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ALFRED C. LANE, STATE GEOLOGIST

VOL. IX
PART I

THE DELTA OF THE ST. CLAIR RIVER

BY
LEON J. COLE

ACCOMPANIED BY FOUR PLATES

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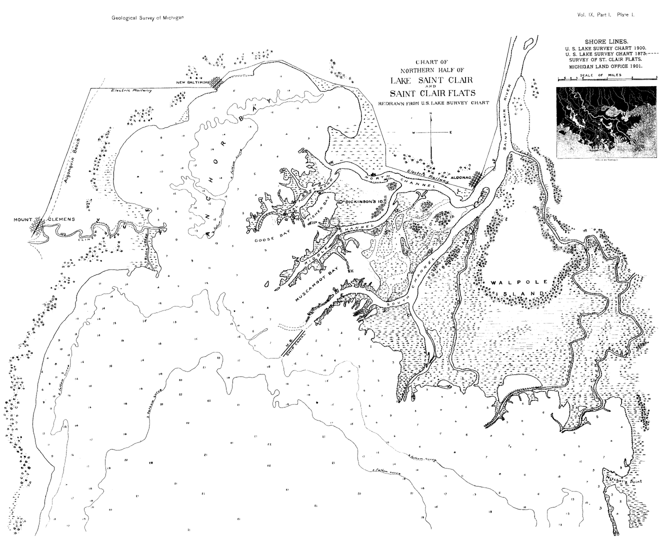


[Plate I. Northern half of Lake St. Clair and St. Clair Flats. Soundings in feet. (To show changes indicated by successive surveys. Red line, U. S. Lake Survey chart, survey of 1867-71; black line, U. S. Lake Survey chart with additions of 1902; green line, Michigan State Survey, 1900.)]

OFFICE OF THE STATE GEOLOGICAL SURVEY,
LANSING, MICH., September 10, 1903,

To the Honorable, the Board of Geological Survey of Michigan:

HON. A. T. BLISS, *Governor and President of the Board.*
HON. L. L. WRIGHT, *President of the Board of Education.*
HON. DELOS FALL, *Superintendent of Public Instruction and Secretary of the Board.*

GENTLEMEN—Herewith I transmit as Part I, the first part of Vol. IX, a report containing the results of examination of the Delta of the St. Clair River, known as St. Clair Flats, prepared by Leon J. Cole. At the time, Mr. Cole, now assistant at Harvard University was a student of Prof. I. C. Russell, who suggested the report. Prof. Russell was interested in the exceptional fact of the formation of so extensive a delta from a river which is the outlet of a large lake, and in recommending to your Board to defray the field expenses of the same, I had hoped that information of value to the State would result, as to the rate of growth of the delta correlative to the erosion of the shore north of Pt. Huron which we have recently studied. Although the earlier maps do not prove to be accurate enough to give as much as I had hoped, yet the information gathered is desired at once by the Attorney General's office, and I therefore recommend its prompt publication.

With great respect I am your obedient servant,
ALFRED C. LANE,
State Geologist.

ERRATA.

Herson Island is thus spelled on the Farmer map of 1838 and the Lake Survey map. Recently in the Farmer map of 1901, the Rand McNally maps, the Bartholomew survey map, the Bridgman maps, etc., it is more commonly spelled Harsen, but without adequate reason for the change that I have discovered.

In correcting proof of the maps Mr. Cole writes:

"It was found very difficult to make direct comparison of the State Survey sheets with those of the Lake Survey, for while the latter give only the main contours accurately, and only approximate the shapes of the smaller islands, cutting off points and leaving out channels—the former on the other hand, gives these things in detail, and since it was impossible to get all in when the thing was so much reduced it became a problem as to where to draw the line—literally as well as figuratively.

Again I know from my familiarity with the place, many places where the Lake Survey has indicated as land, what the State Survey has rightly put down as rushes. Refer, for instance, to the lower end of the Chenal About Rond. Similar cases are numerous—especially where the Lake Survey gives islands which the State Survey does not give at all."

INTRODUCTION.

BY A. C. LANE.

From the study of the St. Clair delta by Mr. Cole which is given below, it is apparent that it is quite comparable to other deltas, especially of fine grained deposits. It is apparent from his drawings, and as one sails over it, that the bulk of the material is extremely fine mud. In that respect and in all respects it resembles very closely some of the salt water marshes of the Atlantic coast with these two exceptions; that since the water is not salt vegetation can infringe upon it more easily and that the tidal movement or variation in water level is neither so great nor so regular.

In its growth it resembles any typical delta and I have placed in one corner of plate 1, a little sketch of the Mississippi for comparison, reproduced from Fig. 942 of Dana's Geology. In any such delta, as in the flood plain of a stream generally, the deposits beneath the channel and alongside it are coarser and tend to be more rapid than those farther from it, being composed of sand which may be rolled along the bottom or brought down in times of flood in the extra strong current. The power of transport of different velocities of streams is given by Dana as follows:—

Velocity in miles per hour.	Size of material.
$\frac{1}{6}$	Fine clay, silt and mud.
$\frac{1}{3}$	Clay.
$\frac{2}{3}$	Sand.
$1\frac{3}{8}$	Gravel stones the size of an egg.
$2\frac{3}{4}$	Loose stones.
4	Flat stones.

The current of the river varies as Mr. Cole has stated, from 4½ miles an hour down; the channels of the stream retain, however, considerable current under normal conditions through the delta. The current of the North channel is said to be 2½ miles an hour. Of course the current there will depend somewhat upon the level of Lake St. Clair, and winds from the south raising that level will tend to check them while those from the north which, as Mr. Cole has remarked, are associated with roily water in Lake Huron and the discharge of sediment from it will lower the level of Lake St. Clair. As in the Mississippi also, and as Mr. Cole has remarked, there is most rapid deposition directly adjacent to these channels. There are five different methods by which the land surface of the delta may be assumed to gain upon the water. In the first place there is the deposition of material brought down in times of extra high and roily water. This of course must deposit where the current is most rapidly checked. Now the waters leaving the main channel and filtering through the circumambient growth of rushes have their velocity at once very markedly checked and deposit a very large amount of their load in the banks or levees directly along the river. Secondly, the same growth will tend to strain and filter out floating driftwood from such débris. Thirdly, the vegetation adjacent to the channel has more than its share of air and sunlight and will receive more of the fertilizing mud. In consequence its accumulation by growth and decay upon the spot will be more rapid. The above causes of growth apply to all deltas, and cause growth which is more rapid along the lines of the main channels. There are two further causes of growth which apply to this delta, though not to all, and which would produce a more general advance of the line of the land. For in the fourth place, as Mr. Cole has pointed out, according to the observations of G. K. Gilbert,* the whole land area of the Great Lakes basin is being tilted in the direction north 27 degrees east, at the rate of about .04 of a foot per 1,000 years per 10 miles, the result being that the streams upon the southwest side of the Great Lakes have dead water at their mouths, while on the northeast side they have a rapid current and furnish water powers. As to the various channels through the delta, though Mr. Cole correctly says that there would be a tendency to keep a swift current through the delta owing to the grading up of the channels by the material brought down, yet if the tilting were the other way, inasmuch as the whole difference of the level of the lakes Huron and St. Clair is only about 5 feet, it is probable that the flow would not have been so rapid as we find it. Let us see what the tilting would amount to in the case before us, remembering however, that Gilbert's figures are only approximate and we have no assurance that they have lasted at that rate more than 30 odd years which the measurements cover. The front of the delta is about 6 feet under water and lies pretty close to the south end of the U. S. Ship Canal, for it will be readily noticed upon inspection of the chart of Lake St. Clair issued by the U. S. corps of engineers in 1902, that while it is even a mile or more, sometimes several miles from the point where they draw the land line to the six foot line, the drop thence to 13 to 15 feet of water is quite rapid. The front of the delta is thus fairly well marked, and the thickness of the delta deposit to be inferred corresponds quite well to the results of Mr. Cole's borings. From the front of the delta to the head of the delta, as described by Mr. Cole, where the elevation of the delta surface is some 6 feet above the river level along the same line is about 14.6 miles. The slope of the delta surface is therefore some 12 feet in 14.66 miles, or about a foot (.975 ft.) to the mile. To convert the slope of the delta from the lake level slope to its present slope would require something over 20,000 years, but as a certain part of the slope must be due, as Mr. Cole has suggested, to the slope of the delta growth, and the remaining part only to the tilting, this is a maximum which the age of the delta cannot exceed, unless indeed the rate of tilting has been slower than at present. It would seem more likely that it would be more rapid after the ice age than later.

