ART. VI.—*Preliminary Report on the Geology of the Cobscook Bay District, Maine;* by N. S. SHALER.

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PRELIMINARY NOTE.

THE following report gives a portion of the general results of two months exploring work on the shore line of the waters of Cobscook Bay during the summer of 1884. Some previous studies in this district had shown me that it afforded a very interesting field for enquiry and that it would probably furnish data of importance to the general theory of the New England coast geology. I believe the facts set forth in the following pages will justify this opinion, and moreover will show that this field contains a more interesting assemblage of phenomena than can be found on any other part of the eastern seaboard of the United States.

The United States Coast Survey has not yet mapped this district; there is indeed no chart in existence which shows with any approach to accuracy the shore line of these waters. The sketch map accompanying this report was compiled in the main from the British admiralty chart, with some additions from observations made during my summer work. This admiralty map is extremely imperfect, many minor bays, which have no value to the navigator are entirely omitted. At least ten miles of the shore line being unrepresented on that chart.

Owing to this lack of a satisfactory basis on which to record the geology of the district it has been necessary to make this report in a preliminary form. Within two years the Coast Survey topographical parties will have entered on this field and in a few years thereafter it is probable that the shore line will be so far delineated that the geological facts described generally in the following pages though left unindicated on the map, can be properly set forth.

Although, as I have recently learned, some of the fossils at Shackford head have found their way into cabinets and the fossils near Dennyville have been collected by Dr. John Shehan, a student of the geology of that neighborhood, I am not aware that there has been anything published concerning them. The collections which I made, though affording about one hundred species of fossils in a fair state of preservation, can be greatly increased by further research. It has therefore not seemed advisable to undertake a careful determination of the specimens in hand. The species have been identified only so far as was necessary to secure an approximate determination of the age of the more important fossiliferous sections.

The portion of the report which concerns the glacial and surface geology and also that describing the metalliferous veins of this district is omitted in this memoir and will be published elsewhere.

Topography of the Cobscook District.

The topography of any district is the key to its geological structure. This is especially the case with an ocean shore, for there the action of the waves and tides removes the detrital materials which often obscure the bed rocks of inland districts. A reference to a general map of the eastern coast line of the United States will show that this shore from New York northward has the general topographical form proper to the fjord zone or glaciated shore line of high latitudes.

The shore is intersected by deep inlets which extend far into the land. Although these inlets have been to a considerable extent effaced by the formation of salt marshes and other deposits they are still a very conspicuous feature of this district, separating it widely from other coast lines where glaciation has not worked in moulding the land. As will appear from the evidence hereafter to be advanced in this report, the fjord structure, at least along this shore, is the result of the glacial wearing, acting upon a surface of rock of varied hardness.

