

broad plated white edged orange fins, is the true analogue to the *Char* of Europe. Whilst *Gloverii*, in its brown colour and teeth resembles *Fario* of Europe and *Confinis*, the great lake trout of Scotland's lakes. So far I have never heard of *Corregonus* the analogue to the *Vendace* of England, but may find it at any time; not so with the splendored analogue to the *Grayling* of Europe, the *Signifer* of Sir John Richardson. His range is too northern, and his great beauty and typical dorsal would have betrayed his whereabouts long since.

ART. XI. THE GLACIAL PERIOD IN NORTH AMERICA. BY
THOMAS BELT, F. G. S.

[Read May 8, 1866.]

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I.—INTRODUCTION.

UNTIL the last few years most geologists have taught that the glacial period was one of a great submergence of northern land, over which floated icebergs bearing from more arctic regions, stones, gravel and clay. Agassiz had long ago argued that land and not floating ice had been the effective agent in the glaciation of countries, but his theory met with little support, until the investigations of Norwegian and Swedish geologists proved that the glaciation of the Scandinavian peninsula had radiated from the central mountains, and could not have been produced by currents drifting icebergs from the north. The same result has been worked out in Scotland by Mr. Jamieson, and in North Wales by Prof. Ramsay, and now geologists are agreed that at the time of the greatest developement of the ice in Europe, the land was elevated above its present level and covered with ice, which descending from the higher ranges, deepened and widened the valleys down which it flowed.

The continent of North America is more glaciated than that of

Europe, but there is not the same evidence of the radiation of the transported blocks from central heights; and whilst Agassiz, Dana and other eminent geologists have adopted the theory of land ice, Lyell and Dawson have advanced many arguments in favour of that of icebergs. The question is therefore an open one, and no where can it be more appropriately discussed than before this Institute; for Halifax stands on ice-moulded hills, on an ice-cut harbour, and is surrounded by glaciated rocks and ice-carried drift.

During the progress of the exploratory works of the Nova Scotia Gold Company, carried on under my direction, I obtained what appeared to me conclusive evidence, that neither during nor since the glacial period has the southern coast of Nova Scotia been covered by the waters of the ocean. I purpose in the present paper to describe these facts, prefacing them with a short sketch of the glaciated rocks and superficial deposits of the Atlantic coast of the Province, and afterwards to discuss the question of the glacial period in North America, of which these phenomena are the monuments.

II.—GLACIATED ROCKS AND DRIFT-BEDS OF NOVA SCOTIA.

1. *Eroded valleys and scratched rocks.*—The Atlantic coast of Nova Scotia is cut into by long, narrow deep bays or fiords. The direction of the bays is roughly north and south. The hard rocks that bound them exhibit everywhere glacial scratchings and groovings in an excellent state of preservation and with a similar north and south direction. Going farther from the coast the long bays give place to deep and often narrow lakes, also pointing north and south. Chains of lakes sometimes reaching across the country have the same direction.

The whole country is hugely cut into irregular meridional ridges and furrows, which are as much part of the glaciation of the land as the scratchings and groovings. The valleys are scooped out of extremely hard quartzites and other metamorphosed rocks. These are highly inclined, and their strike is north-east and south-west. The valleys have been excavated across their upturned edges, transversely to their strike. Scratches and grooves might be caused by icebergs grinding along the bottom of a shallow sea, but the glaciation of a continent and especially the scooping out of long valleys, requires the uniform action of a more powerful agency.

2. *Drift-beds*.—It is, however, in the composition and distribution of the drift-beds that we find the most convincing evidence of the supra-marine character of the glaciating agent. In Nova Scotia the hollows are comparatively free from drift excepting where mounds across valleys mark the position of old terminal moraines. It has generally been pushed into recesses in the ranges, or to the south end of hills where it was sheltered from the ice moving southward.

Thus Lake Thomas near Waverly is bounded to the west by a rather steep range running north and south parallel to the lake, down to and into which it rapidly slopes. The structure of this hill has been well exposed by cuttings made in search of auriferous quartz veins. The northern end and the side next the lake has a thin covering of clay, gravel and boulders. The bed-rock is rounded, scored and grooved. Masses of quartz have been broken off from the lode and carried southwards. The southern end of the hill is composed entirely of clay, gravel and large angular stones. A tunnel was driven into it for about two hundred feet and no solid rock could be found, nothing but huge stones and other drift pushed in under the lee of the rocky beds to the north.

