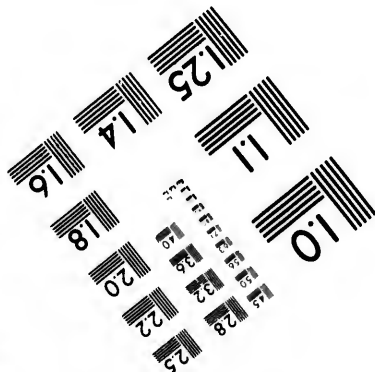
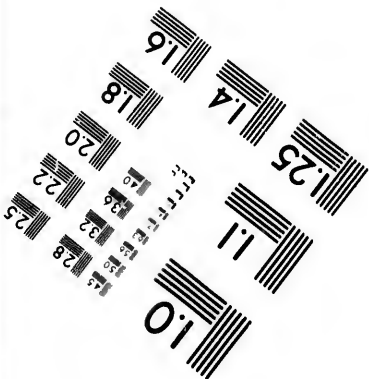
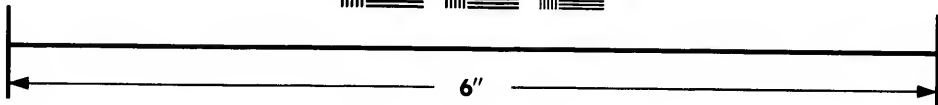
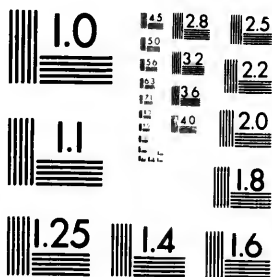


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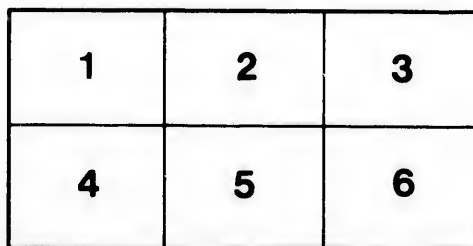
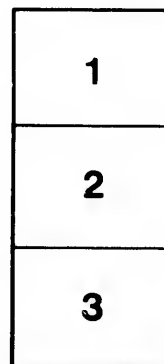
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SECOND SERIES—1897-98

VOLUME III

SECTION IV

GEOLOGICAL AND BIOLOGICAL SCIENCES

THE BAY OF FUNDY TROUGH  
IN AMERICAN GEOLOGICAL HISTORY

By PROFESSOR BAILEY

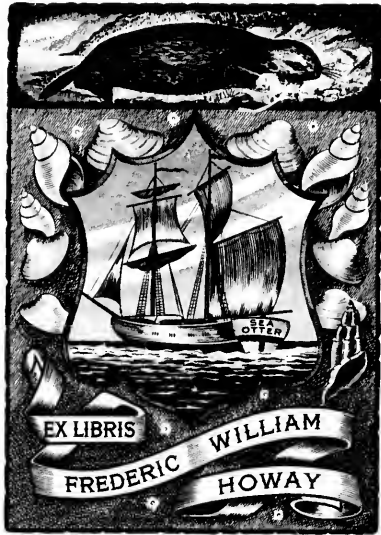
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1897



III.—*The Bay of Fundy Trough in American Geological History.*

By PROFESSOR BAILEY.

(Read June 23rd, 1897.)

The fact that a northeastern or Acadian basin, not only physiographically distinct from other regions of the American continent, but to a considerable extent independent also as regards its biological progress, was a feature of that continent even from the earliest Paleozoic times, was first brought prominently to notice by the late Prof. J. D. Dana, in the earliest edition (1866) of his *Manual of Geology*. In that work the references to this subject, under the heading of "The Eastern Border Region," were for the most part of a very general character; but in the last edition of the same work, published thirty-one years later, the same idea is elaborated in much more detail, and several successive sketch-maps are presented, embodying the author's views as to the geographical evolution of the region to which they refer. As these views have reference to a most important subject, and are likely to be widely read and accepted, any facts which may tend to confirm or to modify them can hardly fail to be of value. It is the purpose of the present paper to discuss some of these conclusions, especially so far as they relate to New Brunswick and Nova Scotia, in view of such information as recent investigations of the latter are calculated to afford.

