Art. LVI.—*The Deformatin of Iroquois Beach and Birth of Lake Ontario;** by J. W. Spencer.

Upon receding from the lake and ascending the high country which bounds the Ontario basin, an observer is attracted to the wonderfully plain shore-lines which record the former expansion of the waters. The terraces, beaches, scarps, and spits across the mouths of valleys clearly represent the deserted shores. But they are no longer horizontal lines as when laid down at the level of the former waters. As distinctive features, the beaches were so striking as to attract the attention of the aborigines, who used them as trails across an otherwise, sometimes, muddy country. The early white settlers, in turn, used them as highways and hence we find the "ridge roads" about Ontario as well as about the upper lakes. But the recognition of the shore-like characters of the raised beaches, by the early writers,† did not contribute much to the solution of the lake history.

Nearly fifty years ago, Professor James Hall observed that the beaches in New York were not horizontal. But Mr. G. K. Gilbert was the first who surveyed and measured the deformation of the beaches upon the southern and eastern margins of Lake Ontario, and the writer upon the Canadian side of the lake to beyond Trenton, whence the same beach swings around towards the north and passes into a broken country. The writer has further carried the survey of the same beach about sixty miles beyond Watertown, the limit of Mr. Gilbert's observations.

There are wide-spread remains of old shore-lines at altitudes so high above Lake Ontario, as to indicate that the same sheet of water (Warren water) covered also the basins of the other and higher lakes. After the dismemberment of this greater sheet of water, the surface of that occupying the Ontario-St. Lawrence valley was gradually lowered, and fell several hundred feet, without pausing long enough to deeply cut out or straighten its changing shore-lines. At last, this shrinkage of the waters came to a pause lasting until the shore-line became more pronounced than that of the modern lake. It is this shore-line that forms the basis of the present chapter, and constitutes that water-margin which the writer has named

* The forerunner of this paper was—"The Iroquois Beach, a chapter in the Geological History of Lake Ontario"—was first read before the Philosophical Society of Washington, January, 1888. Proc. Phil. Soc. for 1888, and was subsequently amplified and published in full in the Transactions of the Royal Society of Canada for 1889.

† For reference to early writers, see "Iroquois Beach," etc., Transactions Royal Society of Canada, 1889, page 121.

the "Iroquois Beach,"* in memory of the aborigines who trailed over its gravel ridges.

The general structure of the ancient shore-lines is somewhat fully described in "Ancient Shores, Boulder Pavements, etc."† but let us here repeat some of the characteristics. Typically, then ancient beach consists of a ridge of gravel and sand rising sometimes to twenty-five feet or more above the frontal plain, which further descends lakeward (as in fig. 1.) Back of the ridge, which rarely exceeds a width of 500 feet, and usually less, with a very narrow crest, there is often a lagoon-like depression. The beach may be broken into a number of ridges (*b* or *c*). The summit marks the height of the wave action. This barrier ridge

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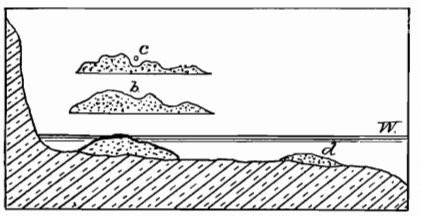

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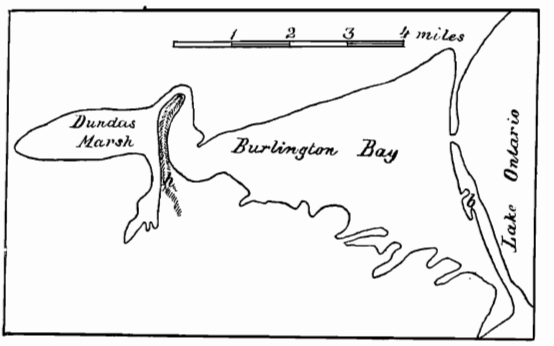

may become a terrace, or it may pass into the form of a spit across some valley (*h* or *b*, fig. 2). Again the ridge may be wanting, but the shore will be represented as a cut terrace (fig. 3), in front of which a bowlder pavement may frequently be seen (P.) This pavement is also often found in front of gravel beaches. In places where the former waters were gnawing away the drift shores, or where rocky promontories rose out of deep water, true beach structure is wanting, or only represented by benches.

