ART. XIV.—*The Amount of Glacial Erosion in the Finger-lake Region of New York*; by D. F. LINCOLN, M.D., Geneva, N. Y.

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THE Lake-region proper does not extend beyond the Devonian belt; it will, however, be instructive to include in our consideration the closely-related "drumlin-belt" of level country adjacent on the north, which covers the upper Silurian area between Rochester and Syracuse, nearly. Within this region occurs the well-marked, though low, Corniferous escarpment, besides some local escarpments to the south: the Niagara exposures being hardly worthy of that name. Most of the formations are exposed at great numbers of points in brooks, and complete sections across the Devonian are afforded by some of the lakes. Beginning at the north, the formations in ascending order are as follows:*

The Medina sandstone along Lake Ontario is thickly enveloped with drift and lake deposits. Five exposures in the beds of brooks are mentioned by Hall in Wayne County. (Report for the Fourth District, 1843). In the Clinton shales and limestone Hall names twelve exposures, adding that "almost every stream north of the road from Wolcott to Rochester exposes one or more members of this group." The Niagara shale is soft, and forms very gentle slopes. It is exposed, though not deeply cut, in "all the small streams which flow into the lake" (Hall).

The Niagara limestone occupies a tract a mile or two wide, crossing the middle of the lake counties from west to east. Its position is marked by a line of lime-kilns across the country. Little cascades or rapids occur wherever the streams pass from it to the shale. It is characterized by frequent low anticlines, with axis approximately N.-S., the backs of which come within a foot or two of the surface. Broad levels, underlain by sheets of this rock, with only a foot or two of soil, have been observed at Sodus. On the whole, the contour of the landscape is not distinctly affected by this formation.

The Salina formation, being to a great degree composed of weak rocks, is probably excavated and buried more deeply than the others. The Clyde, the present outlet of the Finger lakes, runs through it lengthwise (W.-E.); for several miles west of Lyons its valley is deserted by its wandering occupant; the banks are there 30 feet high exclusive of drumlins, and rock is not exposed.

Distinct evidence in regard to the depth of the drift-covering is less easily had in this formation than elsewhere. The

* For a sketch map of the Lake region, see this Journal, October, 1892.

drumlins are numerous, and intercept the drainage to such an extent that the low grounds between them are largely filled with alluvium, and often swampy. Hall, however, mentions 16 localities where the rock is exposed. A comparatively continuous series of exposures is seen along the line of contact with the next following rock.

The Corniferous limestone makes itself seen in many places along the south side of the Auburn branch of the New York Central railroad. It comes close to the surface at many quarries; and its low escarpment, resembling an old stone wall, west of Geneva, has forced the railway to diverge four miles to the north. Upon this escarpment, a mile south of the New York Central, runs the new line of the Lehigh Valley road, cutting through some low anticlinals of rock resembling those mentioned in the case of the Niagara limestone, and with a similar (N.-S.) axis. Both roads run for some miles west of Geneva over broad levels of Corniferous limestone covered with a little soil and occasionally swampy. The Lehigh road has found it impossible to plant posts in the usual way, and stone-laden cribs are used to support the fences.

With the Corniferous begins the series of exposures belonging to the lake-region proper. In this region no other escarpment of equal development exists. Locally, however, we may name that due to the Tully limestone, a sheet of rock a dozen feet or more in thickness, surmounting the Hamilton group. At its outcrop in the rising land between Seneca and Cayuga Lakes, just north of Ovid, there is a shoulder or upward jog in the landscape, quite well seen at a distance of eight miles. The "basal limestone" (J. M. Clarke), which forms the lowest layer of the Hamilton shale, parting it from the Marcellus, is the cause of the bluff northerly termination of a certain detached hill, four miles south of the outlet of Seneca Lake; the soil is very thin over a large tract, and the coral reef is bare in spots. Many hundreds of little ravines, entering the Finger Lakes from the sides, and cutting through the Devonian series, have made the region classic ground for the collector of fossils. The drift-coating, as shown in these cuts, is usually thin (1-5 feet) at least within a mile or two of the lakes. In many places, however, the delta-terraces are prominent, and where cut through by the railways might mislead the observer's estimate. It is fair to presume that these accumulations of drift were not, for the most part, taken from the general surface, but from those surfaces which have now been converted into ravines and gullies. The general sweep and slope of the country is not towards the ravines, as a rule; the upland contour is broken abruptly by the line of the gorge, and there plunges at an angle of from 20° to 90°. Hence, little general loss of drift has probably taken place through stream-action.