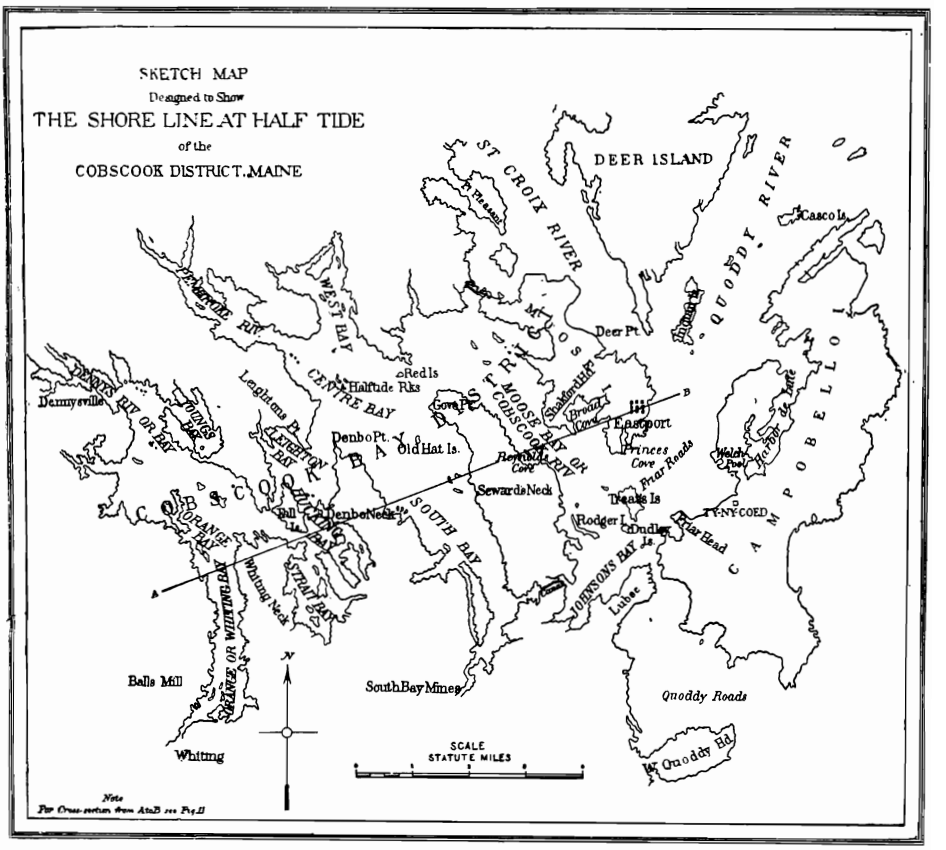
Within this glacial or fjord zone of the Eastern United States we may notice several distinct varieties in the shape and character of these inlets. Along the shore north of Long Island Sound and as far east as Cape Cod the inlets are relatively far apart; their mouths are separated from each other by considerable lengths of tolerably straight shore line. Along this southern shore of New England the axes of the inlets lie nearly in the north and south line. The inlets themselves have few islands in their basins, and are in most cases relatively narrow.

From Cape Cod to Cape Elizabeth, the inlets or fjords are fewer in number and have a general east and west trend; islands are rare and, when existing, are usually composed of drift materials. The relative rarity of inlets on this part of the coast is doubtless to be attributed to the general north and south trend of this part of the shore; its trend being approximately parallel to the direction in which the glacial ice moved.

East of Cape Elizabeth the shore trends in a direction nearly at right angles to the course in which glacier flowed. Here the fjord structure is seen in its fullest development: all of the shore line is in fact made up of these inlets. The extent of the indentation may be the better appreciated by the fact that while the direct line from Cape Elizabeth to Eastport is only

about two hundred miles in length, the length of the shore line, between those points, at high tide, including the coast line of the adjacent islands, probably exceeds three thousand miles.

Along this coast region of Maine we find a considerable variety in the type of fjord structure. About Portland, within the district of Casco Bay, there are no deep inlets but a profusion of small islands. From that bay to the Penobscot the strip-like fjord type of shore, narrow bays with equally narrow promontories, is the prevailing feature. At Mt. Desert the massive crystalline rocks of that region cause the coast to change its character; the bays or inlets become wider and there is an extensive fringe of islands south of the main shore.



The normal type of fjords is again found on the shore from Mt. Desert to Quoddy Head; this section differing in no important topographical respect from that between Portland and the Penobscot.

Cobscook Bay, which is a branch of Passamaquoddy Bay lying north of Quoddy Head, differs from all the other fjord systems of the United States coast in certain important features. As will be seen from the sketch map the system of fjords known by the general name of Cobscook Bay have a curiously embayed nature; all the other similarly extensive fjords of this coast communicate directly with the sea by their southern extremities, but in Cobscook Bay there are many inlets of considerable length which discharge their waters through east and west channels into each other and into the waters of Passamaquoddy Bay. It will be seen that this system of bays has three main divisions to which I have given the provisional names of Moose Bay, Center Bay and Orange Bay. This innovation in the way of names is made necessary by the fact that there are no accepted designations for these divisions though they have great topographical importance.

The general trend of these bays differs considerably from that of the other inlets of the coast. The Cobscook bays have a general northwest and southeast axis, while the other bays of this region are usually inclined a little to the east of north and west of south. In fact the Cobscook system of bays is the only system of inlets on this coast where the major axes of the basins so closely coincide with the direction of the glacial movement.

The system of bays has the further peculiarity that their borders are remarkably intersected by smaller indentations; the whole forming one of the most complicated shore lines in the world.