Among the features which especially distinguish Prof. Dana's latest presentation of the subject is that of the recognition, among what he terms "areas of geological progress," of an "Acadian channel," this being described as embracing the Bay of Fundy, and thence extending easterly to western Newfoundland, and in the opposite direction along and off the New England coast, probably as far as Narragansett bay. This Acadian trough is further described as persisting through Paleozoic time, and as being separated, at least during the earlier portion of that time, from another and more northerly trough—designated "the Gaspé-Worcester" or "Maine-Worcester" trough—by a range of Archæan rocks, possibly extending across the Gulf of St. Lawrence to Newfoundland; while to the south it was delimited by another Archæan range, termed the "Acadian protaxis," occupying, in particular, central Nova Scotia, and thence extending westerly to Long Island. Finally, in the series of sketch-maps, to which reference has been made, representing the supposed geographical conditions of eastern America in successive periods, various limits are assigned to the submerged and emerged areas, the Nova Scotian protaxis being retained in all.

These views would, therefore, make the origin of the Bay of Fundy trough, as well as the associated ridges and depressions, coincident with and the result of the very earliest orogenic movements of which we have any knowledge, and to any one interested in the probable history of this portion of the country, must be regarded as of extreme importance. We have now to inquire how far they are in accordance with our present knowledge.

In the first place it is to be noticed that in recognizing two belts only of Archaean rocks as traversing the Acadian basin, viz., that of northern or central New Brunswick and that of Nova Scotia, the only group or belt of rocks which in the former province is known to be of the Pre-Cambrian age is entirely overlooked; the great central basin of New Brunswick being at the same time made continuous with the Bay of Fundy trough, from which these Pre-Cambrian rocks now completely separate it. As to the ridges north of the central basin, now occupied by the Coal measures, and dividing the latter from the Gaspé-Worcester trough, it is true that a portion of these have, in the reports and maps of the Geological Survey, been represented as Archaean; but even if this be their age, of which there is as yet no definite proof, the area which they occupy is not large, and no evidence whatever is available to show that they were connected either on the one side with the rocks of Newfoundland, or on the other with those of southern Maine and Massachusetts. It seems much more probable that, if Archaean at all, the rocks in question represent one or more of several insular groups in the Cambrian seas, of which others were to be found in northern Maine, in southern New Brunswick and in eastern Nova Scotia.

If now we consider the facts connected more particularly with the Bay of Fundy trough, we find definite proof not only of the existence of terrestrial areas in this vicinity at the opening of the Cambrian era, but that these were so disposed as to determine a northern border to the trough, not widely different in position from that which now limits it in the same direction. For although among the formations adjacent to the Bay are found representations of all the successive eras, from the Laurentian to the Trias inclusive, they occupy in general very small areas, forming a mere fringe, as it were, to the Archaean ridges, which, for much of their length, rise directly and precipitously from the waters of the bay. That they similarly thus rose in early Cambrian times, or at least that ridges in part above the sea-level were not very distant, is fully shown by the nature and distribution of the Cambrian sediments, by their physical markings and by their contained fossils, as long since pointed out by Matthew. It seems probable, however, that their height was somewhat less to the eastward than to the westward, the Archaean rocks, which to the west of the St. John river form one broad belt, being to the eastward of that stream divided into several, possibly insular, ridges, by intervening parallel troughs of Cambrian sediments.



The northern border of the Bay of Fundy trough being thus fixed for the early Palaeozoic with some degree of certainty, though not in the position assigned to it in the manual of Prof. Dana, we have now to inquire as to the corresponding border on the south.

At the present time this southern border is, throughout its extent, marked by the trappean range of the North Mountains, which cannot possibly be older than the Trias, and is probably Jurassic. Eliminating this and the associated red sandstones, and uniting, as would then be the case, the waters of the Minas basin, Annapolis basin and St. Mary's bay with those of the Bay of Fundy, we find the rocks which next border the trough on the south side to be of Silurian or Eo-Devonian age, resting for the greater part of their length upon the granite ridge of the South Mountains, the latter forming the backbone of the Nova Scotian peninsula. But is the backbone Archaean? It is so represented in Prof. Dana's manual; but it is safe to say that, as regards all that portion at least of the peninsula which now lies south of the present Bay of Fundy, it contains no Archaean rocks whatever. The granites were long since described by Sir Wm. Dawson as being intrusive and of Devonian age, a conclusion which all subsequent investigation has tended to confirm; and though both that author and Dr. Selwyn were disposed to regard the hornblende and chloritic rocks of Yarmouth as probably Huronian, there is now no question that these too are really more recent, they being a member, and by no means the lowest member, of the same series as the gold-bearing rocks of the southern coast, usually regarded as Cambrian. Thus there are no rocks, at present disclosed to view, in the portion of Nova Scotia lying south of the present Bay of Fundy, which can properly be pointed to as a portion of the "Acadian protaxis"; the only rocks of Archaean age to be found in the province being limited to the island of Cape Breton, and possibly to some portions of the Cobequid mountains.