The *general topography* of the district—its hills, valleys, and slopes—furnish important aids to determining the amount of drift. On the whole, these features are formed of rock, veiled under a very few feet of drift. Although the country along the lower (northern) reaches of the lakes is in general level, yet it is not without marked features. The hill of coral limestone just described is one of several, similarly elongated parallel to the lake-axes, and formed of shale. They are described in this Journal for October, 1892. Other hills and ridges may be added to their number. Farther south, towards the neighborhood of the moraine of the second Glacial period, as defined by Professor Chamberlin, the country rises very considerably, forming for the most part a series of broad backs, plateau-like, intersected at short intervals by straight, trough-like valleys, running nearly N.-S. Most of these valleys contain lakes. The moraine is very weak on the high lands, over which it lies in loops bending northward. It crosses the valleys a short distance south of the present lakes, and has evidently determined their position. In the valleys, the accumulations are vast, with extensive overwash deposits southwards towards the Susquehanna, and northwards towards the lakes (?) Over a great part of the rolling uplands it is safe to say that the rock lies within from one to ten feet of the surface. They are in places characterized by rock-flats covered with thin soil; in other parts they undulate in broad clumsy lines, forming certain high hills and a few transverse or E.-W. valleys with rock sides. A good example of the latter is found at Dundee, which lies about ten miles north of a locality named by Chamberlin as belonging to the moraine. The existence of such a valley at such a point is not suggestive of a heavily drift-blocked country. Several other valleys, in similar situations north of the moraine, remain as the last survivals of a topography which is clearly *not post-glacial*; they appear in harmony with the valley system of the Allegheny plateau of western Pennsylvania.

These remarks, however, must be understood as limited to the high lands lying southward; whose topography in fact much resembles that south of the moraine. The lower lands, including the northerly reaches and the troughs of the lakes, produce the impression of a typically glaciated country, with few prominent features. The forms are smooth and flattened, even when demonstrably due to rock-structure. Any long stretch of horizon tends to resemble a line drawn with a ruler. Looking east or west, the sky-line is nearly level; looking north or south we have broad planes inclining to the lakeside.

On the lower levels—say up to 900 feet above tide—a good deal of the land between the lakes is provided with drumlins of moderate size, and of a different aspect from the bolder

and larger forms of the parts nearer Lake Ontario. The material of these small drumlins, if spread over their own neighborhood, would not exceed 10 or 20 feet in thickness.

Kames and osars have been observed in three counties, but not with sufficient system to enable an estimate to be offered. It is not believed that the material they contain would add very greatly to the total.

The deepest parts of the lakes may be assumed, with probability, to be nearly free from drift. On the south they are prolonged in alluvial plains, reaching several miles, which may not be all Post-glacial. The northern ends of several lakes also appear to be choked with Glacial deposits. At Geneva several wells have been sunk at the water's edge, passing through gravel, sand, clay, and till, with many large boulders, and striking bed-rock at 205, and 240 (?) feet. Adjacent drumlins rise to the height of 90 feet. A mile from the lake, at an elevation of 100 feet, the drift is 60 feet thick; half a mile further, on higher ground, shale crops out in several spots. This drift-mass extends six or eight miles to the southward, occupying the width of a mile on the west bank of the lake, and very probably shoaling a corresponding portion of the lake. On the whole, it may be estimated that $\frac{2}{3}$ of the surface of land lying between the Finger Lakes and extending to (but not including) the terminal moraine, is covered with drift, averaging from 1 to 5 feet in thickness. Another $\frac{2}{5}$ may average from 5 to 30 feet. The remainder may be included, for the most part, between 30 and 100.

