ART. II.—*Deformation of the Algonquin Beach, and Birth of Lake Huron;* by J. W. SPENCER.

FROM the ship's deck, my attention to the high terrace, which skirts the coast of Georgian Bay, was first attracted. But long before, fragments of this ancient shore-line were used by the Algonquin Indians, in the same manner as the Iroquois tribes had trailed over the "Ridge Roads" of Ontario and Erie. Mr. Sanford Flemming, C.E., described in 1853, some of the drift ridges at the head of Georgian Bay, and recognized certain high level beaches.* Later the Geological Survey of Canada measured the elevation of some of the raised terraces.† But those early investigators did not recognize either the extent of the beaches or their deformation from the water-level. No systematic explorations of the old shores were made until the summers of 1887 and 1888, when the writer, assisted by Professors W. W. Clendenin and W. J. Spillman surveyed portions of them. In the autumn of 1887, Mr. G. K. Gilbert visited some of the Canadian terraces. In August, 1888, I abruptly left the field and reported some results before the Cleveland meeting of the American Association for the Advancement of Science.‡ Some references to the Georgian Bay beaches were made in "The Iroquois Beach, etc.,"§ and later Mr. Gilbert generalized upon the history of the Upper Lakes, in an interesting paper entitled "The History of the Niagara River,"‖ wherein some of his raised shore-lines were taken from my survey, unpublished portions of which having been furnished to him.

Upon the Canadian side of the lakes, there are well preserved shore-lines, marking the same episodes, as those upon the American side, when all the lakes were covered by a common sheet of water (the Warren water). These raised beaches have been more or less surveyed, but they belong to an episode earlier than that recorded in the beach, which confined the waters to the Upper Lake basins not embracing that of Lake Erie. This beach, which skirted the head of Lake Huron, cutting off the waters from the Erie basin, is now submerged at its southern end, but it rises as a conspicuous feature in the

* Valley of Nottawasaga, Can., Jour. Toronto, vol. i, 1853.

† Geological Survey of Canada. 1863.

‡ "Notes on the Origin and History of the Great Lakes of North America," by J. W. Spencer, Proc. A. A. A. S., vol. xxxvii, 1888.

§ "The Iroquois Beach, a Chapter on the Geological History of Lake Ontario." Read before Phil. Soc. Wash., Jan. 1888, and Roy. Soc. Can., May, 1889. Proc. Phil. Soc. Wash., 1888. Trans. Roy. Soc. Can., 1889.

‖ Sixth Annual Report of the Commissioners of the State Reservation of Niagara for 1889.

topography of the country. I have named it after the Indians who, long ago, used it for a trail—the Algonquin Beach.* It forms the basis of this paper.

Between Lakes Huron, Ontario and Erie, at respective altitudes of 582, 573, and 247 feet above the sea, the land rises to 1709 feet. It shows water action to within 20 feet of its summit. From the highest ridges or plains, the land falls away towards the lakes, sometimes gradually, but often by abrupt steps, especially upon the northeastern side. Over this peninsula, there are many ridges of drift. Exclusive of the ridges, the general surface of the country is composed of fine stony till, or of modified drift,—the product of wave action upon the stony clay, the result of which has been the formation of beach ridges of sand and gravel, separated by plains of silt or clay soil. In many cases, these floors slope so gently as to appear level, and from two to five or six miles may intervene between successive beaches, whose altitudes do not differ by more than 50 or 60 feet. The silt on these plains is that which was washed out into the deeper water, by the assorting action of the waves that were building sand or gravel beaches in front of their coast lines, composed of the older stony clay. In such cases, the lithological recognition is striking. Upon surveying, the beaches are all found to rise in altitude toward the north and east, with a slightly increasing divergence between the ridges in the same direction, for the differential uplift has always been greater toward the northeast, than in the opposite direction.

The methods of investigation have been similar to those pursued in the survey of the Iroquois Beach. Boulder pavements are rather more important features of the Algonquin Beach than of the Iroquois. About the head of Georgian Bay the country is sandy. East of Georgian Bay, there is the same kind of broken wilderness as that among the Archæan rocks of the Adirondack Mountains of New York, with more or less stony sand in place of stony clay.