Before dismissing the Pre-Cambrian rocks it is interesting to note, in the case of those of southern New Brunswick, the large amount of volcanic matter which they contain, and which, in the rocks referred to the Huronian system alone, has been estimated to reach a thickness of at least 10,000 feet. So vast an accumulation of igneous matter along lines parallel with the present course of the Bay of Fundy trough, not only strongly marks out the latter as a subsiding geosyncline as far back as Pre-Cambrian time, but as exhibiting, even then, conditions which, in later eras and in the same geosyncline, were repeated in the igneous extrusions of the Silurian, the Devonian, the Lower Carboniferous and the Trias.

We have now to consider more particularly the information to be obtained from the study of the Cambrian rocks.

The littoral origin of these rocks, as regards their earlier members, is, in New Brunswick, sufficiently attested by the coarseness and bulk of the conglomerate which constitute these members; while their origin is as clearly indicated in the fact that their contained pebbles are identical with that of the Archean ridges near by. Even higher in the series, though increasing fineness indicates a deepening of the waters in which the beds were deposited, the occurrence of wave-marks, ripple-marks, mud-cracks and worm trails continue to afford conclusive evidence of shallow water origin. And, finally, this conclusion finds confirmation in the nature of the fossils, the well-known studies of which, by Matthew, have enabled him not only to determine, in great detail, the successive changes in that fauna as affected by the varying conditions under which it was developed, but to draw probable conclusions as to its relations with equivalent faunas elsewhere, and possible migrations from one region to another. The most important point in connection with the comparisons, so far as the subject under discussion is concerned, is that of the much closer resemblance of the Acadian Cambrian fauna to that of Europe than to that of interior America. Following the suggestions of Dana, this is believed by Matthew to be due to the existence of a barrier separating the Acadian basin from that of the continental interior, accompanied at the same time by a difference in the temperature of the waters, those of the region east of the barrier feeling, as now, the influence of a comparatively cold Polar current, while those to the west, including the St. Lawrence channel and probably the Gaspé-Worcester channel, were relatively warm. It would seem to follow, as a corollary, if these inferences are correct, that no similar barrier existed between the eastern coast of America and the western shores of Europe; and Matthew, in a map illustrating his views, extends the zones indicating the distribution of the trilobitic fauna directly from the one to the other, Nova Scotia being included in the probably submerged area. So, again, Walcott, in a map showing the supposed distribution of what he terms the Keweenaw land or continent, while recognizing the Archean rocks of southern New Brunswick as an extension of the Appalachian protaxis, and as being above the sea level, does not include therein any part of Nova Scotia.

Unfortunately, in passing to the last named province, to which we would naturally look for further information, we find this to be of a very unsatisfactory character; for though it is usual to assign to the Cambrian system the great group of rocks along the southern coast, in which are situated the various auriferous deposits now so extensively worked, there is as yet no definite proof that such is their age, and there are those who directly deny it. All, however, are agreed that these rocks cannot be newer than Cambrian, and, although, adopting the latter view as the most probable, we find, as in the case of the St. John rocks, evidence that this source could not have been far distant, there is still no

distinct evidence of its existence within that part of Nova Scotia which now forms the southern boundary of the Bay of Fundy basin.