In close connection with the above study, a question of great interest awaits solution—that of the origin of the trough-like lake-basins. The reader will not fail to recall the diversity of opinion, which has been recently developed by the discussions upon the origin of mountain lakes, in the pages of "Nature" for 1893. It is not my present purpose to enter into this discussion. Certain facts, however, in part new, may well be mentioned here, as deserving to be weighed before we take sides. In part, these favor the theory of deepening by Glacial erosion; in part, that of tilting or differential uplifts, whereby valleys that once ran continuously to the sea have been bent so as to hold water like a spoon. For the sake of simplicity, let us confine the presentation to Seneca Lake, which will serve as a type. Situated in the axis of the system known as the Finger Lakes, this valley has been cut down to a depth considerably greater than either of its neighbors; in addition to which, it is the one about whose rock-contours we have most definite information. We will consider it as incidental to a valley, 58 miles long, running from the flat land at Geneva south to a junction with the Chemung Valley at Elmira; of

which valley the lake occupies the northern 36 miles, and the terminal moraine with its dependent deposits occupies the remaining 22 miles.

FIG. 1. Section from Lake Ontario southward through Seneca Lake to Elmira. L.O., Lake Ontario, bottom 492 below tide level; L, Lyons, 407 above tide level; G, Geneva; O, Ovid, 1061; L.S., Seneca Lake, surface 441, bottom -177; H, Hector (summit) 1805; B, Burdette; N, Newfield, 2095; D, Odessa; W, Watkins; V, Havana; M, Moraine; P, Pine Valley; E, Elmira, 863.

The greatest depth of the valley is at and to the south of the middle of the lake, where the bottom lies 150-176 feet below tide. At the north end, the lake comes to an abrupt end, choked with drift and alluvium; the valley also disappears to the eye and is not traceable farther north. The apparent depth of the lake at this part is 40 feet; its true depth is probably not much in excess of 200 feet, as may be inferred from the section (fig. 2) in which the borings are shown to represent two localities, distant 1700 feet in a line at right angles with the channel, and near its probable axis. The lake-level being 441 A. T., the buried channel would be at 241 A. T.

FIG. 2. Section across Seneca Lake at Geneva, from west to east, showing probable depth of buried channel. R, Reservoir; C, Castle Creek; G, Geneva Nat. Gas Spring Co.; Ch, Chase's well; N, Nester's well; M, outcropping of Marcellus shale.

For the part of the valley lying south of the lake the following data have recently been obtained. At the mouth of the "inlet" at Watkins, near the middle of the valley, a well has been driven "by blows from a sledge" 224½ feet in the alluvium. Four miles south, at Havana, a well was sunk at Cook Academy, near the middle of the valley, which passed through 435 feet of sand without reaching rock. Six miles farther south (one mile beyond Millport) a well was sunk

by Mr. U. Hall to the depth of 186 (?) feet in sand, without touching rock; the site of the well was near the brook, which has cut its gorge to the depth of 100 feet (estimated) below the level of the drift at that point, which indicates $300 \pm$ feet of drift in all. At Elmira the valley is two miles and a half wide; the Erie road runs near the middle; borings have been made at the Table factory, just west of the road, giving *less* than 200 feet of gravel, and at the Rolling mills, just east of the road, striking rock at less than 60 and 120 feet; while at the Blast furnace, in the same region, I am informed by a former official that their well could not have gone more than 100 feet in depth before striking rock. These data are all that seem at present available. We may therefore assume that the drift deposits of the valley equal or exceed 300 feet in thickness until we approach Elmira, where they probably become less than 200, perhaps less than 100 feet thick. This places the southern end of the valley at 680–780 feet above tide = 850–950 feet (in round numbers) above the deep parts of the lake-floor; the northern end of the valley being about 400 feet above the lake-floor.