The transported blocks and the direction of the scratchings show that the glaciating agent moved from the north. If it had been floating ice and the hill at the time a submerged rock, the icebergs ought to have stranded on and deposited their freight at the northern, and not at the southern end. If on the contrary it was glacier ice the phenomena are just such as we might expect to find.

Again, if this drift had been dropped from icebergs floating over a submerged land, and we could imagine any possible means by which it could be arranged as we find it, we have still to account for the greater difficulty, that whilst the land slowly rose again from beneath the waters of the supposed glacial sea, and was exposed to the action of the waves on the spreading coast line, these ridges of incoherent drift were left unlevelled, and these bare hollows were left unfilled.

3. *Gold in the Drift*. — Through much of the drift grain gold is sparingly disseminated, and its distribution affords another argument in favour of the supra-marine theory. In Australia all the most important deposits of alluvial gold have been found in valleys lying immediately above the bed rock, beneath beds of gravel and clay; wherever surface washings have been discovered much richer

deep sinkings have been found in the vicinity. This indeed seems to be a necessary result of the sorting arrangement of water.

But in Nova Scotia, though denuded auriferous quartz lodes are abundant, no similar deposits have been found with one exception, to the consideration of which I will return. The gold instead of being concentrated at the bottom of the superficial deposits, is either distributed throughout them, or occurs in greater abundance at the surface than below.

At Lawrencetown extensive washings were projected, in consequence of the discovery of spangles and grains of gold in the surface soil. It was expected that it would be found in larger quantities in the lower parts of the beds of gravel, as in other gold producing countries; but these expectations were not realized. A little gold was found throughout the gravel, but nowhere so abundantly as at the surface. Probably the gold had been originally distributed throughout the drift, and its partial concentration at the surface had been caused by subærial denudation. The process of denudation may be seen in operation on every hill side. During the severe winter the ground freezes to about two feet from the surface; when the spring thaws set in this is completely disintegrated, and much of the finer soil is carried off into the rivers by the water from the melting ice and falling rains. The heavier stones and the gold are left behind, and thus are produced the surface gold washings, and the surface accumulations of stones culminating in the well known barrens of the Province. Since these gravels were deposited, they cannot have been rearranged by water; its sorting action would have carried the heavier gold to the bottom of the deposits, as in other gold producing countries.

The great richness of the gold washings in Australia and their scarcity and poverty in Nova Scotia, notwithstanding the abundance of auriferous lodes that have been denuded, may be thus explained: In Australia the denuding agent was water, which carried off the ground up rocks but left behind the gold—so that in the gravel beds nearly all the gold but only a small proportion of the original rock mass is left. In Nova Scotia the denuding agent was glacier ice, which carried off alike the stony masses and their metallic contents. The drift-beds left contain only the same proportion of gold as ex-

isted in the original rock mass, excepting where subærial denudation has concentrated it on the surface.

Perhaps in sediments older than the glacial period and which have escaped destruction during it, or in the beds of existing streams, or on the present sea coast, deposits of grain gold may be found, but they will be only the exceptions to the general rule. I have mentioned one exception. It belongs to the third class: it has been produced by the waves of the sea on the existing coast line. I refer to the gold washings at the Ovens, near Lunenburg, which, though limited in extent and soon exhausted, for a time largely remunerated some of those employed upon them. From the side of a rocky promontory, traversed by numerous small auriferous quartz veins, spreads out a bed of glacial drift, throughout which grain gold is sparingly disseminated. The sea is slowly eating into this bed and rearranging its materials. It grinds up the stones to shingle and finally to sand and mud, which it carries off to deeper water, leaving behind the tough heavy gold. This is found at the bottom of the shingle between tide marks, on the surface and in the crevices of the bed rock, where the gold formerly distributed throughout a large mass of drift has been concentrated. Now if the country had been submerged during the deposition of the glacial drift, every part of it, during its subsequent elevation, would at some time have formed a portion of its ever advancing coast line, and been subjected to the action of the waves; and such deposits as those of Lunenburg instead of being confined to the present shore would have been formed all over the emerging land.