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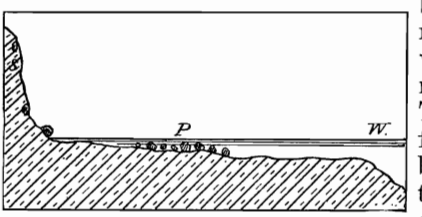


* The name was first printed in Science, Jan. 27th, 1888. p. 49.

† By the writer, in Bulletin of the Geological Society of America, vol. i, 1879, p. 71.

In the survey of the Iroquois Beach, the shore-line has been followed by one or another of its characteristics, even across areas of broken physical features. The altitude of the highest ridge, where the beach is broken up into a series of ridges, is that which has been everywhere taken, for it is the one giving most accurate results. No elevations have been adopted except those of the summit of the crests (as in fig. 1), or of the spits (at *h* or *b*, fig. 2). The measurements consequently represent the maximum height of wave-action, in place of the mean surface of the water, which was a few feet below. The writer's leveling has everywhere been done instrumentally.

The coast materials, out of which the Iroquois shores have been carved, are mostly bowlder clay, or stratified clays or sands, deposited upon the floor of the lake when the waters were at higher levels. At a few places the shores rest against Paleozoic rocks, in which case the materials of the gravel beach are more scanty, as the pebbles were mostly derived from the stony drift, or there may be an absence of the beach.

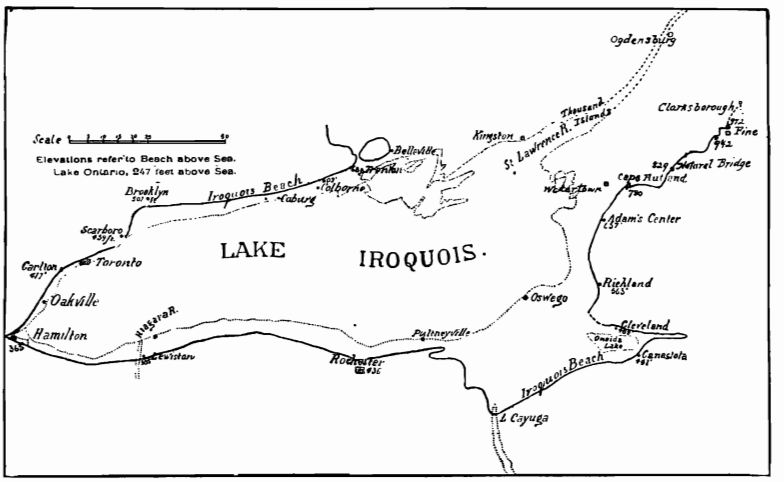
Except in spits across old valleys, the thickness of the sand and gravel of the beach does not usually exceed 20 feet, but in front of valleys it may reach a thickness of 100 feet (*h*, fig. 2). The internal structure always shows stratification, with such sloping and false-bedding as are characteristic of beaches.

There are frequent exposures which show that the Iroquois Beach rests upon stratified stoneless clay—the silt washed into the waters when the waves were encroaching upon older and higher shore-lines, and assorting the bowlder clay, which, at the higher elevations, formed the coast. Eastward of Watertown, the beach rests upon stratified sand in place of clay, as there was but little stony clay in the drift to furnish silt for the older lake floor.

From near Trenton to the head of the lake, and thence around the southern and eastern borders to near Watertown, the Iroquois Beach is not hard to follow; but eastward of that point the features are more complex. The old coast of stony clay is there replaced by stony drift sand, and hence there is but little lithological distinction between the frontal plain and the older sandy drift shores. Moreover, such a coast is apt to be defaced by the sand being heaped into dunes. Again, in the region beyond Watertown, the Iroquois Beach is interrupted by promontories of Paleozoic limestones and shales, rising out of deep water, upon which at most only benches were cut. Farther, northeastward, the beaches trend among bold headlands and islands of crystalline rocks. Wave action, which carves broad terraces out of drift materials, can cut only moderately well-marked benches out of limestones. But when the same intensity of wave force is applied to hard crystalline

rocks, especially when interrupted by islands, the benches become less conspicuous than when excavated out of limestones, or they may become very obscure. Still, upon the flanks of the Adirondack Mountains, the Iroquois Beach can be followed and identified by the remains of barrier ridges, terraces, bowlder-pavements, benches, and above all by the occurrence of spits across old valleys.