It is usual to divide the supposed Cambrian rocks of Nova Scotia into two distinct members, of which the lower consists chiefly of quartzites or fine sandstones, with much thinner intercalated slates, and the upper almost wholly of slates, partly light coloured or banded, but mostly very black and pyritous. The thickness assigned to the former by Gilpin is 9,000 ft., by Mr. Campbell it is made 10,000 ft., while W. F. Prest, from measurements both on the Sissaboo and at Waverley, has estimated the same thickness as high as 16,000 ft. It is doubtful whether, in a region so extensively folded and faulted as this, any estimates of thickness can be looked upon with confidence; but no one who has made sections across the supposed Cambrian belt, anywhere between Halifax and Shelburne, can doubt that the thickness, with all allowance for probable errors, is something enormous. That the beds, especially of the lower division, should exhibit such great uniformity, as regards both their extension and their depth, is scarcely less remarkable; while their character is such as to indicate that they could hardly have been deposited in very deep water or that their source was very far distant. It is true that, as compared with the Cambrian rock of New Brunswick, they lack the coarse red beds usually (but not always) found there at the base of the system, but apart from their arenaceous character, the occurrence of ripple-marks and occasionally of pebble beds leaves little doubt of their shallow water origin. And yet over the whole of southwestern Nova Scotia we find nothing to indicate the source from which they came. On the contrary, it is now known that, with the exception of the granite and small areas of Eo-Devonian and Trias. to be presently noticed, no other rocks than those of the Cambrian system (so called) are to be found over all this region. As, moreover, there is reason to believe that the granite itself is but an excessively metamorphosed condition of the Cambrian quartzites (this metamorphism not occurring, however, until a much later period), we are forced to the conclusion that all the portion of Nova Scotia under discussion was, during a large portion of Cambrian time, in a condition of submergence, forming a portion of a subsiding trough, whose southern and eastern limits cannot now be defined.

As regards the slates which overlie the quartzites, it is evident that they indicate a still deeper submergence, possibly to considerable depths. Their thickness has been variously estimated at from 4,000 to 10,000 ft., but if only 5,000 ft., this, if added to 10,000 ft., as a reasonable estimate for the quartzites, would indicate for the whole Cambrian system in Nova Scotia a subsidence of nearly three miles. It may be that this subsidence will, in part, account for the remarkable absence of fossils in the Cambrian rocks, the presence of cold currents traversing the submerged area being unfavourable to the growth or spread of organic forms.

If now we advance a step upward in the geological scale, we find that the information to be obtained is still very scanty. No rocks of undoubted Cambro-Silurian age have been identified in that part of Nova Scotia which lies directly south of the present Bay of Fundy, and they occur very sparingly on its northern border. It is probable, however, that extensive areas of such rocks have been removed by denudation, the *Dictyonema* slates found at the mouth of the St. John river showing such relations to the Cambrian rocks, on which they rest, as to indicate that they at one time completely covered them. (Matthew.) It is probable that they spread over much of Nova Scotia as well, but of this no definite proof has yet been obtained.

In the Upper Silurian the data are more ample. In New Brunswick the rocks of this age are widely distributed, but between those of the northern and those of the southern part of the province a great contrast exists. In the northern portion the rocks are calcareous slates and limestones, and both by their character and fossils (which include many corals), show deposition in clear waters, marking, in fact, the continuance of the old Gaspé Worcester trough. In *southern* New Brunswick, on the other hand, the rocks are almost exclusively slates and fine sandstones, almost without limestones and corals, but with much volcanic debris, showing, unmistakably, both by their character and distribution that they were deposited in shallow bays and straits in and among the old Huronian hills, these latter then existing as islands in the Silurian sea.

There can be but little doubt that the source of these materials, so far as New Brunswick is concerned, was still, as in the earlier Cambrian, to be found in the waste of the old Archean ridges near by, and remnants of which, like islands, are seen projecting through them; but while the northern edge of the trough now occupied by the Bay of Fundy thus continues to be more or less clearly indicated, we are still wholly without evidence as to its southern border. We do, indeed, find, all along the southern side of the Annapolis valley, in the basins of Bear River, Clements, Nictau and Torbrook, a great body of rocks, which are abundantly fossiliferous and contain extensive iron ore deposits, both indicative of their marginal or shallow-water origin; but through much of their length the rocks with which they come into contact are granites, which at the same time show, by their penetration and alteration both of the fossil beds and the ore beds along their line of contact, that they are of later origin. The fossil-bearing strata being clearly of Eo-Devonian age, and the granites as clearly of later Devonian origin, while to the south no rocks more recent than those of the Cambrian are to be found, we are again forced to the conclusion that, as in the earlier Palæozoic, so through the Silurian and Devonian eras, the Nova Scotia peninsula, in its western part at least, still lay below the sea level, the old protaxis, if any, lying outside of and to the eastward of its present limits; also, that

it was to the continued subsidence of the Bay of Fundy trough, of which Nova Scotia may have represented the axial line, that we are to ascribe the vast number of igneous dykes by which, on both sides of the bay, its sediments are intersected, as well, probably, as the origination of the granite which, again on both sides of the bay, was the closing event of the Devonian age.