4. *Marine Beds of the St. Lawrence.*—In the valley of the St. Lawrence marine beds with sea shells are found at various elevations, up to five hundred feet above the sea near Montreal. These beds lie above the glacial drifts, and prove that subsequently to the deposition of the latter, the country was submerged to at least the height at which the marine beds are found. From a consideration of the facts stated above, I am convinced that the Atlantic coast of Nova Scotia did not participate in this depression, and a study of the marine deposits themselves leads to the same conclusion. At Montreal sea shells have been found up to a height of five hundred feet above the sea, but lower down the St. Lawrence they do not occur excepting at a lower level. Thus on the Metis river they are found at a height

of two hundred and forty-five feet, and lower down still at Matan river they have not been found much higher than fifty feet above the sea. I do not suppose that these shells mark the extreme heights to which the sea has reached at the different places, but so far as the observations go, they show a decrease of the submergence towards the mouth of the Gulf. I am not acquainted with the drift-beds of the Province of New Brunswick, but I have no doubt that they will be found to bear out the same inference, namely, that going eastward from Montreal the elevation of the marine beds marking the former submergence of the land gradually decreases, until in Nova Scotia it reaches zero.

The gold washings of the valley of the Chaudiere within the area that we know, which from the evidence of sea shells was submerged after the glacial period, show us what would have been found in the auriferous districts of Nova Scotia, if that Province had also been submerged. The absence of gold washings in Nova Scotia and their presence in Lower Canada, are strictly in unison with the absence of marine deposits with sea shells in the one district and their presence in the other.

II.—ORIGIN OF THE GLACIAL PERIOD.

1. *Theories of origin.*—It is far beyond the scope of this paper to enter upon the discussion, or even to give an account of the various theories that have been advanced in explanation of the origin of the glacial period. It is less necessary for me to do so as the whole question is quite a modern one, and the views of Croll, Frankland and others have been so recently made public, that the scientific world is well acquainted with them and with the objections that have been urged against them. I will therefore confine myself to the consideration of the one that seems to me the most satisfactory

Sir Chas. Lyell in his admirable *Principles of Geology* long ago showed that the extremes of heat and cold might be produced by the grouping of the land; in the one case, about the equator, and in the other, about the poles. There can be no doubt that a rise of polar and a submergence of tropical and sub-tropical lands, would greatly lower the temperature of the arctic and temperate zones.

That during the glacial period or part of it, the land now glaciated stood somewhat higher than at present, has been inferred from

the depths to which fiords have been excavated, and from the fact of littoral shells having been dredged many miles from existing coasts. With regard to the submergence of tropical and sub-tropical lands, it is now well established that at the same period the African Sahara was covered by the waters of the ocean, so that we have an approach towards the conditions required for the production of extreme cold. That the conditions were all fulfilled is very improbable, indeed that they were not is proved by the ice having extended much farther south in North America than in Europe.

2. *Recent changes of level of the land in northern hemisphere greatest towards the pole.*—In a paper on some movements of the earth's surface in recent times,* I have remarked that in two instances in the northern hemisphere, one of depression, the other of elevation, the movement is greatest towards the pole. This matter is so important in dealing with the question of the probability of a rise of Arctic lands in the glacial epoch that I may be permitted to refer to it again, and to supplement the argument with some additional facts bearing upon it.

It has long been known that parts of the coasts of Sweden and Norway were slowly rising, and in the time of Linnæus marks were made on the rocks by which the rate of elevation at different points has been determined. It appears that at Gottenberg in the south, the land is only being raised about four inches in a century, but that the rate of motion gradually increases northwards, until at Cape Cod, the extreme point where it has been measured, the land is being raised about four feet in a century.

Opposite to this area of elevation, on the other side of the Atlantic, there is a corresponding area of depression. It appears to be well established that the Atlantic sea board of North America is slowly sinking. In New England the subsidence is scarcely perceptible, but it gradually increases as we proceed northwards. In Nova Scotia the submergence of marsh lands and of rocks has been generally remarked by the residents on the coast, and Cobequid bay and Cumberland basin submarine forests attest the long continuance of the downward motion. This subsidence attains its maximum on the west coast of Greenland, where the land is so rapidly sinking that in quite recent times the settlers have had to move

*These Transactions, vol. I, Part I, p. 24.

inland more than once the poles on which their large boats are placed. Here again the rate of motion is greatest towards the pole.