Combining the surveys of Mr. Gilbert and the writer, the position of the Iroquois Beach is shown on the accompanying map.



The following table gives the elevation at salient points along the Iroquois Beach. The elevations given are those of

	Feet above the sea.	
Lake Ontario, surface of	247	(U. S. Lake Survey).
Hamilton	363	(Spencer).
Burlington Heights	355	"
Waterdown Station	365	"
Cooksville Station, about	400	"
Carlton Station	417	"
Kingston Road, crossing railway 12 miles east of Toronto,	459	"
Whitby, 6 miles north of lake, near	507	"
Colborne Station, 2 miles north of	602	"
Trenton Station, 2½ miles north of	682	"
Lewiston, N. Y.	385	(Gilbert).
Rochester, "	436	"
Canastota, "	441	"
Cleveland, "	484	"
Constantia, "	489	"
Richland, "	563	"
Adams Centre	657	"
Prospect Farm, 4 miles east of Watertown	730	(Spencer).
Natural Bridge	829	"
East Pitcairn, one mile northeast of	942	"
Fine	972	"

the crest of the highest ridge, where the beach is broken into a number of ridgelets, having sometimes a vertical range of twenty-five feet or more.

Thus we see that the Iroquois Beach has been deformed to the extent of 609 feet, between the western end of Lake Ontario and Fine, of which only 78 feet of rise occurs upon the southern side of the present lake, while the great proportion of the uplift is found west and northwest of the Adirondack Mountains. Upon the northern side of the lake, the eastern equivalent of uplift is more pronounced. At the western end of the lake, the mean maximum uplift is 1·60 feet per mile in a direction of N. 28° E. This rate increases towards the northeast. To give a mean rate of rise, at the eastern end of the lake, does not convey a correct idea, for the uplift increases in a progressive ratio. Thus in the region of Oneida Lake, the uplift is 3·5 feet per mile, while in the region of Watertown it amounts to 5 feet per mile; and farther northeastward the deformation reaches 6 feet per mile, in the direction of N. 60° E. This seems an extraordinary amount of measurable terrestrial movement, but the records are inscribed in the beach. It is not yet known where this upward movement ceases.

Upon the Erie beaches, outside of the Ontario basin, Mr. Gilbert found a considerable amount of warping recorded at Crittenden, N. Y., over the horizon at the western end of the same lake. I have traced the Erie beaches around to the southeastern side of Lake Michigan. Combining our results, I find the measured uplift between the two regions amounts to 324 feet. But the beach, where last observed near Lake Michigan, is 45 feet above its surface. Indeed, it is there difficult to trace, owing to the dryness character of the sandy country. By the assistance of other beaches found in that region, the conclusion is readily arrived at that the shore-line under consideration must pass from 40 to 60 feet beneath the waters of the lake at Chicago. It is then evident that the terrestrial uplift, between Chicago and Crittenden, amounts to not less than 410 feet. Crittenden is nearly on the line of strike of the Iroquois beach (S. 62° E.), at its lowest point, with Hamilton. The Erie beaches, eastward of the Niagara River, were deformed to the extent of 0·4 feet per mile before the Iroquois episode, the remainder of their uplift having been synchronous with that in the Ontario basin. But the pre-Iroquois differential uplift of the beaches farther west is reduced to almost zero, for the beaches south and west of Lake Erie have suffered very little deformation. Consequently a sufficient amount of deformation of the beaches has been measured to allow for inaccuracies when we take the elevation of the Iroquois Beach above

the sea level (363 feet), as the amount of movement that must be added to the Iroquois plain in order to represent the terrestrial uplift of the Ontario basin since the Iroquois shore was formed. Therefore, it is apparent that *the great Iroquois Beach was constructed approximately at sea level.* The total amount of uplift since the episode will then be the height of the beach, at any place, measured above the sea level, which, at Fine, is 972 feet.