These peculiarities of outline indicate local differences in the bed rocks on which the glacial sheet has acted. They are sufficiently accented to make it clear to anyone who has had a little training in the interpretation of topography, that this district is occupied by rocks having a different character from those that form the other portions of the New England coast. It was indeed these peculiarities of outline that led me to begin my detailed study of the New England coast at this point. It seemed clear that there must be some important geological causes for the abnormal geography. As will be seen in the sequel this opinion has been amply justified by the results obtained.

Geology of the bed rocks of the Cobscook district.

The geology of the bed rocks of this district presents certain remarkable peculiarities. Those rocks consist of a very thick series of stratified deposits of Paleozoic and perhaps Azoic age intermingled with numerous sheets of igneous rocks which are partly intruded and partly interbedded deposits, the latter in

the main apparently composed of true lavas but at certain points evidently composed of fragmental volcanic rock in the form of ash beds and breccias. In their composition, in their attitude and in their fossil contents they present many eminent peculiarities.

In the absence of any sufficient topographical survey of the district it has not been found possible to prepare a geological map which will represent even the more important features of this structure.

The following account is intended only to present the more general facts which were determinable by a preliminary inspection of the ground.

The first point that strikes the observer is that the exposures of rocks of Silurian and Devonian age which are shown in the Cobscook district, i. e. the region lying to the east of Moose Island, have nearly uniformly eastern dips. The following table of these dips will show that in localities fairly representing about one hundred miles of shore line in the Cobscook series of bays, there is very little departure from this uniform direction. It is also evident that the amount of this dip is not great and is very regular; it rarely rises above 60° and rarely falls below 20° of inclination. The few instances in which the dip of the rocks departs decidedly from the general easterly direction may be explained by local accident and do not indicate any general change in the direction of the dip. It should be said that the dips given in the table represent about the average of over two hundred observations from which the selection was made.

Selected list of dips observed in Cobscook Bay.

Locality.	Strike.	Dip.
McMaster's Island	N. 45° E.	S.E. 10–60°
Eastport Island, W. side	N. 45 W.	N.E. 60.
" " " "	N. 60 E.	N.W. 20.
Reynolds Cove	N.	E. 20–30.
Pembroke River	N. 10 W.	N.E. 30.
Pembroke Neck, W. side	N.	E. 20–30.
" " E. "	N. 125 E.	S. 17.
" " " "	N. 110 E.	S.E. 10.
Dudley Island	N.	E. 50–60.
Pembroke River	N. 45 W.	N.E. 55.
" "	N. 45	N.E. 45.
" "	N. 130 E.	S.E. 30.
South of Seward's neck canal	N.E. to N.W.	E. 10–30.
South Bay	N. 50 E.	E. 30–40.
" "	N. 45 W.	E. 15–25.
Straight Bay	N. 40 W.	E. 35.
" "	N. 40 W.	E. 35.

Locality.	Strike.	Dip.
Near Dennysville	N.W.	E. 15–30°
Near Denbo Point	N. 10 W.	E. 42.
" " "	N.	E. 45.
" Bay	N. 15 W.	E. 10–30.
" "	N.W.	E. 22.
" "	N. 90 E.	S. 15–30.
" "	N.	E. 35.
" "	N.	E. 20–35.
" "	N.	E. 32.
" "	N.	E. 25–30.
" "	N. 40 E.	E. 40.
Pembroke River	E. & W.	N. 20–30.
" "	N. 45 E.	S.E. 20–40.
" "	N.	E. 20.
Johnston's Bay	N.	E. 30–50.
Shore	N. 45 W.	E. 30–50.
Fall Island	N. 45 W.	E. 28.
Orange Bay	N.	E. 50.
" "	N. 30 W.	E. 20.
" "	N.	E. 30–40.

At many points the igneous rocks which seem to be interbedded among the stratified deposits may be seen in what appear to be massive strata, often a hundred feet or more in thickness, having the same general dip as the rocks between which they lie. At no points are the upper and lower contacts of these igneous masses and the stratified beds clearly enough seen, or at least well enough studied, to make it possible to determine the question whether they were injected between the beds or were contemporaneous deposits.