*See the report on Huron County, Vol. VII. part 1, page 36. The tilting with the correction there made is .037 feet per mile in 10,000 years.

We assume as an average distance of the delta from the axis of the tilting at the head of the Detroit River about 20 miles. The delta would then tend to rise in the neighborhood of Tashmoo Park about .08 of a foot per 1,000 years which would mean about 5,120 feet advance of the delta front in 1,000 years or 256 feet in 50 years.

The fifth cause of advance of the land line is the cutting down of the outlet of the Detroit River and the consequent lowering of the Lake St. Clair level. At present the policy is in improving the Detroit River to keep the cross section and the carrying capacity of the river as a whole the same, but it may be doubted if in the earlier improvements they kept sufficiently in mind the fact that the effect of deepening Detroit River without filling in the same section in lowering the lake level would be much greater on the small lake than on a large lake like Lake Huron. The St. Clair River has been deepened near the outlet but considering its length, the size of the reservoir behind and the small amount of total descent, it is doubtful whether this deepening has made any change in the regime of the Great Lake System appreciable even in the remotest degree.

Thus all geological indications are that the delta is growing and a land advance of something like 5 feet per year may not be far from the truth as an average, but the growth is undoubtedly more rapid near the channel. The actual state of the water level is however, as Mr. Cole remarked, very variable. When I visited the same on September 1, 1903, the water level was obviously distinctly higher than normal as judged by the vegetation. This, as Mr. Cole has remarked, is a quite sensitive index to the condition. Besides the regular algæ such plants as the bulrush (*Scirpus lacustris*) occur in quite deep water. Some I pulled were in 40 inches of water. They may grow sparsely and scattered through the water, or they may be so dense, that it is difficult to push a boat through, and at a little distance to an unexperienced observer the tract might be taken for land. Yet their dark blue-green color is readily recognizable and wherever they are is surely lake, as Mr. Smith remarked. With this may be associated the pond-lily (Nymphaea) and Equisetums. In not too deep water they are adjoined by the cat-tails and the sedges (Cyperaceae like *Carex filiformis*) though one might still be knee deep in water* and legally (according to the Standard Dictionary) sedge flats on the seashore are classed as below high water mark. But when to the sedges are added blue joint (*Calamagrostis Canadensis*) and various shrubs and bushes, milkweed and golden-rod, etc., we are on firmer ground.

*Reed grass and several other grasses will also grow readily below water level.

THE ST. CLAIR DELTA.

BY LEON J. COLE.

INTRODUCTORY.

The delta at the mouth of the St. Clair river is something of an anomaly in that it is being formed by a river which serves as the outlet of a great lake, Lake Huron, but a short distance above. Since large bodies of water act as settling basins it would be expected that the river acting as the outlet of so large a lake would be comparatively free of sediment and consequently would be incapable of forming a delta of much size at its mouth. Attention has been called to this fact by Professor I. C. Russell* who explains that the shore currents in Lake Huron bring débris to the place of the outlet, the materials are swept into the river, and so carried, to be deposited in Lake St. Clair some forty miles below. It was at the suggestion of Professor Russell, and with the cooperation of Mr. Lane, the State Geologist, that I was enabled in the Spring of 1902, to make a study of the delta, which, however, was greatly limited in time, and the present report can only be considered as preliminary and rather fragmentary on that account. My thanks are dup to both Professor Russell and Mr. Lane for suggestions and help at all times, and I am especially indebted to Professor D. C. Schaffner of Emporia, Kansas, who was at that time a student at the University of Michigan, and who accompanied me on my several trips to the St. Clair Flats, as the region of the delta is generally known, assisting materially in the rather arduous task of making borings with a hand auger. The government engineers stationed at Detroit, officers of the Grand Trunk Railway, and others have been uniformly courteous in placing at my disposal charts and maps and any information in their possession.

*_Lakes of North America_, p. 40. Ginn & Co., Boston, 1895.
Rivers of North America, p. 183. J. P. Putnam's Sons, New York, 1900.

GENERAL CHARACTERS.

Enough has been said above to define the position of the delta under discussion, but some description of the general features of the region may not be out of place.

The River.—The St. Clair River, as stated above, is about forty miles long, and has a mean breadth of nearly one half mile. It is nearly straight, the greatest bend being against the Canadian shore at Sarnia; the course is slightly to the westward of south. Just below Lake Huron there is a stretch known as the Rapids, where the stream is narrowed by a spit reaching out from the eastern shore, and it is here that the current is strongest, some four and a half miles per hour. The banks, which are composed for the most part of blue clay with yellow clay and sand or gravel above, are low for the most part, having a height of fifteen to twenty feet for only a comparatively short distance, and on the upper portions of the river. Back from the river the land rises to low hills. At Algonac the stream divides into two large branches, the more direct being known as the South Channel, while the North Channel, which is the larger, being deeper and having a stronger current, turns rather sharply to the westward. This in turn divides some five miles below to form the Middle Channel, and again further along gives rise to the Chenal About Rond, or as is usually known locally, the Sny. These channels all give rise to minor distributaries in true delta fashion, as may be seen at a glance on the accompanying map (pl. I). The character of these channels is not clearly shown, however, on this plate, which makes the true channels appear much broader than they really are; there is usually a broad shallow on one side or the other, which suddenly dips off steeply into the comparatively narrow and deep channel. The steepness of the sides of these channels under water is most remarkable, being sometimes almost vertical for a distance, while a greater dip than 45° is probably characteristic. There are nine channels, including Baltimore Channel and the Ship Canal, which have a depth of over three fathoms to the bars at their mouths. Throughout the most of their length the main channels have an average depth of about thirty to forty feet, but the north channel, in the large bend south of Algonac, reaches a depth of ninety feet* and is sixty feet and more deep to some distance below the North Channel Club House at the junction of the Chenal About Rond. The river above the head of the South Channel ranges in depth from thirty to sixty feet.

*Rough soundings were made here and at several other places, but so far as could be ascertained, there had been no appreciable change in the depth since the original charting 30 years ago.

In 1817 when the survey of the Flats was made by Lieut. H. W. Bayfield, R. N., the North Channel was known as the New Ship Channel, while the South Channel was called the Old Ship Channel, but since the building of the government piers at the entrance to the South Channel, the northern route has been used only by boats of very light draught bound for New Baltimore. The international boundary line follows the South Channel.

