since the old valleys of the region—farther south than the hills described—unite with the lakes and with each other at very acute angles.

The hills may constitute a very insignificant remnant of old hills; or may even have been carved out *de novo* from rock which occupied levels below the roots of their predecessors. In other words, the corrasion at the latitudes of Geneva and Auburn may have removed one hundred or several hundred feet. Definite evidence limiting these estimates is not before me. Apart, however, from the numerical estimate, it is interesting to note the parallelism between the axes of these hills and those of the drumlins which are found close by. Their material, a soft shale, yields readily to force applied horizontally, and it is not beyond the province of legitimate speculation to suggest that their forms may have been carved at the same time and in similar circumstances with the drumlins. Their bluffer northern sides, and their exceedingly gentle southern slopes, add much to the likeness.

A system of small valleys for local drainage, opening lakeward, doubtless existed before glaciation. We can point to no surviving representatives of these valleys at the lake level unless the slight depressions in the cliff line be taken as such. These descending curves run but a short distance below the lake level, and represent but slight inward bends of the rock-shore. If the lake were drained, the present mouths of the brooks flowing in these hollows would be a mile from the main stream which presumably occupied the axis of the valley. In going this mile they would fall from 300 to 600 feet. Such streams must have cut deep and wide gorges extending far inland. How deep some of these would have been at parts of the lake where the shores are bolder, may be estimated by considering that the land at the upper part of Seneca lake rises in six miles to upland pastures nearly 2000 feet above the bed of the lake.* The continuity of cliffs for 15 miles along the west coast near Watkins, and the frequency of rock exposures on the high lands, forbid the belief that such gorges exist.

The inference from these considerations is that the preglacial river which has been developed into Seneca lake must have occupied a level many hundreds of feet above the present bed of the lake.

Some drift-buried valleys certainly exist. One such, probably with a meridional course, seems to lie to the east of Aurora, where two E.–W. ravines appear to cut it, one of which exhibits a till-section 100 feet thick, with bottom not reached. However this be, there still exists a large system of valleys, with banks several hundred feet high, subsidiary to the lake valleys and in several places communicating with them. These valleys are rock-cut, and often show rocky bottoms; they run mainly parallel to the lakes, but occasionally branch in a transverse direction. They run straight through the line of terminal moraine. Their trough-like aspect north of the moraine points to probable widening and deepening, as in the case of their much bigger brothers, the lakes.

As an illustration, take the large valley, 20 miles long, entering Cayuga lake 6 miles north of Ithaca. It is cumbered with some drift, but its walls rise 400 feet above its bed, in full sight from the lake.

Perhaps the case of certain upland valleys will add confirmation to these views. East of Watkins there is a system of these at 400–600 feet above the lake. The main drainage of this system is at present southward, but it communicates with the Seneca valley by two wide gaps, allowing several short streams to enter the lake, which they do by a sudden plunge—one of them cutting the beautiful Havana glen in its descent. These streams must have fallen 1,000 feet in three miles in order to have reached the Seneca valley bottom at its present level. In like manner the stream which has excavated the celebrated Watkins Glen descends about 500 feet in its last mile through a canyon with vertical walls, while its upper five miles are mostly in an old valley with moderate grades.

Again, Dundee, situated three miles from the west shore and ten miles north of Watkins, stands 600 feet above Seneca lake. It occupies a site apparently near the mouth of an old valley, bounded by rock-hills from 300 to 400 feet high, and displaying a rocky bottom in the stream at Dundee. The valley has four or five branches, extending six miles above the

*Seneca lake bottom is 177 feet below tide; high points W. of Watkins, near 2100 feet above tide.

village in several directions, with very moderate grades. In the direction of the lake the valley-sides become lower, and the valley itself disappears, debouching upon the lake side at an imaginary plane in mid-air. From this point the lake-side descends smoothly and rapidly, while the stream, with many cascades, falls 500 feet in two miles.

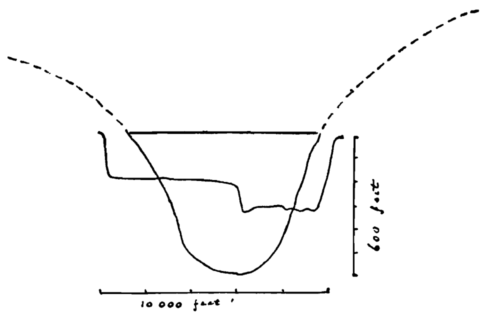
If these valleys, or any of them, had a preglacial existence, and a rational connection with the lake valley, it would seem necessary to suppose that the bed of the latter then stood at an elevation 800 (?) feet higher than at present. If they drained away from the lake, they would soon have been cut down by robber-streams falling into the Seneca valley. The present Chemung river valley, which would be the southerly exit, is 1200 feet higher than Seneca valley floor.

The trough of the present lake runs straight south from Watkins to the open valley about Elmira, 22 miles distant. The present bottom of the lake is 1,000 feet below the river at Elmira; a discrepancy which may be harmonized by either of two hypotheses,—glacial erosion of the lake bed, and filling of the valley at Elmira with overwash from the moraine. That the truth is a composite of both, seems very probable.

The belief that the lakes are deeply gouged by ice is consistent with the fact that their depth (in the case of the two largest) is much the greatest in the southern third. Considered relatively to the glacial movement, this is the downward part, and the fact agrees with Geikie's statements regarding the rock-cut lochs of western Scotland, which form basins, deepest toward their outlet. The section of Seneca lake along its axis is like that of an elongated tablespoon, pointed to the north. But until we know more about the depth of alluvial and drift deposit at the ends of the lakes, this consideration may be waived. It is nearly certain, however, that the lake bed is not more than 300 feet deep at Geneva where the apparent depth is 40 feet.

The direction of preglacial drainage may perhaps be inferred from the considerable and continuous slope of the land toward Lake Ontario. The height of land between this slope and that toward the Susquehanna system is near the south ends of the lakes, and it does not seem necessary to suppose that it was formerly placed much farther to the north. Such valleys as Seneca may have had their divide near the southern ends of the present lakes. A number of streams seem to have run southward across the divide; of which Keuka lake, and much of the distribution of the valleys about Canandaigua and Owasco lakes, offer strong suggestions.

Few borings have been made north of the lakes, and it is not advantageous to speculate upon a possible outlet for the north-flowing streams. The lowlands north of Cayuga lake (Montezuma marshes) offer a very slight barrier to such a discharge. It is worth noting that a boring made at Geneva, at the lake side, encountered obstacles from bowlders at about 100 feet, and struck no true rock until 240 feet below the water line. A valley three miles wide between existing rock-exposures, and 300 feet deeper than the present lake surface, apparently opening to the north, is indicated at Geneva: some of this depth may be ascribed to glacial action.



Section of Channel of Wisconsin River (Report of U. S. Geol. Sur., VI. p. 230) partially filled with river-gravel; compared with that of Seneca Lake at deepest point. The latter section is adapted to scale from that given on the map published by Cornell University; the dotted slope of bank is obtained from contour-lines of map. Ratio of vertical to horizontal scale nearly = 10 : 1.

The accompanying cut is given to show the contrast between the much-glaciated banks of Seneca Lake, with thin smooth gentle curve leading to the upland levels, and the unglaciated banks of the Wisconsin River, falling at a sharp angle from the level of the plain in which the valley is cut. The section is from one of the narrower parts of the river, in its course through the non-glaciated region. The river valley is filled to an unknown but considerable depth with material brought from glaciated territory. The lake valley, judging from the outline given, is free from heavy glacial or postglacial deposits for many miles; its ends, however, are deeply filled.