The present period of subsidence was preceded in part of eastern North America by one of elevation, which brought up the marine deposits of the Champlain period; to which the Montreal beds already mentioned belong. On the southern borders of New England these marine beds are only found up to about forty feet above the sea. As we proceed north they are found higher and higher. At Montreal they reach to five hundred feet above the sea, and in the extreme north, on Cornwallis and Beechey Islands in Barrow Straits, they have been found at an elevation of over one thousand feet. Here again the elevation is greatest towards the pole and gradually decreases southwards. To produce extreme cold according to Sir Chas. Lyell's theory, we only require a similar movement on a larger scale, and these smaller oscillations with their vertices towards the pole, may point to some general law governing the upheaval and subsidence of the earth's crust which would, if it could be deduced, explain the elevation of the land towards the north and its depression towards the south during the glacial period.

3. *Effect of shutting off warm currents from the Polar Basin.*—We do not know how small a change in the distribution of land and water might again produce a glacial climate. The effect of a change in the direction of the Gulf Stream, has been discussed by Mr. Hopkins and other writers, but I do not think that it has been noticed that a much greater change of climate would be produced, if all warm currents were shut off from the polar basin. Sir John Herschel has indeed stated that if Behring's Straits, which are only thirty miles broad, were closed so as to prevent the water circulating from a warmer region, finding its way into the polar basin, there would probably be a continual accretion of ice which might rise to a mountainous height.*

But if, besides the closing of Behring's Straits, there were a partial emergence of land from beneath the ocean, connecting Europe through Iceland and Newfoundland with America, we can scarcely appreciate the effect it would have in altering the climate of the northern hemisphere. There would not only be a great lowering of temperature through the increase of land around the poles, but

*Herschel's Physical Geography, page 41.

the heat of the Gulf Stream and other warm currents that is now expended in tempering Arctic seasons and melting polar ice, would then be spent in evaporation; and greater evaporation would give greater precipitation on the frozen lands of the north. The formation of continental ice requires both a low mean temperature and an abundance of moisture. The rise of northern lands, and the closing of the Arctic basin to southern waters, would give the one, and the greater warmth of tropical and sub-tropical seas, into which no polar currents ran and from which no warm waters flowed, would give the other.

IV.—ACTION OF THE ICE.

1. *Statement of the question.*—Turning our attention now to the possibility of land ice having glaciated the whole of eastern North America, we encounter the difficulty that has prevented many from accepting the theory of continental ice, who are fully impressed with the satisfactory solution it affords of the distribution of the drift-beds and the erosion of valleys. It is that whilst the rock scratchings and transported blocks prove that the glaciating agent moved from the north, there are no mountains in that direction from which it could have descended, and that any elevation of Arctic regions sufficient to give a slope that would bring the ice southwards like a great glacier is utterly improbable, if not physically impossible. With this opinion I fully coincide, but so far from considering it fatal to the theory of land ice, I believe that no such slope was necessary, and that the theory better explains the phenomena of the drift, on the supposition that there was no great elevation of northern lands than by a contrary hypothesis.

The subject may be best understood by tracing in imagination the accumulation of the ice and its progress southwards, its culmination and subsequent retreat, and noting whether or not its probable mode of action will account for the facts to be explained. It will be convenient to limit the discussion to one great area such as that of eastern North America, where the glaciation though on a grander scale than elsewhere, is more uniform from the very vastness of the agent that effected it.

2. *Accumulation of the ice.*—As the glacial period, from whatever cause, came on, snow and ice would gradually spread from the arctic circle southwards. Wherever there was not inclination of the

surface sufficient to carry it off bodily, as a glacier it would accumulate and be piled up until the higher portions slipped over the lower.