The Islands.—What is collectively known as the Flats consists of the various islands, large and small, which form the limiting shores of the channels. In the upper part of the delta these are often of a considerable size, but lower down they are cut up by the numerous small channels and by many artificial cuts which have been made in order to form boat-ways, and more commonly to get earth on which to build, the soil dredged from the cut being spread out on the surrounding low land, thus raising it to two feet or so above the water level. Russell Island and the upper parts of Herson, Squirrel and Walpole Islands are well above mean water level—some three to five feet—and are partially covered with heavy forests, while much of the land is under cultivation, making excellent farming land. The lower islands are wet and marshy, as a general thing not over a foot above water, and often with low, marshy, indefinable margins. They are almost perfectly flat, and in the summer are covered with a luxuriant growth of grasses and sedges, shading off into the cat-tails and rushes at the water's edge, which last extend far out into the shallow bays.

The Lake.—Lake St. Clair is about thirty miles long, from north to south, and twenty-four miles wide in maximum width. The greatest depth is twenty-two feet, and the mean depth over the central area is about twenty feet. The bottom is for the most part a fine blue clay or mud, covered in places with a thin layer of fine sand. The water surface is five and four tenths feet below that of Lake Huron. About one-fourth of the original basin of the lake has already been filled by the sediments brought down by the river, and the process is steadily going on.

Large shallow bays extend between the islands of the various channels; these seldom exceed four or five feet in depth, and in the summer become largely filled up with growing rushes. Even when the vegetation is at its highest, a person with his head a few feet above the grass can see for miles across what looks much like a waving green prairie, interrupted here and there by winding channels and ponds of water.

THE GROWTH OF THE DELTA.

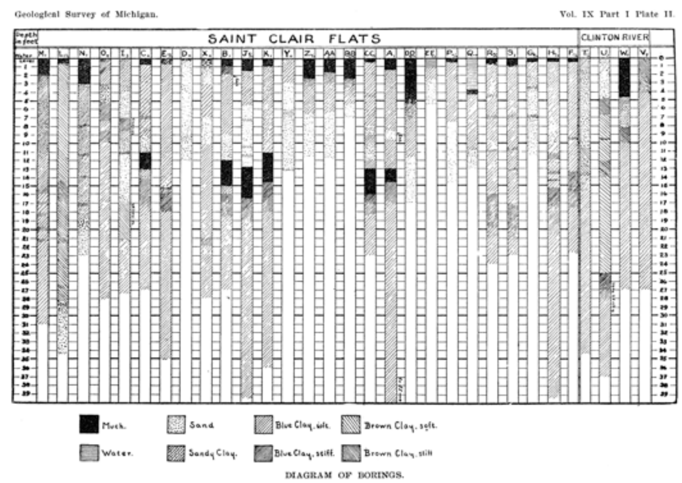
Source of the Material.—The first question requiring attention in a consideration of the growth of the delta is the source of the material of which it is composed. As will be seen later, in the discussion of the borings, the greater part of the deposit is composed of clays of varying consistency and of sand, which is, in the main, fine, but ranges from that up to very coarse and gravelly. It has been suggested that we have here not a true delta, at least of the present St. Clair River, but in reality an old deposit through which the present river has cut channels for itself since it broke through at the southern end of Lake Huron and formed an outlet for the water of the upper lakes. Such an hypothesis would furnish an explanation of the height of the upper islands above the present water level, but the borings, together with other data to be presented, can leave no doubt that the foundation is a recent one and that the processes of its building up are still in action.

That the greater part of the sediments come from Lake Huron can hardly be questioned, though important additions are undoubtedly made by streams tributary to the St. Clair River, which are always turbid in times of freshet. Although, as noted above, Russell referred to the sweeping of débris into the river as due to certain currents in the lake, he made no analysis of this action: Rut Spencer* in describing his researches on the Algonquin Beach says: "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 mouth 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," and Taylor† has applied this fact to the formation of the St. Clair Delta. He points out that the predominant run of the waves towards the south would tend to carry the débris formed by the cutting of the banks in that direction, and anyone who has ever watched material being moved along the shore by the waves striking at an angle will be prepared to agree with him. While the waves rush up the beach obliquely, the water runs back in a direction normal to the trend of the beach, and thus each time an object is moved, the resultant of the movement is in the direction of the wave action. This will be true regardless of the direction of off-shore currents. Although the resultant annual wind direction at Port Huron as ascertained for a period of fourteen years is S. 51° W.** it is northerly for about four months in the year, and a moment's thought will show that it is only these latter storms that can have a great influence in moving the sand, as they alone will have the opportunity to produce large waves at the southern end of the lake. It should also be borne in mind that while the wind may blow from a southerly direction a greater part of the time, most of the severe storms, which would produce the highest waves, are northerly. Conditions similar to these have piled the sand in great dunes at the southern end of Lake Michigan, but in the case of Lake Huron the outlet is at this point, and the sand instead of collecting, is swept out and down the river by the strong outflowing current.

*Spencer, J. W.—"Deformation of the Algonquin Beach and Birth of Lake Huron;" Am. Journ. Sci., Vol. XII, p. 13, 1891.

†Taylor, Frank Bursley.—"The Second Lake Algonquin;" Am. Geol., Vol. XV, p. 171. 1895. Taylor was mistaken in regarding the delta as being built of pure sand.

**See Harrington, Mark W.—"Surface Currents of the Great Lakes;" U. S. Weather Bureau, Bull. B., p. IV. 1895.



[Plate II. Diagram of borings made at St. Clair Flats and along the Clinton river. The borings are lettered consecutively as made, but are here arranged as well as can be according to location, beginning with the head of the delta and going towards the periphery in radial lines. The positions of these borings will be found indicated by the corresponding letters on Plates I and III. Depths are referred to water level at place of boring. The height of the ground surface relative to water level is given in each case by the small subscripts to the letters.]

That the source of sediments is not confined to the east shore of Lake Huron is shown by the work of C. H. Gordon† who studied the destructive action of the waves at a point on the west shore some fifteen miles north of Port Huron. By comparison of surveys made in 1823 and in 1901, Gordon finds that one estate, which contained 184.90 acres at the earlier date, with a water front of something less than a mile, lost in the intervening seventy-nine years, 27.25 acres of land, which was washed away and carried into the lake by wave action—an average of .345 acres per annum. The total average recession of the shore line within this area was 449.46 feet, or an average recession of 5.7 feet per annum. The amount of material removed was 878,944 cubic yards, and it is safe to assume that a great deal of this eventually found its way into the St. Clair River, both on account of the direct wave action along the beach, as on the eastern side, and by the shore currents, which on this side run close to the shore and would catch the lighter materials that did not sink at once to the bottom.

It is of importance to note the character off the sediments contributed at this place, where the bluff twenty feet or so in height gives a good section of the glacial deposits which compose the land. According to Gordon the section is made up as follows:

		Feet.	Inches.
1.	Soil-top loam	1	6
2.	Light colored, or drab sandy soil; small pebbles	9	9
2a.	Brownish band: apparently a soil horizon........................		6+
3.	Blue clay; more compact than No. 2a	7	
4.	Blue clay; darker and more compact than No. 3...............	4	

†Gordon, C. H.—"Wave Cutting on West Shore of Lake Huron, Sanilac County, Michigan;" Rept. Mich. Geol. Survey for 1901, pp. 283-291, figs. 5-7 pls. XI-XV. Lansing, 1902.