In the distribution, character, and fossils of the Lower Carboniferous rocks in the Acadian region is afforded pretty satisfactory information as to the condition of that region at this latter period. At its opening the land on either side of the Bay of Fundy trough undoubtedly stood somewhat above its present level, the main difference between its contour at that time and the present being in the absence of the North Mountains, which now mark its border; but as the age advanced, differential movements, with increase of subsidence in the direction of the gulf, led gradually to the expansion of its waters until these, in New Brunswick at least, spread over the highest hills of the southern coast, as they did also over much of the interior and over some of the ridges bounding the Gaspé-Worcester trough. Annapolis and Minas basins, with the lower portions of the valleys of the Avon and Shubenacadie, would then be continuous with the main trough, the southern border of which would be marked by the South Mountains; Nova Scotia would have been separated from the mainland by the submergence of the peninsula now connecting the two, and nearly midway in the strait thus found the Cobequids would have stood as a long island, parallel with the axis of the trough. As in earlier periods, continued subsidence led to igneous extensions, but these, instead of being, as heretofore, of granite, were now confined to more limited areas and took the form of doleritic dykes and overflows, such as everywhere cap the Lower Carboniferous rocks of southern New Brunswick.

In the case of the rocks of the Coal Measures, the principal facts to be noticed are the occurrence of them everywhere around the shores of the Gulf of St. Lawrence, as well as upon Prince Edward Island, etc., indicating their former continuity over the area now occupied by the waters of the gulf; the extension of the latter over the central counties of New Brunswick almost to its western border; similar extension across the Isthmus of Chignecto, indicating similar conditions there; but, finally, with a most wonderful contrast in the thickness of the beds there deposited, as compared with those laid down over the mainland of New Brunswick, the one represented by a thickness of 14,000 ft. or more, while the other probably does not exceed 400 or 500 ft. The attitude of the beds in the interior is nearly horizontal; that of the strata bordering the bay shows everywhere evidence of profound disturbance. Thus, the Bay of Fundy trough as a subsiding area is again strongly accentuated, while the vast thickness of the strata about the head of the bay, as

represented at the Joggins, together with their very sparing occurrence to the westward on the New Brunswick shore, and entire absence on that of Nova Scotia, would seem to indicate either that the conditions for their accumulation were here less favourable, or that, if ever deposited, they have been removed by denudation. Prof. Dana seems to have regarded the coal-making swamps of the Gulf of St. Lawrence as having been connected, through the Bay of Fundy, with those of Massachusetts and Rhode Island; but the facts stated above seem rather to favour the idea that a barrier of some kind existed between the two.

As regards the rocks of the Jura-Trias there is no reason to doubt that the generally accepted view which would make them of estuary origin, and as having been laid down under conditions similar to those of the Connecticut valley, are correct. It is, however, worth noticing that the igneous rocks which here, as elsewhere, form so conspicuous a feature in connection with these beds are wholly confined to the Bay of Fundy depression, being found on both sides of the latter as well as in the island of Grand Manan, but nowhere at a distance from the present limits of the bay. The strata are also faulted in the direction of the axis of the bay.

Of later Mesozoic rocks nothing definite is known, and hence data are wanting from which conclusions can be drawn, except so far as these are afforded by regions outside the limits of the area now under discussion. It has, indeed, been ascertained that a portion, and probably a considerable portion, of the strata of the Annapolis valley, which it has been usual to regard as altogether older than the traps of the North Mountains, contain in places large embedded blocks of such trap, and hence that these strata, if not contemporaneous with, are more recent than the latter, but no fossils have yet been found by which their real age can be determined, and no satisfactory conclusions with regard to them are as yet possible.

It only remains to consider briefly the possible condition of the Bay of Fundy trough in the Quaternary era.

As to the Glacial or Drift Period, the question here, as elsewhere, involves a decision between the rival theories which would, on the one hand, presuppose a general upward continental movement, with a corresponding enlargement, both in extent and depth, of the polar ice-cap, and the consequences incident thereto, and, on the other, would advocate a depression rather than elevation in the higher latitudes, with local glaciation only and a much wider distribution of ice-laden currents. In the one case the Bay of Fundy would be practically annihilated by an elevation of both its bed and borders, as well as by the filling of the former by ice; in the other view, though retaining its general position and form, the bay would have somewhat wider limits, and, as in some earlier periods, would become a strait opening freely into the Gulf of St. Lawrence, leaving Nova Scotia disconnected with the main land. The glacial phenomena of the latter would thus be almost wholly local.