The waves of the lake are encroaching upon the eastern coast of Huron, and consequently modern beach-making is not a characteristic feature, except in proximity to the mouths of some streams or in sheltered places, where terraces or bars are constructed. The encroachments of the lake upon the land have washed away, in many places, the bluffs upon which the Algonquin Beach rests. But a sufficient number of fragments remain, for its identification, especially as the position relative to its elevation, compared with the next higher shore-lines, which are well marked by beaches, is known.

* The name was first printed in Proc. A. A. A. S., p. 199, 1888.

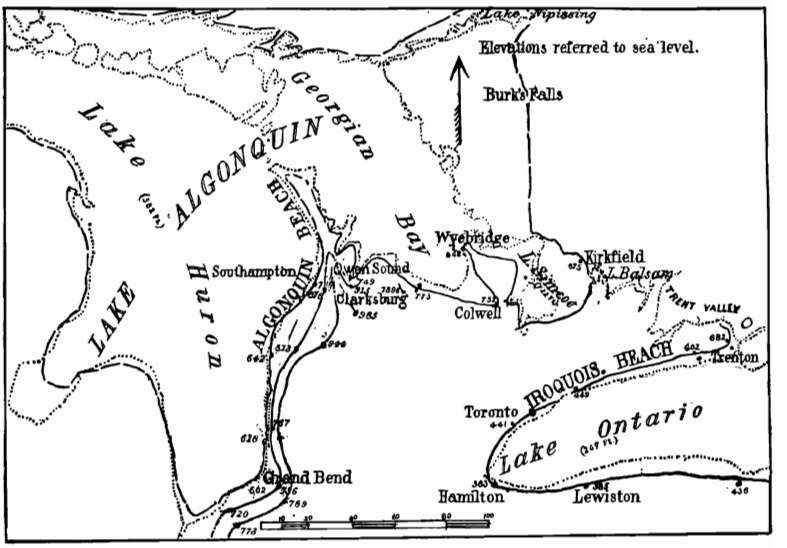

Fig. 1.—Map showing the Algonquin Beach about the eastern portion of Algonquin Lake. Other beaches are also shown.

The following table gives the levelled elevations of salient points along the Algonquin Beach, at or near the places mentioned:

	Feet above the Sea.	
Surface of Lake Huron	582	(U. S. Lake Survey.)
Beach at one or two miles lakeward of modern outlet of Lake Huron, calculated	562	(Spencer.)
Grand Bend (of Au Sable River)	602	"
Wilson's (14 miles northward, terrace at 608 feet, calculated)	618	"
Eighteen Mile Creek (terrace 637 feet, calculated)	647	(Barometer.)
Southampton (back of which a sand dune rises 13 feet higher)	714	(Spencer.)
Thence the beach skirts Indian Peninsula, and at Owen Sound	749	"
Clarksburg	773	"
Collingwood, 4 miles west of	767	"
Colwell	752	"
Elmsvale	802	"
Wyebridge, east of	842	"
Orillia, about	800	(Barometer.)
Thence the beach descends and swings around Lake Simcoe and again rises at Kirkfield	875	(Spencer.)
Burk's Falls (+ or −) (?)	1171	(N. W. & N. Ry.)

Beyond Kirkfield, the survey was not carried, but from the topography of the country and from the fragments of the beaches, the position of the Algonquin Beach is approximately that of the broken line on the map. The gravel ridge at Burk's Falls is probably part of the beach, as the mean rate of northern rise would represent its position near this point.