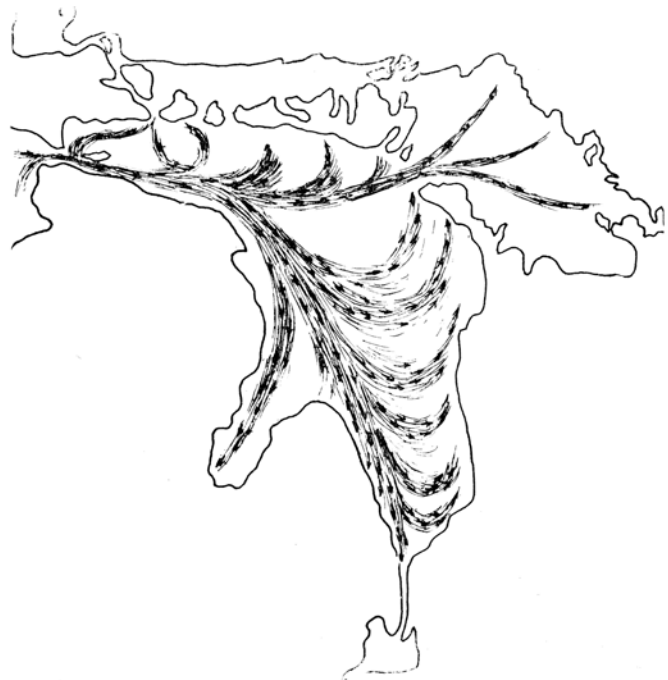


Fig. 1.—Chart showing principal surface currents in Lake Huron. After U. S. Weather Bureau.

These materials being carried into the river, are re-assorted and deposited in Lake St. Clair, as we shall see later.

In the work mentioned above Harrington* charts the principal surface currents of the Great Lakes, as determined by bottle floats, and Fig. 1, which is redrawn after one of his maps, shows the results of these observations as determined for Lake Huron. It will be observed that the main current hugs the west shore; at the southern end of the lake a part of the waters turn to the eastward and up the eastern shore, but a large and definite current flows directly through the outlet into the river. The heavier sands being worked southward on both shores of the lake tend to choke the outlet, and it may be this current that keeps the channel open on the western side, while on the eastern side of the outlet a long spit has been built out, contracting the river to one-half its average width below and causing the rapids which occur at this place. Taylor† remarks that "The spit on the east side is well developed and its point has been turned down stream by the current of the river," and adds, "The predominance of drift from the east shore has crowded the river over against its west bluff and filled in the old channel for a mile and a half on the east side,"—but it seems not unlikely that the west shore current has had more to do with keeping the river channel open on that side and preventing the formation of a spit than a great predominance of sand coming down from the other shore.

*U. S. Weather Bureau, Bull. B. 1895.

†Am. Geol., Vol. XV., p. 172. 1895.

The water of the St. Clair River is usually remarkably clear for a stream that is forming a great deposit at its mouth, but after severe rainfalls and wind storms this is not true, for at such times the water becomes very turbid, though it can never compare with the Mississippi and its tributaries in this respect. The greatest source of this sediment is undoubtedly from Lake Huron, but that a large part of it comes from the small rivers flowing into the St. Clair, such as Black River at Port Huron, and Pine River at St. Clair, and from the erosion of the banks of the St. Clair River itself, had been clearly shown by Wheeler*, who made a careful examination of the matter for the United States Engineer Office, to determine the influence of the cutting away of the right bank of the stream in obstructing navigation. It was found that the right bank here, which is composed of much the same kinds of soil as that described above, in Sanilac County, but not so high on the average, is similarly being cut back by the action of the current and waves, the swells produced by passing steamers being especially effective. At one place between St. Clair and Marine City there is about two miles of nearly continuous erosion on a bank eight to fifteen feet high, going on at a rate of two to three feet a year. The highway had been set back twice and there was in 1885, but seven feet between the fence and a vertical bank at one point of the road, and for a quarter of a mile there was barely room for two teams to pass. The greatest erosion was on a three to five foot bank near Marine City, where the wash had been ten rods in forty years.

*See report of O. B, Wheeler, Assistant Engineer, in "Preliminary Examination of Saint Clair River and Saint Clair Flats Canal, Michigan;" Ann. Rept. Chief of Engineers, U. S. Army for 1885, Part III, Appendix LL 21, pp. 2199-2202. Washington, 1885.

Erosion is also taking place on the Canadian side of the river, as noted by Wheeler, thus tending to make the river broader and shallower, but no detailed observations were made on that side, and his estimate of the amount of material removed in a year applies only to the American side of the stream. By a rather elaborate method he estimated that the under water erosion on the inclined sides of the channel bed amounts annually to 52,800 cubic yards which is nearly double that above water on the banks of the river; the sum total would thus be in the neighborhood of 79,000 cubic yards removed in the course of a year. But measurements made after a severe storm showed that under such conditions a far greater amount of sediment than this may come down from Lake Huron and the tributary rivers in three or four days. In making this estimate samples of water were taken while the turbidity was about at its highest, the solid matters weighed, and the amount carried by the river computed on the basis of a discharge of 233,726 cubic feet of water per second, as ascertained by the Lake Survey. In a quart of water from the bottom of the river at a depth of forty feet the solid matter was found to weigh one and two-thirds grains. Computation on this basis gave 72,000 tons as the amount of sediment being carried down the river in a day, or 216,000 tons during the three days' duration of the storm. Allowing eighteen and a half cubic feet of clay to the ton, this would amount to 148,000 cubic yards, or nearly twice as much in this short time as is eroded from the right bank of the river in a year.

The amount of sediment found by Wheeler is about two and one-half times as much as was found in samples that I took on July 4, 1902, at a point in the Chenal About Rond a little over two miles below the North Channel.* A heavy downpour of rain occurred on the night of July 2d, accompanied by a high southwesterly wind, and by 2 p. m. on the third, the water at this place had become very roily. On the fourth, the channel was still roily and the roiliness had extended into the bays, but only in the deeper parts where there is probably some current; by noon on the fifth, the channels were clearing up, but the roiliness had spread completely over the bays even into the shallow water among the grass and rushes near shore and into sheltered coves.

The suspended matter gives the waters of the channels and bays, which is usually bluish or greenish, a peculiar yellowish or even at times a whitish or milky color. Examined in a glass vessel it is seen to have a flocculent appearance, and upon settling produces a fine clay of varying consistency.

*The samples of water were taken as the roiliness was about at its highest and yielded the following measurements:

(1.)	Sample from near the bottom (24 feet) in mid-channel—	
	Volume of water in sample	720 c.c.
	Weight of solid material contained	0.027 grams.
	This is equal to 0.0375 grams of sediment to the litre, or 0.548 grains to a quart of water	
(2.)	Sample from surface in mid-channel—	
	Volume of water in sample	723 c.c.
	Weight of solid material	0.029 grams.
	Equals 0.04 grams to the litre.	
(3.)	Sample from surface near the shore—	
	Volume of water	715 c.c.
	Weight of solid material	0.024 grams.
	Equals 0.0335 grams to the litre.	

It will be seen that in mid-stream a slightly greater amount of sediment was found at the surface.

The sample from the bottom was obtained by lowering a weighted and stoppered bottle, and then pulling out the stopper by means of a separate string attached to it.

The determination of the amount of sediment in these samples was made for me by Mr. Howard S. Reed, of the Universtity of Michigan.

Deposition of Sediment and Formation of Islands.