Were the Erie beaches recognizable in the Adirondack wilderness near Fine, they would be found at altitudes of 1600 feet and more above the sea. But this is a calculation outside of our subject, which is based upon measurements.

The terrestrial movements recorded in the beaches have not been those of subsidence towards the west, but of uplift towards the east, in the same direction as those changes which have left unquestioned marine remains deposited at high altitudes in the St. Lawrence valley.

One focus of the warping about the western end of Lake Ontario and about Georgian Bay appears to have been in the region of lat. 48° N., long. 76° W. Another focus of uplift is somewhere beyond the last point of rise measured in the Adirondacks. Thus the axis between these foci appears to coincide, more or less, with the old Archæan axis of the continent, as suggested by Professor Dana.

The uplift of the Iroquois Beach has been since the episode of the uppermost deposits of drift or till, for higher and older beaches than the Iroquois rest upon the newest stony clays of Ontario, Michigan and other slates. The Iroquois Beach rests upon the mud floors of the earlier sheets of water which covered the till deposits. The rate of northeastward regional uplift has been gradually diminishing, for we find other beaches, lower than the Iroquois, whose rate of rise is much reduced below that of the great beach. But the Iroquois plain was the great event in the history of the Ontario basin.

In the rising of the land, after the Iroquois episode, there were pauses, but not of such duration as to permit of the formation of great shore-lines like that just described. After the waters had fallen about two hundred feet below the Iroquois plain, there was a conspicuous rest. This is recorded in a terrace near Watertown at 535 feet above the sea. At Oswego, we find a beach descending to near water level, at about 185 feet below the great Iroquois beach. Farther westward, it passes below the lake. The dip of the Iroquois Beach, between the region of Oswego and the western end of the lake, is about 78 feet; and accordingly we should find the remains of this younger shore-line (for a large proportion of the regional uplift has been effected since its formation) submerged

to 65 or 70 feet at the western end of the lake. Behind the modern bars and beaches, the water of Irondiquois Bay (a narrow river-like channel) is 78 feet deep; the Niagara River, 72 feet; and Burlington Bay, 78 feet. These conditions indicate that the lake covering these channels was at one time withdrawn, leaving only a few feet of water in the rivers which flowed through the otherwise dry valleys. Here, then, in front of the bays, submerged or buried by more recent accumulations (upon re-submergence), is the position of this lower beach extending westward of Oswego, which was formed at a level now 70 feet below the surface of the western end of the lake. Indeed, the uniformly narrow Burlington Beach (*b*, fig. 2), with a length of five miles across the end of Lake Ontario, is thus easily explained as having originated as a small barrier, in front of the shallow river, flowing down the Dundas valley and across the now submerged floor of Burlington Bay. With the more recent backing of the waters of the lake, this bar grew to the proportions of the modern beach, built out of materials derived from the older shores and not from river deposits.

At the time when this young beach—now beneath the lake—was being formed, the waters had receded for only from three to five miles from what are now the western shores of Ontario, but they extended farther landward than at present upon its northern side, as shown by the raised beaches, and by the absence of submerged channels.

The Niagara River was about three miles longer than now, cutting its way over a projecting point of shaly rocks. But this channel is at present filled, and is again further submerged beneath the lake.

During the continued rise, the waters of the Ontario basin may have been even somewhat further shrunken at its western end, and the waves may have moulded some of the submerged escarpments upon the southern side. The waters upon the southern side could have nowhere been more than about 200 feet below the present level, even if that amount of shrinkage, which represents most of the barrier holding the basin above the sea, ever obtained. However, no important geographical event is recorded in any of the possible coast-lines submerged at levels below that just described.