For comparison with the Algonquin Beach, the positions and the elevations of the two next higher beaches, east of Lake Huron are given on the map, and the tables of elevations are here added. Of next beach, at or near:

	Feet above the Sea.	
Forest	720	(Spencer.)
Parkhill, east of	736	"
Bayfield, east of	767	"
Ripley	813	"
Walkerton (terrace)	825	"
Paisley (terrace)	860	"
Burgoyne (east of Southampton)	876	"
Rockford, north of	915	"
North coast of Lake Simcoe (probably that) on the insular ridge north of Barrie	910	"

Of the second beach above the Algonquin, at or near:

Watford	773	"
Ailsa Craig	789	
Varna	845	(+)
Walkerton	944	
Chatsworth	985	

A still higher beach has been surveyed for many miles, and several fragments of even more elevated shores are now well identified. Some of these upper beaches have been traced over long distances, and have been found resting upon the land north of Lake Erie, and even extending to the high country between Lake Ontario and Georgian Bay.

From the figures recorded in the three tables, it will be found that the mean rate of warping in the Algonquin Beach, from the southern end of the lake to near Southampton, is 1·33 feet per mile; of the next beach, between Parkhill and Burgoyne, 1·5 feet; and of the higher beach, between Watford and Walkerton, 1·71 feet. These rates of differential uplift are reduced at their more southern extensions, but increased to two feet, or somewhat more, at the more northern.

After skirting the Indian Peninsula, the position of the Algonquin Beach surrounding the head of Georgian Bay is such that it can be triangulated, and hence the average amount of uplift, as well as its direction can be obtained. Accordingly, it is found that the uplift upon the more south-

western portion of the beach, at the head of the bay, is about 3 feet per mile, in a direction of N. 20° E., with an eastern equivalent of about one foot per mile. The uplift increases so that east of Georgian Bay the mean rise is 4·1 feet per mile in a direction of N. 25° E., with the eastern equivalent of 1·7 feet per mile.

At Grand Bend, the beach rests upon a fine stony drift clay—the latest deposit of till in that region—which is charged with numerous scratched stones. It is also indistinctly stratified. The same holds true at Wilson's and other places. About Georgian Bay, it also rests upon the upper till. In short, the waves, which formed the beach, have commonly removed the silt deposits that covered the floor of the lake, during the earlier episodes of the higher beaches, and cut into the underlying drift deposits during the Algonquin episode, before the beach structure was laid down. In many places, especially about Georgian Bay, the boulder-pavements are well developed, especially between the different ridges of the Algonquin Beach, for it is often broken up into a series of prominent ridgelets, the lowest being, where developed, as much as 28 feet below the upper.

There are several beaches about Georgian Bay, at lower altitudes than the Algonquin, but these rise less rapidly toward the northeast than the greater named beach. At Clarksburg, there is a beach at 81 feet above the lake, and terraces at 62 and 45 feet, besides a numerous series of beaches extending from 28 feet down to the water level. Near Wyebridge, the more conspicuous terraces are at about 183, 73, 55 and 11 feet above the lake; and there are numerous fainter shore-lines. These all show that the time of the subsiding of the waters was marked by numerous pauses.

Between Kirkville and Balsam Lake, there is a depression a few feet below the level of the upper part of the Algonquin Beach. But of this later.

No animal life has been found in the beach itself. But in a terrace, adjacent to the Saugeen River (bridge east of Southampton), where there is an embayment of the Algonquin Beach, there is a bed of fresh-water shells, discovered by Mr. Spillman. This is at an altitude of 90 feet above the lake, or over 40 below the beach. This deposit may have been on the floor of the lake during the Algonquin episode, or it may belong to a lower water-level. The river has now cut down its bed far below this level. At the head of Georgian Bay, fresh water shells have been found up to 78 feet.*

There are several depressions across the Laurentian Mountains, between Lake Huron and Hudson Bay which do not

* Geology of Canada, 1863.