As is to be expected the sand and heavier materials brought down by the river are the first to be deposited upon a slackening of the current as the various channels open out into the large bays and the lake, and they accordingly contribute to the formation of bars around the mouths of all the outlets. That the water of the channels is appreciably higher than in the bays is shown by the strong currents obtaining in the small cuts connecting the two. Such cuts have been dredged out in many places often where the distance through an island from the channel on one side to the bay on the other is but a few rods, and not only does the current which at once sets in keep these canals open, but in many cases scours them out to fully double their original depth, while at the same time bars of corresponding size are formed around their outlets, where the water is no longer confined to the narrow channels but spreads out into the broad bays and is diminished in velocity.

A cut which was dredged for Mr. F. H. Bryant, connecting the Chenal About Rond with Pollet Bay, which in turn opens into Anchor Bay, may be taken as an example. When dredged in August, 1900, this cut-was 32 feet wide, six feet deep and 900 feet long. Mr. Bryant writes me that in May, 1903, it is 10½ feet deep and 37 feet wide, so that 6,550 cubic yards of earth have been cut away by the water in less than three years, or slightly more material than was originally dredged out. The deep water of the channel now also extends some distance into Pollet Bay, but is terminated by a shallow bar of its own formation.

The sands which form these bars are probably for the most part rolled along the bottom; the lighter materials suspended in the water are deposited more evenly over the entire areas of the bays, and even far out into the lake.*

*Wheeler, in his report mentioned above (U. S. Engineer's Report 1885, Part III, p. 2201) mentions observing the roiliness extending six miles into the lake below the end of the ship canal.

In the following discussion of the deposition of the sediments only subaqueous deposition will be considered at first, and the building up of the islands above water level will be taken up later. In this study the re^ suits of the borings made at various places will be of great assistance. These borings were made by hand† with a two-inch auger; as the auger was lowered sections of gas-pipe* were coupled on, and were screwed off again as the auger was raised.

†Altogether thirty-one borings were made, aggregating a depth of 693 feet, or an average of 22⅓ feet to each boring, records and samples of the materials passed through, being taken when the drill was pulled up at short intervals. On Plate II, the results of these borings are shown diagramatically, their depths being reduced to water level at the place of boring, and at the time the boring was made. It will be seen that a source of error in the comparison of different borings has been introduced in this way, for two reasons; (1) the water level is higher towards the head of the delta than around its periphery, and (2) there was undoubtedly some fluctuation in the general level of the water surface during the time that these records were being obtained. The second of these factors makes it impossible to correct for the first; but it is believed that if they are kept in mind the general conclusions need not be affected by them. The borings were lettered consecutively as made; their locations will be found designated by these letters on the map (Plate I).

*Two lengths were used—4 feet and 8 feet; the depth of boring could thus be calculated directly at any time by knowing merely the number of sections of pipe that had been put down.

Two generalizations of special importance to us now may be made from an examination of Plate II. In the first place it will be noted that in more than one-third of the borings (C, E, B, J, K, CC, A, R, S, H, F), a layer of stiff blue clay, two to three feet thick, was struck at a depth of 14 to 16 feet, and that below this in all cases it gradually became softer and continued so, passing into a homogeneous soft blue clay through which the drill could usually be pushed without turning, as deep as the hole was put down, in one case to 55 feet. In fact, in the later borings the drill was not put down as far as it could have been, but when this stiff clay was struck with softer below, the boring was only continued deep enough to make sure we were in this homogeneous layer. The deepest boring made was to 56 feet below the surface of the ground; it was not discontinued at this point so much on account of the difficulty of getting the drill down as pulling it, back out, because of the softness of the clay, through which a clean hole of the diameter of the auger could not be maintained. From data obtained from wells, put down on the mainland in the vicinity of the Flats†, and from the preliminary borings and final excavation for the St. Clair tunnel of the Grand Trunk Railway, it seems certain that this is the same great bed of clay that covers the Antrim "bed rock," (earlier called St. Clair shale) of all this region, varying from a thickness of 80 to 100 feet at Port Huron to 150 to 200 feet at Algonac. In the subsequent descriptions I shall speak of this as the *bottom clay*.

†See Geological Survey of Michigan, Vol. V, Part II. "The Geology of Lower Michigan, with reference to deep borings;" edited from notes of C. E. Wright, by Alfred C. Lane, Landing. 1895; also, Annual Report for 1901.

The second point to be observed is that in the case of six of the borings (C, B, J, K, CC, A), a stratum of muck 1½ feet to 3 feet in thickness was found at a depth of 11 to 13 feet. This stratum of decaying vegetable matter was of a rich dark brown color, and pieces of plants, such as stems and grass leaves, could still be picked out, and seemed to be in a fair state of preservation. The decay going on in this stratum produces gas, which often collects in some quantities where there are layers of tough clay above; thus in borings A and B, as the drill was withdrawn after passing through a layer of rather stiff clay, at about 9 feet in the former and 2 feet in the latter, there was a violent bubbling of gas. There was not enough of the gas to produce a continuous flame at the open top of the hole, but it would produce a considerable flash when lighted. There is a place in Muscamoot Bay, known as the Gas Well, and so designated on the Lake Survey charts. I was told that at this place the gas bubbled up continually through the water from holes in the bottom, but when I visited the place there was, unfortunately, so high a wind that I could not locate the spot on account of the roughness of the water. It is also said that ice does not form over this particular spot in the winter. I was later directed to another locality on the shore of Fisher Bay opposite a pond known as Little Lake (See *, Plate III), where the waters of the bay wash up against a vertical bank about a foot high above the water. At several places continuous streams of small bubbles were seen rising to the surface from little holes in the clay bottom, close to the bank, where the water was about a foot deep. A stick pushed down for two or three feet anywhere in the immediate neighborhood, and then withdrawn, would make a hole for the escape of the bubbles, showing that the gases which formed underneath were prevented from escaping, to a large extent, on account of the deposits of clay above. In borings, C, CC, J, and K no gas was noticed; the clay above the muck in these places was more porous on account of the greater amount of sand it contained, and no gas has accumulated below. The probable significance of the great deposit of bottom clay and of the stratum of muck, which, there seems little doubt, forms a single horizon, will be considered later in the historical discussion of the region.

Some of the deep borings, although they go deeper than 17 feet, which is the lowest record for the top of the bottom clay, do not show any evidences of that bed at all. Borings L and N illustrate this well, probably also I, for although a layer of harder clay was struck at this place at a depth of 17 feet, it was yellowish in color, thus differing from the stiff blue clay found at the top of the bottom bed in all the typical cases. Unfortunately, in many cases where much sand was found, near the surface, without any clay, it was impossible to put the borings down more than 12 to 15 feet on account of the caving in of the sand along the sides of the hole (D, Y, Z, AA, etc.). The deep borings mentioned above undoubtedly represent old channels which formerly cut through the bottom clay at these places, but were abandoned and have become filled in. In some places a smaller stream still follows the path of the earlier channels; in others the channel has become entirely closed at its head and is completely filled in, or may still have dead water occupying a part of the old course. The first of these conditions is illustrated by Blind Channel, which branches off from the Canadian side of South Channel a short distance below Russell Island (see Plate I). That a channel about as wide as the present South Channel used to flow through here is shown (1) by the old banks (indicated on the map by dotted lines at the head of the channel) which are some three to four feet high and are a conspicuous feature; (2) by the vegetation, which changes markedly in character from the low ground which fills the old channel, to the higher ground which formed its banks,—from swampy ground overgrown with sedges, one passes to dry ground with a vegetation of grass and other plants that require such a soil, e. g., yellow-eyed grass (*Xyris Caroliniana*), the common blue violet (*Viola palmata cucullata*), and bastard toad-flax (*Contandra umbellate*); (3) The borings indicate the same thing; boring N, which is taken on the bank of the present stream and is about in the middle of the old channel, strikes the gravel bottom of the old stream at a depth of 19 feet. Boring O is on the crest of the old bank, and here gravel was struck at a depth of 3 feet. The present stream at this place is 7 to 10 feet deep; it is shallower at its head, showing that a bar is forming there which will probably cut the rest of the channel off from the waters above and connect it into the type to be considered next.