In the valley of the Susquehanna, between Wilkesbarre and Bloomsburg, a similar state of inversion has been shown to exist (2d Geol. Rep. of Pennsylvania, G 7). Wilkesbarre is 124 miles down-stream from Elmira; Bloomsburg is 40 miles further. At Wilkesbarre the existing river deposits have been pierced by boring to the depth of 180 and 185 feet before striking rock, showing the existence of a buried bed at 340 feet above tide; while at Bloomsburg the rock-bed is exposed in the stream at a height of 450 feet above tide, giving a tilt of 110 feet in a direction contrary to the present course of the river.

The hypothesis of crust-bending is obviously available to explain such differences of level as the above. It seems to me however, that the arguments for the other side are of great importance. There are three principal ones.

1. The magnitude of the valleys of Seneca and Cayuga Lakes demands an explanation which has not yet been offered. The Seneca valley at its wider and deeper parts greatly exceeds in dimensions that of the Ohio below Pittsburg; this would not be inconceivable, if we supposed both the Susquehanna and the Chemung to have flowed north past Elmira and Geneva Ontario-wards; but it is less easy to account for a second valley, that of Cayuga Lake, parallel with it at twenty miles' distance, and nearly as large as the first. Further, the character of the valleys of these lakes changes in going south to the moraines; they become narrower, and assume the aspect of cols. See fig. 3.

2. A much more important group of objections exists, which may be summed up under the title of Incompatibility of Levels.

a. To the east and west of the Seneca valley, at a distance of 6–12 miles, there run two upland valleys; on the east, that of Cayuta Creek, 26 miles long and half a mile wide; to the west, that of Pine Creek, about half that length. They begin opposite Watkins and run southward. In this situation it is hardly conceivable that a general flexure, capable of affecting the beds both of Seneca and Cayuga Lakes, should fail to affect similarly the valley of these creeks; especially as Cayuta valley lies between the south extensions of Cayuga and Seneca valleys. But in point of fact, this is what has occurred:—the valley of Seneca falls *northward*, its probable bed descending nearly 900 feet in 30 miles (Elmira 700 $\pm$ A. T., lake-bottom 176 below tide]. The valley of Cayuta Creek falls *southward*, descending probably 300 feet in 26 miles (and doubtless considerably more, if its rock-bed were uncovered at its lower part). Pine Creek similarly falls 337 feet *southward* in 13 miles from Beaver Dam (1279) to Corning (942). It is of course quite possible that streams should interlock in this way over a divide, flowing in opposite directions for a time. But it is unlikely that a large river (by supposition, the upper Susquehanna) should have run from Elmira north with a descent of 30 feet to the mile for 30 miles. If such were the state of things, a deep narrow gorge with vertical sides would have been produced, extending back at a relatively rapid rate far down into Pennsylvania. The actual outlines of the section of the lake (fig. 3) are absolutely contradictory of this view.

FIG. 3. Combined sections of Seneca Lake and the Ohio River, on the same scale (vertical 4 times the horizontal). The lake is taken near the southern end, on line III of Cornell University map; from Reading Centre east to hill at Burdett. The river (ABBA) is an average section within 12 miles below Pittsburgh obligingly furnished by Prof. F. W. Very of Allegheny, Pa. Width of lake 6250 feet; width between the Ohio bluffs (B-B) 7000 feet; width of lake-valley between high points 22,000 feet. Depth of water in lake 540 feet. (The greatest depth is 2 miles north of section = 618 feet.) Depth of Seneca valley, from level of bluffs 800 feet; from level of plateau (Reading Centre), 1400 + feet. Depth of Ohio valley, from plateau at bluffs (B-B), near 500 feet.

2b. The incompatibility between the Seneca valley and those of the high land appears further in this: that if they had coexisted, the deeper must have "robbed" the less deep.