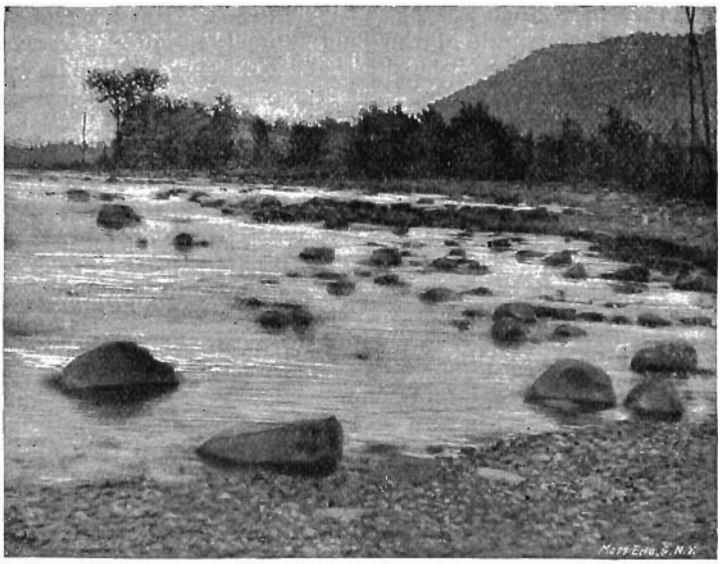

FIG 2 —MODERN BOULDER PAVEMENT ON GEORGIAN BAY,
NEAR THE END OF BLUE MOUNTAINS OF COLLINGWOOD, ONT.

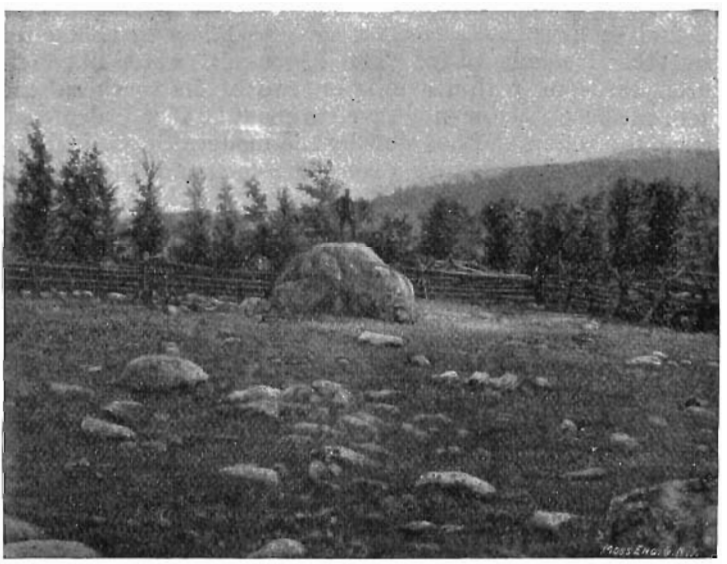

FIG. 3 —ANCIENT BOULDER PAVEMENT OF ALGONQUIN BEACH.
(whose crest rises 187 feet above Georgian Bay) upon the N. E. side of Blue Mountains of Collingwood, Ont.

rise much more than 900 feet above the sea. But towards the northeast, the altitude of the land is everywhere high, except along the depression in which Lake Nipissing lies. The barrier there descends to 707 feet above the sea. Beaches and shore lines are known to exist upon the land north of the lakes, and I have seen such upon Manitoulin and Mackinac Island. But they have not been directly connected with the more southern beaches. Consequently, all deductions, in the study of the lake involving that district, must be somewhat provisional. From the character of the terrestrial rise increasing towards the east, it is probable that there are no depressions north of Lake Huron, lower than the plain of the Algonquin Beach. This beach (by calculation from the mean rate of rise) should be found in the vicinity of Lake Nipissing, at from 600 to 700 feet above that depression.

Combining the Canadian series of beaches about the upper lakes with corresponding series on the southern side of the lakes (my survey of those in Michigan being still unpublished), I find that there has been a differential elevation, since the Algonquin episode, between the southern end of Lake Michigan and the vicinity of Grand Bend, on Lake Huron, amounting to about 290 feet. Hence, we know that the Algonquin plain was down to a level, at least, of less than 300 feet above the sea. By a triple series of calculations, the Algonquin plain is found to have had a position somewhat less than 300 feet above the Iroquois plain. The Algonquin water filled the Huron basin to within a mile or two of its southern end, where the beach is now submerged to about 20 feet, (calculated). Hence, the waters did not flow by the modern St. Clair River to the south. At this time a considerable area of the southern end of Lake Michigan was laid dry, as the beach bounding the Algonquin water should now be submerged to 290 feet below the waters of that modern lake. But the northern part of the Michigan and Huron basins was filled to an elevation far above their present surface, as the basins had not yet received that great tilting which partly overflowed their southern margins and lowered their surfaces toward the north.