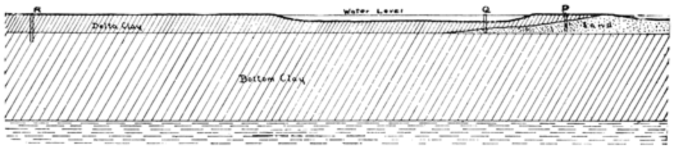
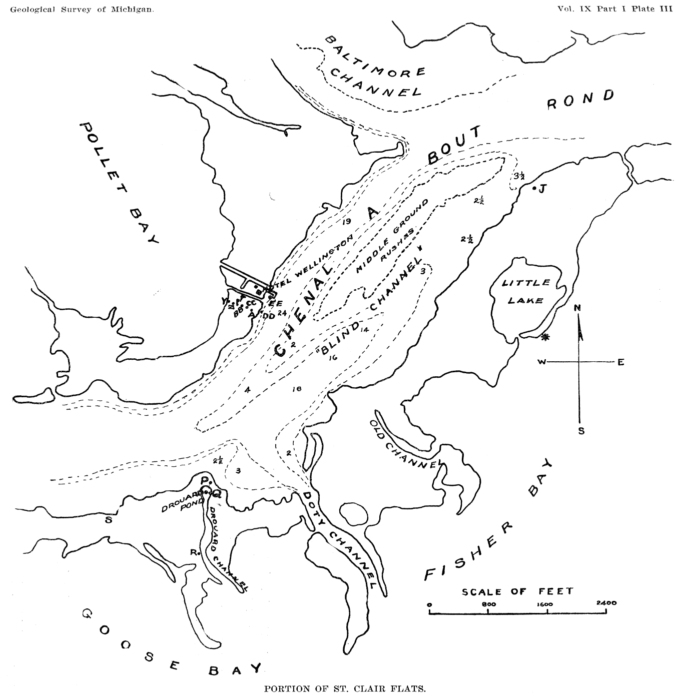


Fig. 2.—Diagram showing probable section through borings P, Q, R. Vertical scale two times horizontal scale.

This stage in the process is well illustrated by Drouard Channel (see Plate III), which, however, was never a channel of major importance. The head of this channel has been entirely closed by a sand bar which formed across it, and which is shown in borings P and Q. The blind channel thus left opening into Goose Bay is now slowly filling with the fine sediments which find their way into its waters, and by the action of vegetation. The first of these processes is very slow, for it is only after severe storms, when the waters become very roily, that any considerable amount of the sediment will extend up into a channel of this nature. That the action of vegetation in filling quiet waters of this kind is more important than is usually supposed has been shown by students of plant ecology, and it is probable that under such conditions as we have here, the process is not essentially different from what it is in the small glacial lakes in the interior of the state*, except that fewer plant zones are concerned. It is probable that Drouard Channel was shallow even when functional and that its bed was on the top of the bottom clay. On this supposition, a small piece of what was evidently decaying wood which was struck at this level could be interpreted as a piece of water-logged wood that had sunk to the bottom of the old channel. Fig. 2. represents a probable cross section through borings P, Q, and R.

*Reed, Howard S. "A survey of the Huron River Valley,—I. The Ecology of a Glacial Lake;" Botanical Gazette, Vol. 34, pp. 125-139. 1902.

The complete closing of the Drouard Channel is a comparatively recent event, and may well have happened since the advent of white men to the region; a similar condition, but somewhat further advanced, is shown by the blind water marked "Old Channel" on the same map; and it is only a question of time before the connection from the point at boring J across to the Middle Ground will similarly cut off the present water known locally as "Blind Channel," the Middle Ground will be built permanently above mean water level, and the Chenal About Rond will be narrowed to a third of its present width at this place. When the water of Blind Channel becomes dead the growth of the bar which already extends down from the Middle Ground past the mouth of the Doty will be facilitated and that channel will eventually be added to the number of dead streams that are filling up to become land.



[Plate III. Map of portion of the Flats on the Chenel About Rond showing special features of delta-formation.]

While the formation of bars across their heads is the common method of the closing up of channels, it is also one which acts comparatively slowly. Much more rapid changes are produced by another cause, which is not only an important physiographic agent but is also a serious menace to early spring navigation. This is the formation of ice dams in the river and distributaries and is again largely due to the peculiar relation which the river bears to Lake Huron. When the ice breaks up on the lake in the spring it is often driven by the wind so that it forms a great pack at the end of the lake. Such a pack, which formed in the spring of 1901, was held by jamming in and forming a bridge across the head of the river, until on April 27, a field of ice 12 miles in width had accumulated. The ice which went down the river again gorged near Algonac, forming a complete dam, and lowering the water on the Flats until many acres of the shallower portions were above water, while in the river above the level was correspondingly raised. At Marine City on May 1, the water was 4 feet above the normal level. The effect of such obstructions as this in the changing of old channels, and in causing breaks to occur across the existing embankments above the dams, when they form in the lower parts of the delta, may readily be understood.

Little Lake shown on Plate III, may be taken as a good illustration of another process which is contributing materially to the increase in area of the island masses. This shallow pond undoubtedly represents what was originally a small bay or cove off from Fisher Bay; by the action of wind and waves a bar was raised which has eventually shut it completely off from the large bay, except for a very narrow connecting channel. This process may be seen in various stages at many places on the Flats; in fact, on this same island just north of the

Doty Channel is a small pond now entirely cut off from the bay, which evidently represents a still later stage than that of Little Lake. When a pond has become entirely enclosed in this way, its ultimate filling in depends entirely upon the encroaching vegetation and the débris formed by its decay, except in case of exceptionally high water when the whole island is flooded and sediment-laden water from without finds its way in.

At the Flats, lagoons and ponds may also be formed in another way, which is common to delta-formation, and is especially noticeable in the case of the delta of the Mississippi. As has been noticed, each of the distributaries as it advances builds a pair of embankments or levees, and tends to form a secondary delta at its mouth; the levees of the neighboring secondary deltas may unite and so enclose the bay which lies between. Fisher Bay and the upper end of Muscamoot Bay are already nearly closed in by land in this way, and will eventually become lagoons unless they become filled before the land across their lower sides has completely joined.

We have so far considered mainly the growth of the islands to a level with the water surface; the question remains, How do they become raised above the level of the lake? Taking into account for the present only the lower portions of the delta, there are two factors which seem chiefly to be concerned in its growth: (1) high water, and (2) vegetation. High water in Lake St. Clair may be caused by freshets and heavy rains, or by southerly winds. Either of these may raise the general level a foot or more, and sediment is thus deposited among the grass roots, and on land which is out of water at normal levels. It is obvious that these influences will not account for the height of three to five feet above water of the upper islands, but this is a feature of most deltas, and is here to be accounted for, in large part at least, in the same way. A stream carrying considerable sediment and forming deposits at its mouth, must change its grade as this goes on, and as a result the head of the delta travels upward along the stream.* Later, if the load of the river becomes reduced at any time, corrasion will begin along its upper reaches, and the stream will thus cut into the deposits at the head of the delta. Another factor which has undoubtedly increased this effect in the case of the St. Clair River is the differential uplifting of the Great Lake region in the northeast which has been going on in post-pleistocene time and is still acting. It was this tilting which brought the St. Clair River into existence again after the outlet of the upper lakes had been to the northeast, and its subsequent action has been to increase the gradient of the stream throughout its whole length, thus causing it to cut more deeply into the deposits that had been made.