The smaller upland creeks above named, lying nearly 1000 feet higher than the Seneca bottom, and distant only 4 or 5 miles, without obstructing elevations of ground, must inevitably have become its tributaries. But not the first step seems to have been taken towards this end. The upland systems were uninfluenced, during their formation, by such an attraction; hence we may infer its non-existence.

3. Probably the most important argument in this direction is drawn from the *absence of side valleys* along Seneca and Cayuga Lakes. In this respect, the lake-scenery presents a remarkable contrast to that of the valleys lying beyond the line of moraine, which are entirely typical in this respect. The contrast is observed immediately on crossing the moraine, e. g. to the south of Havana; still better, along Cayuta Creek. While the latter valleys are notched down to the flood-plain level, every mile or two, the lake-side for stretches of 10–15 miles seems like an artificially smoothed garden-slope.

Professor Chamberlin noticing this, suggests as a probable view, that at least one-half of the depth of the old side-valleys has been lost through the shearing action of the glacier upon the projecting bluffs. The remainder of the effect is due to filling with drift. This is exactly in the direction of the present line of thought. But it seems necessary, in view of certain conditions, to carry this observer's views to a somewhat more radical conclusion. These conditions are the following:

The upper twenty miles of Seneca Lake is bordered by a continuous line of cliff, varying from 20 to 100 feet in height, but presenting only very gradual changes in level. As the coast forms almost a straight line, the inference is clear that no deep incisions exist at that level, or from 500 to 600 feet above the lake-bottom—practically, about half-way up the valley-side, where the side-notches would have made the deepest incisions. These remarks are intended to apply only to such small, but deeply cut notches as would correspond to streams of half-a-dozen miles in length: such, for instance, as may be seen by following the valley ten miles southwards from Watkins. Larger valleys, joining the lake at near the present water-line, may be instanced; Seneca Lake has one such at Dresden, which seems to have formed the original outlet of Kenka (Crooked) Lake; the Post-glacial gorge follows the same route. Cayuga Lake has the valley of Salmon Creek, opening at Ludlowville, near Ithaca, and running some 16 miles midway between Cayuga and Owasco Lakes. The bottoms of these valleys contain a very heavy deposit of drift, but not enough to prevent their forming impressive features of the landscape. Other than these, no important valleys enter the two lakes. The fluctuations in the height of the lake-cliffs suggest that

we may yet trace the residue of the old side-notches in degraded forms. The same is suggested in places by curves in the higher landscape.

As representing several aspects of this discussion, let us consider the case of the valley at Dundee, which lies ten miles north of Watkins. Its banks are composed of Chemung sandstone, thinly coated with drift; they rise several hundred feet above the little valley at a moderate angle. The stream runs in a tolerably direct course towards the lake for about five miles, with a moderate fall of 4-20 feet per mile. Passing the village of Dundee—where it runs over rock for a mile—the stream cuts under the viaduct of the Fall Brook railroad, and at once begins a plunge of 500 feet, which it accomplishes in less than two miles by a line of post-glacial gorges. If it could descend to the bed of the lake, the remaining 600 feet of fall would be accomplished in one mile. Such a case appears to show (1) the loss, through lateral shearing, of the Dundee valley, beginning at the point where its plunge commences. The modern landscape suggests the same. (2) The deepening of the main channel of Seneca, to an extent sufficient to enable us to bring it into correlation with such tributaries as this upland stream. Obviously, this implies a large figure—several hundreds of feet both laterally and horizontally.

In conclusion, it is worth notice that Dundee valley, and other valleys at corresponding heights across Seneca Lake, on the east side, agree very fairly in elevation with the system of petty valleys antedating Glacial time which empty into the Chemung near Elmira. The trough of Seneca Lake (with that of Cayuga) stands an exception to the harmony, and its excessive depth is from several points of view irreconcilable with the hypothesis of pure river-erosion, with or without crust-bending.

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