There is a well-marked terrace and beach deposit on Mackinac Island, at about 190 feet above the lake. This is nearly in the line of strike, or line along which there is no differential elevation, of the lowest part of Algonquin Beach about Georgian Bay. This old shore line, on the island, is better developed than any of the Huron Beaches, situated elsewhere, except the Algonquin. From its position, there seems no reason to doubt that the waters of Algonquin lake stood at that elevation in the strait between the Michigan and Huron basins. Accordingly, tilting in the Michigan basins has amounted,

since the Algonquin episode, to about 430 feet in 300 miles, or a little more. This approximation is close upon the mean rate of uplift measured east of Lake Huron. Parenthetically, it may be added that President Chamberlain found clays upon the western side of the lake which represent a differential uplift of 400 feet (although they belong to an older episode), which were in part involved in the earlier Pleistocene movements.

The Algonquin water also covered most of Lake Superior, probably to within a short distance of its southwestern end, as that basin is so deep; yet the waters must have been very much shallowed. Indeed, the recent backing of the waters towards the head of Lake Superior is apparent in the open bays behind the bars, which cut off Fond du Lac, at Duluth. The area of the Algonquin Lake or Water may be seen from what has been written, to have been vastly greater than now, filling the upper lake basins, nearly to their extreme margins, and overflowing the land northeast of Georgian Bay, as shown on the map. On Mackinac Island and adjacent portions of the mainland, there are several shore lines lower than that assigned to the Algonquin plain and of inferior importance.

In the early history of the Algonquin water, there was an overflow by way of Balsam Lake and the Trent valley. My first impressions of the importance of this outlet were overdrawn in the preliminary communication* of observations from the field, before all of the relations had been explored. At first I attached as much importance to the Balsam outlet of the Algonquin basin as Mr. Gilbert did to his Mohawk outlet of the Iroquois basin. As both are too shallow, the demands are satisfied in neither case. Only at its highest level did the Algonquin Lake overflow into Balsam Lake. Even the overflow was sluggish, permitting of the formation of beaches about the outlet. Before Algonquin water sank to the level of its lower beaches, its discharge was by a channel below Balsam outlet. The occurrence of an overflow in this last direction, is only one of the coincidences, as in other cases, in the growth of the lake. The outlet of the Algonquin Basin, by way of Lake Nipissing and the Ottawa valley, was through a depression, which now rises to 707 feet above tide. This trough has now an absolute depression of 168 feet below the Algonquin Beach at Kirkfield. But the altitude of the beach, in the region of the old Nipissing outlet, is estimated at 600–700 feet above its floor. In short the outlet was a broad strait leading into the Iroquois Basin, or like the modern connections between Lake Michigan, Lake Huron, and Georgian Bay, unless the basin were closed by a dam, and that of ice. The

* Proc. Am. Assoc. Adv. Sci., 1888, p. 197.

case is not settled so easily as that of the Ontario basin, for we have not yet the instrumentally measurable proof that the Algonquin plain was lower than 300 feet above the sea, although it probably was, and against which probabiltiy there is not the slightest evidence, for we do not know what was the initial plain of upward movement. Without applying the objections made to an ice dam closing the Ontario basin during the Iroquois episode, let us examine some conditions of the Algonquin basin.