With the regional uplift, the barrier across the St. Lawrence valley eventually cut off free communication with the sea, at a common level. This uplift has continued until the Iroquois Beach now rests at 972 feet above the sea at Fine, and the modern lake at 247 feet. *Thus the modern lake had its birth.* This warping at the northeastern end of the lake, during the later and since the Pleistocene period, has been enough not

only to account for the rocky barrier holding the lake above the sea, but to account for all of the barrier across the St. Lawrence valley closing the ancient basin of Ontario to a depth of nearly 500 feet below sea level.*

In the Iroquois Beach no shells have been found. Only the remains of mammoth, elk and beaver have been met with.† Consequently, the question arises as to the freshness of the waters. Not far from the eastern end of Lake Ontario, the remains of a whale were found at 450 feet above the sea—at an elevation which would admit of the free access of oceanic waters into the Ontario basin.‡ Still no other marine or fresh-water fossils have been found in the beaches. It therefore appears to me that the absence of such organisms speaks no more in favor of fresh water conditions than of brackish or even salt when the Iroquois shores were being formed; and does not preclude the idea of free communications with the sea any more than when the whale came landward in waters 200 feet higher than the present lake surface. Indeed, I look upon the Ontario-St. Lawrence valley, during the Iroquois episode, as resembling the Gulf of Obi, which is a sheet of water from 40 to 60 miles wide, and 600 to 700 miles long, into which so much fresh water is discharging as to render even the Arctic Sea for sixty miles beyond the mouth of the gulf so fresh as to be almost potable,§ and sufficiently fresh to destroy marine life.

The only dam that has been hypothecated as filling the St. Lawrence valley is that of a glacier. As the Iroquois Beach was at sea level, no dam ought to be required to hold up the water, but at most only to keep out the sea. However, I have followed the beach for sixty miles within the margin of the hypothecated barrier without finding the traces of an ending of the old shore markings upon the confines of the Adirondack wilderness. Even the coincidence of the shallow and small channel, discovered by Mr. Gilbert, connecting the Iroquois waters with the sea, by the Mohawk valley, or of the broader and lower valley of Lake Champlain, does not prove the necessity of a former barrier across the St. Lawrence valley any more than the narrow channels among the gigantic islands north of Hudson Bay would prove the former presence of a dam holding in the waters of that bay, were the whole country elevated. For a glacial dam to exist across the Adirondacks, even

* See Origin of the Basins of the Great Lakes, by J. W. Spencer, Q. J. G. S., vol. xlvi, Part 4. 1890.

† Col. C. C. Grant of Hamilton has recently found other vertebrate remains, but not yet determined.

‡ Sir W. Dawson, Can. Nat., vol. x, p. 385. The remains are in the Redpath Museum at Montreal.

§ Nordenskjöld in "Voyage of the Vega," p. 140.

at the narrowest point, it would need to be 50 or 60 miles wide. If it had no greater depth than the water north of Fine used to have, the ice would need to be thick enough to fill a channel of 800 feet. But as the differential uplift probably continues throughout the Adirondack region, we would need to be prepared to accept a dam of at least 1300 feet in thickness, and a hundred miles across. Apparent beaches in Vermont at 2100 feet above the sea (Hitchcock),* and the Post-Pleistocene emergence of Mt. Desert, observed in the coastal markings to its summit of 1500 feet (Shaler),† increase the probability of our regional uplift continuing throughout the Adirondacks.

Any water-proof dam in front of the Iroquois Beach would have had to endure throughout the long period of its formation. But all known glacial dams are small and evanescent. Yet the one suggested as closing up the Ontario's basin would have had to restrain a greater sheet of open water than that of modern Lake Ontario, receiving not merely the waters of the then upper lakes, but also those of the melting of the hypothecated glacial dam. It is questionable what thickness of ice would hold in the waters, for the modern glacial dams of Mt. St. Elias discharge beneath 500 feet of ice for a distance of eight miles.‡ As soon as the waters fell below the Mohawk outlet, the discharge of the glacial lake ought to have melted and lowered the ice on the one side and carved out terraces on the other, unless the river were 50 to 100 miles wide. And there are terraces upon the northern side of the Ottawa valley, as well as upon the flanks of the Adirondacks.

There seem to me to be no phenomena in the later lake history of Ontario necessitating the existence of a dam across the St. Lawrence valley. In short, the Iroquois water was a gulf. The Adirondacks and New England formed great islands. The Iroquois episode commenced almost synchronous with the birth of the Niagara Falls. And the history of Lake Ontario records interesting and great changes which now form a simple story.

* Geology of Vermont.
† Geology of Mt. Desert. Eighth Annual Report of U. S. Geol. Survey.
‡ Harold Topham in Proc. Roy. Geog. Soc., 1889, p. 424.