While the subject is too lengthy for full discussion here, the present writer feels compelled to express his dissent from the views lately put forth upon this subject by Mr. Chalmers, of the Geological Survey, as favouring the second of the two hypotheses referred to. While fully admitting the facts brought forward by that gentleman in support of his conclusions, the writer believes that these have all to do with the closing portion of the Glacial Period, and that a far greater array of facts in favour of a previous condition of general or continental glaciation can easily be brought forward. Thus, the vast numbers and the enormous size of the granite and Cambrian boulders strewed over the whole peninsula and upon its highest summits; the fact that here, as elsewhere, the chief movement of the boulders has been in a southerly direction; that among the boulders occurring on Digby Neck and Briar Island are some wholly unlike anything to be found in Nova Scotia, but closely resembling those in southern New Brunswick, while blocks of the characteristic North Mountain traps occur all along the south side of St. Mary's bay, as well as on the Atlantic shore of Yarmouth and Shelburne counties, show a general movement southward, such as could only be possible if the whole peninsula were covered with a single icy mantle, and this a portion of a still greater ice sheet coextensive with the northeastern portion of the continent itself. When to these evidences of continental glaciation we add the wonderfully perfect illustrations of moraines and kames, some of the latter thirty miles in length, with which the interior of the southwestern counties abound: the course and parallelism of the numerous fiord-like indentations of the southern coast, accompanied, as they frequently are, by evidences of glacial ploughing, which are phenomenal in their character; the similar direction and parallelism of the transverse troughs, such as Digby Gut, Sandy Cove, Petite and Grand Passages, which more or less completely divide the North Mountain range, and which again show evidences of glaciation to and below the present sea level; the phenomena, as a whole, appear to be of such a character as to demand some more general and some more energetic source than that of such ice as would gather around a few low islands, or even from the entire province.

That evidences of a northward transfer of drift are to be found in the Annapolis valley, in the occurrence there of numerous boulders derived from the South Mountain granite, is, of course, not to be denied; but, in the writer's opinion, these boulders belong only to the closing era of the Glacial Period, their northward transfer being the natural result of the higher lands, such as the South Mountains, being the last to become freed of their burden of ice, and, therefore, for a time left in the condition of *mers de glace*, from which ice streams might descend in any direction. In partial confirmation of this view it may be of interest to note, that, according to the statements of farmers occupying the Annapolis valley, the granite boulders in question are never met with at depths of more than ten or twelve feet below the present surface.

In contrast with the supposed elevations of the Glacial Period, the evidences of depression in the succeeding Champlain Period are clear and unmistakable. Not only do we find along the New Brunswick shore marine clays, as at St. John and St. Andrews, filled with Post Tertiary fossils, but similar clays and associated sands also occupy, more or less completely, the Annapolis valley, indicating a former considerably greater depth to that valley. At St. John the height of the beds above the present sea level is about 200 ft. ; in Nova Scotia the clays of Middleton, holding marine shells and Ophiurans, are not more than twenty or twenty-five feet above the tide ; but it is probable that the total submergence was much more than this, with the result of connecting Annapolis basin eastward with the Basin of Minas and westward with St. Mary's bay the North Mountains and their extension in Digby Neck being reduced to low-lying ridges and islands.

The evidences of modern subsidence in and about the Bay of Fundy, as shown by the submerged forests, eroded shell-heaps, etc., need not, of course, be here dwelt upon, but are in accordance with the movements of earlier times, and similarly point to this Bay of Fundy trough as a probable line of comparative instability in the earth's crust.

In presenting the views advocated in this paper the writer is aware of the objection which may be urged against them as being too theoretical. But the facts of observation are only of interest and value as they are brought into correlation, and used in explanation of the events or processes by which they have been determined ; and, as in every branch of scientific inquiry, the "scientific imagination," as it has been termed by Tyndall, must go hand in hand with observation and trial, he trusts that the efforts here made to discuss some of the probable phases in the development of an important portion of the continent may at least be suggestive of further lines of inquiry.



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