The Algonquin plain stood at an elevation of about 300 feet above the sea, when the lower Iroquois Beach commenced its growth. Were its waters held up to that altitude by an ice dam, or had they shrunken to the lower level (which, however, would not have dismembered the upper lake) and were they connected with Lake Iroquois by a strait 300 or 400 feet deep, like the modern outlet of Lake Michigan? Up to this time, there had not been any warping to separate the lake basins, for the greater part of the barriers has been uplifted since the episodes of the Algonquin and Iroquois Beaches. I have shown that the greater proportion of the differential movement, even in the higher beaches about Lake Erie has been since the Iroquois episode.* In the earlier part of this paper, it has also been shown that most of the warping of the beaches, east of Lake Huron, has been since the Algonquin episode. Now these higher beaches are identical with those south of Lake Erie, whose movement have been compared with those of the Iroquois Beach. Hence, it is not difficult to understand that the unequal uplift of both the Algonquin and Iroquois plains has been nearly synchronous, since the completion of the latter beach. I speak only of the differential movements that have deformed the old water levels, and not of the absolute rise, which lifted the Algonquin plain above the Iroquois, unless the waters which made the former beach were retained at the higher altitude, for long ages, by an ice dam.

At most, no ice barrier could have longer blocked the Nipissing outlet than the episode of the lowering of the waters, 300 feet, to the level of the Iroquois Beach, for at that time, all glaciers had shrunken back beyond the Ontario basin, and the two basins were connected by the deep Nipissing Strait. And of such a dam we have not proof, or even probability, to even as great an extent as in the case of a hypothetical Iroquois dam. With the continued regional uplift, the waters of Algonquin Lake were further lowered, as is shown by the numerous beaches, until the lake was dismembered, and *Superior, Michigan, Huron and Georgia had their birth* and drained through

*"Deformation of the Iroquois Beach," etc. This Journal, vol. xl, page 443, 1890.

the last, at the level of the Nipissing outlet, only by a river flowing into the valley of the Ottawa.*

As we ascend to the elevation of the higher beaches, the question of glacial dams becomes more difficult, for we must assume them to have been hundreds of miles long and at enormous altitude, damming up bodies of water which had the proportions of inland seas. Such, I do not here propose to construct or dissipate, but I am compelled to assume the initial plain of the Algonquin Beach at sea-level, irrespective of glaciers which may then have been moving into the St. Lawrence valley, and obstructing open communication with the sea, but not damming the waters at high levels. There is as much evidence of submergence in these deserted beaches as there is in Professor Shaler's beaches † up to 1500 feet, on Mt. Desert Island, without the intervention of dams, or of Mr. McGee's Columbian formation‡ which I have seen in Alabama, at altitudes of about 700 feet without the support of dams. Indeed, there is additional evidence, for crustaceans of marine species have so adapted themselves as to still live in the depths of Lake Superior,§ as also maritime plants upon its shores.‖

As Algonquin water received so much fresh water, the marine conditions, indicated above, were modified, so that almost immediately after, if not during the formation of the Algonquin Beach, the waters became sweet, as is shown by shells referred to above. With the continued emergence and northeastward warping of the continent, a rocky barrier across the Nipissing outlet was raised which eventually caused the waters of Georgian, Huron, and Michigan Lakes to unite and overflow the southern extension of the lower beaches. Finally, this warping, as before pointed out,¶ so tilted the basins of the lakes that the waters overflowed the southern rim of the Huron basin, and established the modern drainage of the upper Lakes by way of Lake Erie. Not until this event did the lakes assume their present form.

* See History of the Niagara River, by G. K. Gilbert.

† Geology of Mount Desert, by N. S. Shaler. Eighth Annual Report of U. S. Geological Survey, 1888.

‡ By W. J. McGee. Bull. Geol. Soc. Am., vol. i, 1889.

§ "On the Deep-Water Fauna of Lake Michigan." (Stimpson) Am. Nat., vol. iv, p. 403, 1870; also "The Crustacea of the Fresh Waters of the United States." (Sidney I. Smith). Rep. Fish Commissioner, 1872–3, p. 643.

‖ "The Distribution of Maritime Plants in North America." (C. H. Hitchcock). Proc. A. A. A. S, 1870.

¶ Notes upon the Origin and History of the Great Lakes of North America, Proc. A. A. A. S., vol. xxxvii. p. 197, 1888.