It has been suggested above that one of the most powerful causes that brought on the glacial period, was the shutting off the gulf stream and other warm currents from the arctic area, where at the present time they are ceaselessly employed in ameliorating the climate and melting up the ice at its source. They now eat into the very vitals of the icy foe, which attacked and routed in the rear draws in its forces to its inmost citadel. In the glacial period the breaches that now let in the invading waters from the south, were closed, and the icy hosts gathering in the north, pushed out their legions southwards, and drew their very sustenance from the forces that now beat them back to their arctic fortress.

Piled up then in the north the ice and snow would spread southwards. Where it encountered a high range running transversely to its flow, it would at first be diverted from its course, but it would gradually accumulate behind the obstacle until it overtopped it, at first flowing through passes in the range and ultimately overwhelming the whole ridge. In advance of the great mass, streams of ice would flow down pre-existing valleys and through passes in opposing ranges, deepening, widening and glaciating them, like pioneers cutting out roads for the main body. In some cases, passes through chains of hills would determine the erosion of valleys in front of them, by the ice that poured through from behind.

This moving margin of the advancing ice would be the effective tool in glaciating the country. To its action every portion of the surface would be exposed, whether its slope conformed to the course of the ice flow or was opposed to it; just as every part of a coast between tide marks is washed by the rising flood. And as the waves run forward on the shore and retire, to again advance, and again retreat, although the whole body of water is steadily rising, so we may suppose that the ice margin might greatly advance during a series of cold seasons, and retreat during warmer ones, to be again thrust forward and again drawn back, although during a great number of years the advance of the main body of ice would carry the fluctuating margin far forward and subject a new zone to its action. Thus the whole continent from the arctic circle to as far south as

Baltimore and Ohio was slowly and successively worked over. Many of its old valleys would be deepened and many new ones excavated. Lines of faults, of fractured or of softer strata, would be worn into valleys and lake basins. Everywhere the ice would find out the weakest points of the rock masses and work deepest there.

The moving margin of the ice flow and especially the glaciers thrown out in advance, would be the great producers and carriers of drift. The stones borne along upon a glacier are from the cliffs and peaks that rise above it and not from the rocks beneath, over which it passes. The latter are only smoothed and rounded, but the cliffs that bound a glacier are eaten into like a river bank. Masses of rock are undermined and fall down upon and are carried away on the ice, to be deposited in terminal and lateral moraines.

3. *Culmination.*—At last the ice reaches its limits. Mount Washington is glaciated nearly to its summit, and at the time when there was most ice only its top could have stood out—a desolate island in a frozen sea. To the north the whole continent must have been covered without a single peak rising above the universal pall.

It is probable that during the greatest development of the ice, most of the drift that had been produced would be destroyed by being ground to powder under the mighty moving mass, and carried away in the water which we know flows turbid from beneath every glacier. The time of thickest ice was not that of the production of drift, but of the rounding, polishing and grooving of mountain masses. Could the icy covering have been lifted the rocky skeleton of the country would have been exposed, with scarcely a patch of gravel or soil upon its bare, scarred frame.

The scratchings on the highest peaks show that the main body of the ice moved south-easterly. Here we see the action of two forces—one, from the north, was the accumulation of ice in that direction; the other, from the west, was the slope of the continent towards its eastern sea board.

4. *Retreat.*—If then drift was not formed when the ice was at its height, and that which had been produced during its advance was then destroyed; whence the heaps of gravel and the transported blocks that now cover the face of the country? They were distributed during the slow retreat of the ice, when again every part of the country was subjected to the action of the moving margin. Just

as the whole of a sandy beach is rippled between high and low water marks by the retiring tide, so during the gradual retrogression of the continental ice, every portion of the country that had been covered,—from the valleys of the Ohio and the Missouri to the Arctic hills, and from the summits of the hills to the bottoms of the deepest valleys,—became again for a time, as they had been during the advance of the ice, the shore of an ice sea, or the boundary of an ice stream. Again the ice wore into its rising banks and carried off stones and gravel and formed terminal and lateral moraines.

The transportation of drift from any region began as soon as any of its mountain tops emerged above the subsiding ice. The highest peaks would send the farthest carried fragments, and lower and lower as the ice flow ebbed, so nearer and nearer to their source would its burdens be deposited.