*The real head of the delta is probably nearly five miles above Algonac; a small bay which starts off on the Canadian side here is continued by low ground, which leads down to a junction with the Chenal Ecarte (see Plate I) and undoubtedly represents a former distributary. The Chenal Ecarte itself leaves the main river about two miles above the head of Russell Island.

HISTORICAL.

In explaining some of the special features of the St. Clair delta it will be necessary to take into consideration the geological history of the region—at least that portion of the history following the retreat of the last great continental ice sheet.*

The first thing to be accounted for is the great bottom deposit of soft blue clay which underlies not only the Flats and Lake St. Clair but extends over all the low basin between Lake Huron and Lake Erie. Such a deposit must have been laid down in a large body of water which covered the region for a long period. This was the case during the existence of glacial lakes Whittlesey and Warren, when the ice-front stood at a point about a mile and a half north of the site of the present village of Saint Clair, and after it had retreated farther northward to positions now covered by Lake Huron. It is noteworthy that no pebbles or larger stones were struck in the bottom clay, which further indicates that it is an off-shore deposit. The conditions in the St. Clair basin when the ice had retreated further, lowering the level in the Ontario region below that of Lake Erie, and thus bringing Niagara Falls into existence and making Lake Erie into an independent lake, are not altogether clear. If the Trent River served as the sole outlet for the waters of Lake Algonquin for a time, it is possible that the St. Clair basin was drained while that condition prevailed; and it is certain that during a large part of the existence of Lake Algonquin its waters found their way into Lake Erie through a broad strait which occupied the valley of the St. Clair and Detroit Rivers and Lake St. Clair. The beaches formed at this time are well marked along the St. Clair River and around the lake. It seems probable that this connection was a strait rather than a river with any considerable current, as the sediments deposited in this case would be fine and would blend with the deposits already made while the region was covered by a great body of water; in the borings at the Flats, no deposits could be found which could be interpreted as the bottom deposits of a river existing at that time. Nor was any horizon found which indicated the non-existence of a lake in the St. Clair depression at the time when the outlet of Lake Algonquin was supposed to be through the Trent River.

*The literature on this subject during the last twelve to fifteen years is considerable, and is scattered through the various geological publications. Among the principal contributors may be mentioned Gilbert, Spencer, Taylor, Leverett, Upham and Bell. While they do not agree on all points, there seems to be a general agreement as to the major steps in the process, and I have attempted to follow those views most generally accepted. A very readable brief account of these changes has been written by Taylor, called "A Short History of the Great Lakes." It was published as one of the series of "Studies in Indiana Geography," edited by Charles Redway Dryer; Inland Publishing Company, Terre Haute, Indiana. 1897.

But the fact that the Nipissing beach dips toward the south end of Lake Huron makes it reasonable to suppose that at that time the St. Clair region was relatively elevated, and was higher than the level of the Nipissing lakes. It was still, however, probably low, marshy ground, lying in a saddle between the southern end of the Nipissing Lake Huron and the western end of Lake Erie, with its drainage system consisting of small streams flowing either northward through the St. Clair Valley, or southward to Lake Erie, or possibly in both directions at different, or even at the same times. The surface of the old lake deposits—the "bottom clay"—was thus exposed, and became covered with plant life. The evidence of this is found in the layer of decaying vegetation lying at a depth of about twelve feet under the present delta.* Furthermore, the clay immediately beneath the muck is tougher than that further below, and is also darker, results due respectively to surface exposure and to discoloration by decaying vegetation. Exactly similar conditions are to be seen at the present surface (see borings C, B, Z, BB, etc.) The Nipissing vegetation over this area probably consisted mostly of sedges and grasses, and it consequently must have taken a considerable time for the two to three foot stratum of muck to be formed.

That the northeastern elevation which shifted the outlet of the Nipissing lakes back to the St. Clair River is still going on seems pretty well established. This change in level undoubtedly accounts for the well-known drowning of the streams that flow into the western end of Lake Erie, but that, as Taylor† suggests, the shallow water covering the lower part of the St. Clair Flats may be taken as a similar drowning of the delta, does not seem to accord with the facts. In fact, just the contrary must be the case; for all of Lake St. Clair lies to the northeast of an isobase normal to the direction of tilting passed through its outlet, and consequently its bottom and all its shores must be undergoing elevation relative to the outlet.** This would tend to raise the Flats above water rather than to drown them, and has already been mentioned as a probable factor in that process (pp. 2, 19). On the other hand it cannot be denied that all the tributary streams between the head of the Detroit River and Lake Huron are of the type known as drowned streams. As examples of such may be taken the Clinton River and Swan Creek, opening into Lake St. Clair, and Pine and Black Rivers tributary to the St. Clair River; the streams on the Canadian side I have not had opportunity to examine, but Chalmers†† reports similar conditions. The drowning of these streams is to be explained, it seems to me, by the great volume of water now flowing out of Lake Huron. During the time of the Nipissing Great Lakes, when the land in the region under discussion was all above water, the streams cut for themselves deep channels; since the St. Clair outlet again came into use, the amount of water coming through it has been so great that not only has it cut the bed of the St. Clair River much lower than the bed level of the tributary streams, but its surface is also higher than was theirs, and so by backing their waters has converted them into drowned streams. This drowning, instead of progressing, however, is being lessened in these streams by the differential tilting which is taking place.

*No fossil remains of animals were found in the borings, but a large number of shells of Unionidæ have been brought up by the dredging along the Clinton River.

Taylor, F. B. "The Second Lake Algonquin;" Am. Geol., Vol. 15, p. 173. 1895.

**See Gilbert, G. K. "Recent Earth Movements in the Great Lake Region;" 18th Ann. Rept. U. S. Geol. Survey, Part II, pp. 595-647. 1898.

††Summary Report of Geological Survey of Canada for 1901, pp. 167-168.

RATE OF GROWTH.

Attempts to obtain a fairly reliable determination of the rate of growth of the delta as an index to the length of time it has been building have not given very satisfactory results. One way to obtain this is by a measure of the amount of sediment brought down by the St. Clair River in a given time; such observation would have to cover at least a year to be of any value at all for this purpose, and should preferably extend over several years. Except at times of storms the water is very clear, and the amount of light sediment (i. e., not taking into account sand rolled along the bottom) which may come down in a single storm has been computed; from the observations of the Weather Bureau it would be possible to find the average number of storms per year for a number of years, but even then results figured on this basis would be of little value on account of the great variation in the amount of sediments that would be produced by different storms, for we have no measure of what this would be under the various conditions of these storms.