Like its advance, the retreat of the ice was probably slow and fluctuating. During some seasons it would diminish greatly; during others advance again, but taking a number of years together there would be a decided retreat. The ice would act on the rocks during its subsidence as it had done during its rise, but the drift formed and deposited instead of being destroyed by the advancing mass, was left in the valleys and on the hills as we now find it. The only differences on the southern coast of Nova Scotia that we can detect are, that the moraines in the valleys have often been cut through either by the streams that issued from beneath the retiring glaciers, or by those that now run through them, and that large stones and grain gold have been concentrated on the surfaces of drift-beds on the hill sides.

V.—APPLICATION OF THE THEORY TO SOME OF THE PHENOMENA OF THE DRIFT.

1. *Local character of the drift.*—Having thus sketched out the probable action of the ice during its advance, culmination and retreat, and explained the general distribution of the drift, it only remains to apply the theory to a few of its more striking features. The local character of most of the drift stones in Nova Scotia is one of these. Here and there a few blocks of granite are found, that have been brought two, four, or even eight miles, but the great majority of fragments belong to the rock formation over which they lie. Boulders of slate occur where bands of slate cross the country,

and boulders of quartzite where the bed rock is quartzite. Fragments of quartz sometimes containing gold are easily traced to the lodes (invariably to the north of them) from which they have been detached, and thus many auriferous lodes have been discovered.

The local character of the stones in the drift is opposed to the supposition that to the north the land was so elevated that the ice moved over the country like a great glacier, and is in favor of the theory that it was formed by the retreating margin of a great accumulation of ice. If there had been during the glacial period, high mountains to the north of Nova Scotia, far travelled blocks would have been of frequent occurrence. But without high ranges northwards and with its own hills only of moderate elevation, we find as we might expect, that the blocks are easily traced to their parent rock. Some boulders of granite have been carried farther, because here and there granite hills rise above the general elevation of the country.

2. *Transported blocks of Berkshire, Massachusetts.*—Sir Chas. Lyell has described some long trains of large blocks that in Berkshire, Massachusetts run, in nearly straight line, for distances of five, ten and twenty miles, across hill and dale alike.* The direction of the trains is N. W. and S. E., and they cross three chains of hills with intervening valleys running N. N. E., and S. S. W. The blocks, starting from the most north-westerly ridge, pass in long lines across the valley to the next, and on to and in like manner through gaps in the third range.

It is argued that these blocks could not have been carried by glaciers, as they would have followed the slope of the valleys and not have crossed them; and that it is more likely that they were dropped by icebergs when the country was submerged, so that the tops of the hills became islands and the passes straits, through which the icebergs floated driven by a current from the north-west. The argument is a valid one against a theory of local glaciers, but not against that of continental ice. I have already shown how the advancing ice would act when it encountered ranges running transversely to its flow. This is an example, only I suppose the blocks were left by the retiring ice when the same process was repeated. At its greatest height the ice covered the ranges and rounded them. When during its subsi-

*Lyell's *Antiquity of Man*, page 356.

dence the highest points rose above the ice, rocks would be undermined and carried away. As the ice diminished and the ranges emerged, a time would arrive when the passes would become icy straits through which flowed ice from behind. It could not move down the valleys, for at that time the great north and south valleys of the Hudson and the Connecticut must have been filled with the ice that dammed up the lateral valleys.

The first stage in the formation of the trains began when the two valleys were filled with ice, and glaciers streamed through the passes in the most southern range bearing blocks from those behind. As the glaciers wasted the boulders would be left in lines marking the retrogressive points to which they reached. When the passes of the third range were free from ice it would still flow through those of the second, and as it receded it would leave step by step the monuments that now mark the direction it took. The resemblance of many of the phenomena of the drift to those that might have been produced by floating ice, proceeds from this,—that the valleys were filled with ice as they would have been by water in the former case, and that glaciers flowing through the gorges in the hills took the place of the suppositious icebergs.

3. *Drift of the St. Lawrence.*—Dr. Dawson of Montreal, has pointed out that the drift of the valley of the St. Lawrence has been carried up the valley. He argues that it ought to have been carried down it if the transporting agent had been land and not floating ice.

This objection is again rather against a theory of local glaciers conforming to the slope of the valleys, than that of continental ice.