A comparison of various maps of the Flats gave no more satisfactory results. No accurate survey was made until that of the U. S. Lake Survey in 1867-71, and that only outlined many of the islands in a general way. On Plate I the outlines of the chart made from this earlier survey are represented by red dotted lines; those from another edition, with additions made in 1902, are shown by the unbroken blank line. It will be noticed that in the latter Herson Island is extended to about twice the size it was on the earlier map. Blue prints from the recent survey made of the Flats by the State (in 1900 to 1901) were furnished by the land office, and have been reduced to the scale of the Lake Survey Charts; these shore lines, where they differ appreciably, have been put in with green dots and dashes. The earliest obtainable map of the Flats (Plate IV) made from the surveys of Lieut. Bayfield, R. N., in 1817, represents the Flats only in a general way, and is of no use in the present connection. According to this chart there was in 1817 about twice as much land above water as at present. An element to be taken into consideration is, that whereas on the charts the shore of an island is represented by a definite line, such is far from the condition obtaining on the islands themselves, and a rise or fall of a few inches in the water level may bring a great many acres out of water, or may submerge as much below its surface. Taking all these things into account, however, there still seems to be no doubt that the difference in the extent of Harsen Island as shown on the maps for 1867-71 and 1900 and 1902 really represents a growth of the island on its lower side; but in all probability this growth has not been so great as would appear on the map, which in any case indicates only areal expansion, and gives no measure of the amount of material that has been added. It is to be noticed particularly that no extension of the embankments along the principal channels is indicated, with one exception; in fact, in the case of the mouth of the Chenal About Bond, the land is extended farther on the Lake Survey Charts than by the State Survey; this is probably due to the plotting of rushes in shallow water as ground.

In the winter of 1887 a survey was made by H. D. Bartholomew on the ice, in which he "attempted to include within the surveyed portion of this territory all of the submerged lands upon which aquatic plants could be discerned either upon or through the ice."

A series of soundings, if made now, to compare with the careful soundings made in 1867-71, would be apt to give a much better index of the growth of the delta than can be obtained from the outlines of the islands.

THE CLINTON RIVER DELTA.

It will be noticed on Plate I that the Clinton River opens into Lake St. Clair at the end of a considerable projection of land, which forms the southern limit of Anchor Bay on the western shore. On the map this has much the appearance of a delta, which is remarkably large in comparison with the St. Clair delta, considering the size and conditions of the stream which alone can supply it with materials. Investigation showed, however, that most of the land is relatively high and is under cultivation. A distinct bank from about 5 to 6 feet high along the lower parts of the river, to 9 feet or more higher up, could be distinctly traced, and its position is marked by dotted lines on the chart. Between these banks is the meander plane of the river; outside is undisturbed glacial till. The river has formed a small delta deposit, it is true, beginning about a mile above the present mouth of the river. Black Creek* is the principal distributary from the main channel, and has carried much of the material a mile and a half to the southward, where it has built a small delta of its own.

In the few borings made along the Clinton River (T, U, V, W), although what was apparently bottom clay was struck in each, its tougher surface horizon, at about 15 feet, was not found—with the possible exception of boring T. It is evident that some of these borings (at least U) were on the site of a former channel which had cut rather deeply into the clay of its bed.

No deep stratum of muck was found in any of these borings.

*Black Creek is shown relatively too broad on Plate I, in fact, I believe it has now been practically shut off at its head by dredging and the building of embankments along the main channel.

ECONOMIC IMPORTANCE.

The St. Clair Flats have long been a popular summer resort on account of the facilities for boating, and the good fishing and hunting, and the American side of the South Channel is well built up with summer cottages and hotels, which are much more scattered on the other channels. The higher ground of the upper islands is partially forested, and there is also a considerable amount under cultivation. Walpole Island is set aside as an Indian Reservation by the Canadian government, and the land is cultivated by the occupants.

Aside from its use as a summer resort it would seem that what is still unsettled of the American Flats is of most importance to the people of Michigan as possible ground that can be turned to the use of market gardening. The land is at present very cheap, and by dredging at intervals and spreading the soil thus procured out upon the remaining area, a fairly good land can be obtained which will grow many kinds of market produce if properly cared for. If any amount of this were raised, what could not be used by the hotels and cottages on the Flats could readily be shipped to Detroit, either by boat or upon the electric railway which skirts the lake on the mainland.

When the present investigation was undertaken it was thought possible that beds of marl might be found somewhere in the region, which, together with the abundant and excellent clay, could be utilized in the manufacture of Portland cement. Marl beds were hardly to be expected in such places as the borings were made; but this does not make it impossible that they should be found, for instance, by borings made in Anchor Bay, though I think that even here it is rather unlikely.

SUMMARY AND CONCLUSIONS.

1. The St. Clair delta is peculiar in being built by a river which serves as the outlet of a large lake.

2. The materials which compose the deposit are fine sand and clay, and are derived for the most part by the action of the waves on the shores of Lake Huron, with the addition of materials brought in from rivers tributary to the St. Clair, and some eroded from the bank of that river itself.

3. The delta is in most respects a typical low-grade delta, the general laws of the deposition of sediments under water holding as in other cases.

4. The recent northeastern uplift has assisted the stream in cutting through the deposits at the head of the delta since forming them, thus bringing this portion higher in relation to the water level.

5. The clay upon which the delta is built is a deep-water deposit some 150 to 200 feet thick laid down at the time of the existence of glacial lakes Whittlesey and Warren. The surface of this "bottom clay" is but 14 to 16 feet below the present lake level.

6. At the time of the Nipissing Great Lakes this region was drained and covered with vegetation. The muck formed by the decay of that vegetation is now found as a stratum two to three feet thick immediately above the surface of the bottom clay.

7. The "drowning" of the streams tributary to the St. Clair River and Lake St. Clair is due to the large volume of water now flowing through, rather than directly to the uplifting in the northeast. The effect of this tilting is to diminish the drowning in this region, instead of increasing it.

8. Sufficient data are not at hand for determining the rate of growth of the delta with any accuracy.

By a process of reasoning backwards it may be assumed that 5,000 to 10,000 years has been required for the formation of the present delta. This presupposes that Taylor* is right in correlating the beginning of the upper, wider gorge of Niagara Falls with the shifting of the Nipissing outlet back to Port Huron, and that the estimate of time which has been consumed by the Falls in cutting back from this point is approximately correct. While this does not seem too long a time for the formation of the delta, still we have seen that the deposit which has been laid down by the river is not nearly so great as Taylor supposed.†

Instead of being 25 to 30 feet below the present water level, the bottom of the delta rests upon clays only 14 to 16 feet below the surface, though deposits have been made to a greater depth, to be sure, in the beds of old channels which cut through the bottom clay. Since the Nipissing beach, if projected, would pass 35 feet below the present level of Lake St. Clair, it follows that at the time that lake was in existence the land at this place had an elevation of 20 to 23 feet above its water surface.

Supposing the above determinations of time to be approximately correct, with a continuance of present processes Lake St. Clair would be completely filled by the delta of its feeding river in 20,000 to 40,000 years (assuming that the basin has already been one-fourth filled), except probably for one deep channel connecting the mouth of the present St. Clair River with the head of the Detroit River, which would then form a continuous river from Lake Huron to Lake Erie. Long before that time has elapsed, however, it is possible that on account of the dipping to the southwest, the Great Lakes will again be discharging through the Illinois River, with a consequent lowering of their level. This might again withdraw the water from the St. Clair outlet and convert the lake bottom into dry land.

9. Besides its value as a summer resort, portions of the Flats not now in cultivation may be made into productive land by dredging and grading.

10. The Clinton River has formed a small delta at its mouth with a land area of probably about 800 acres.

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*"The Second Lake Algonquin;" Am. Geol., Vol. 15, pp. 167-171. 1895.

†*Loc. cit.*, p. 172.