The great valley runs from south west to north east, and the ice coming from the north must have flowed up it, if it was influenced by it at all. The general direction of the ice flow was from N. N. W. to S. S. E., but it could scarcely fail to be somewhat influenced by such a wide and deep valley running obliquely to its course. The valley must have filled from the bottom upwards, and drift would be carried from the high grounds on the sides to the bottom of the valley farther up, even if the ice was not pushed up by the weight of the mass behind. Again, when the ice from the north reached the bottom of the valley of the St. Lawrence, it would dam it up, and a great inland fresh water sea might be formed, up which would float

icebergs. Thus all the phenomena might be produced that characterise a submerged country, excepting remains of marine life.

The accumulation of ice in the region of Lake Champlain, caused by the valley of the St. Lawrence diverting in that direction that which would otherwise have flowed to the south-east, might furnish the advocates of the excavation of lake basins by ice, with an argument in favour of their theory.

4. *Terraces and stratified deposits.*—In Nova Scotia, terraces and stratified beds of sand and gravel are not uncommon. I have noticed a very conspicuous terrace running at the same height on both sides of a valley running into Cole Harbour, and which is crossed by the Lawrence-town road. Stratified beds of sand are found in many of the valleys tributary to the Shubenacadie lakes. These undoubtedly point to the action of water, but the entire absence of marine remains might make us pause before we came to the conclusion that they were formed by the sea. All the examples that have come under my notice occurred in lateral valleys, such as for instance those running into Cole Harbour, and into the Shubenacadie lakes. I believe that they were formed on the shores of lakes, caused by the damming up of the lateral valleys by the great glaciers that flowed down the principal ones.

VI.—CONCLUSION.

The question that I have discussed in this paper is so extensive that it would require a volume to discuss it fully and in detail.

This I have not attempted to do, as not only was it far beyond the limits of this paper, but already the glacial period both in Europe and America, has received great attention from eminent geologists, and its leading facts are well known. I have therefore confined myself to original observations made in Nova Scotia, and to deductions therefrom; and in the discussion of the general question have only given prominence to what I believe to be new or modified views respecting the origin of the ice of the glacial period and its mode of action. I will briefly recapitulate the conclusions arrived at.

1. The arrangement of the heaps of gravel on the flanks of hills, and the distribution in them of grain gold, in Nova Scotia, are opposed to the theory of the submergence of the country either during or since the glacial period.

2. The submergence of part of eastern North America, during which the marine beds of the Champlain period were formed, was not participated in by the southern coast of Nova Scotia.
3. To explain the movement of land ice from the Arctic regions southwards, it is not necessary to suppose that the continent to the north must have been greatly elevated, nor do the facts connected with the distribution of the drift agree with such a supposition.
4. That there was some elevation of northern lands during the glacial period is, however, probable: *Firstly*, because all the oscillations of level of the lands in the northern hemisphere since the glacial period, with which we are acquainted, have been greatest towards the pole; and *secondly*, because a rise of land sufficient to prevent the entrance of heated currents to the polar basin, would occasion a great accumulation of ice in the circumpolar regions, by the heat of the tropical and sub-tropical waters being spent in evaporation instead of, as at present, in melting the ice within the Arctic circle.
5. The drift-beds were formed during the retreat of the ice, and not during its greatest development.
6. Terraces and stratified beds in lateral valleys, were formed when these were filled with water, dammed back by the glaciers that still flowed down the main valleys.

ART. XII.—GEOLOGY OF ANTIGONISH COUNTY, N. S. BY REV. D. HONEYMAN, D. C. L., F. G. S., MEMBER OF THE GEOL. SOC. OF FRANCE, HON. MEMB. OF GEOL. ASSOC. LONDON, &c.

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THIS county, known until lately as the county of Sydney, is the north-east county of Nova Scotia proper. It is bounded on the north by Northumberland strait, which separates it from Prince Edward Island,—on the east by St. George's Bay,—on the south by the county of Guysboro',—and on the west by the county of Pictou. It is somewhat mountainous, and contains numerous small lakes and streams. The principal mountains are the Antigonish mountains, whose corner nearest to the town of Antigonish is about three miles to the north-west. Considering this range as sub-triangular, one