The igneous rocks of this district may be divided into three classes: 1st. Detrital igneous rocks, those which are composed of fragmentary materials which have fallen through the air. 2d. What seem to be true lavas, i. e. those which have flowed over the superficial rocks. 3d. Dykes which traverse, strike or penetrate between previously existing beds of sedimentary or igneous origin.

1.

Diagramatic section of shore 1½ miles N.W. of Red Island. Length 300 ft. A, greenish diorite. B, greenish and gray flags and slates, with obscure fossils. C, high tide line.

The distinctly fragmental deposits, volcanic ashes in general character, are most abundantly exhibited in that part of Cobscook Bay which forms the channel immediately to the west-

ward of Moose or Eastport Island. This series of ash beds covers a considerable area; in this part of the district the beds have the average dip of the rocks in the region and though their upper and lower contacts with the series of fossil-bearing beds is not well determined there can be little doubt that they are a constituent member of the Paleozoic section.

The best exhibition of these volcanic ash deposits is at McMaster's Island, a small peninsula about midway of the western side of Moose Island. This little island, of only a few acres in area, is almost altogether composed of beds of a fragmental nature. At first sight and from a little distance these beds closely resemble coarse gravel and conglomerates; but, on closer inspection they are seen to be made of fragments mostly angular, which though lying in regular beds have their major axis at all angles to the horizon; moreover, the larger bits which exceed a foot in diameter have evidently fallen with a certain violence into their places as is shown by their crushed form. All these fragments seem to be composed of volcanic or crystalline rocks, among them are many bits of pumiceous material which is rarely so vesicular as to deserve the name of pumice but distinctly related to that class of volcanic products. The evidence derived from the section at McMaster's Island and from the other exposures in the vicinity show that the set of volcanic beds exceeds five hundred feet in thickness and may be far thicker. It is likely from the width of its glacial trail in the region to the southward that this series of rocks occupies a good deal of the space of the channel known as Moose river.

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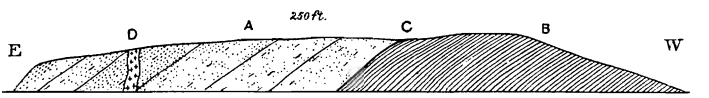


West side of Moose Island near N. end.

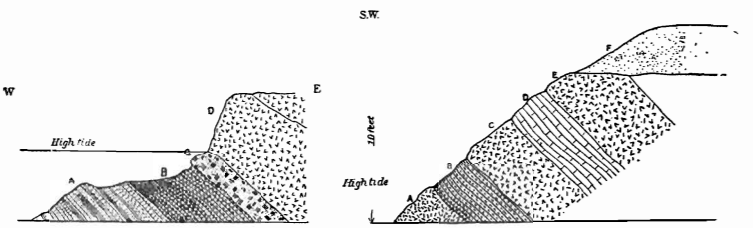
A, greenish ash beds. B, green siliceous flags. C, contact—obscure—apparently overlie. D, red felsite dyke 20 ft. wide.

The evidence goes to show that this series of McMaster's Island was formed some time before the Hamilton period. It seems clearly overlaid by the extensive series of the Shackford Head group and the equivalent beds of the Princes Cove section, while its base appears to rest upon the rocks which are probably of Silurian age.

There are some other points in the Cobscook section whose rocks of the same general structure as those of McMaster's Island are exhibited. The other exposures may or may not be of the same age as those before described. They probably represent several stages of volcanic eruption at various periods in the Silurian age.

It appears from the distribution of these contemporaneous deposits of volcanic nature that the center of eruption was to the northeastward of this district and that the intensity of its effects diminished toward the southwest. There is some reason to believe that this field of volcanic material is the

3. 4.



Sections on Deny's River.

Fig. 3.—A, stratified volcanic ash. B, dark colored shales. C, ash beds as before. D, fragmental trap.

Fig. 4.—A, volcanic breccia. B, shales. C, felsite. D, indurated sandstone. E, banded felsite. F, drift.

extension of the ash-bed district which is known to occur near St. Johns, New Brunswick. The preliminary study of this Cobscook district has sufficed to show that in about this same horizon there are very extensive sheets of lava which were possibly surface flows, though afterwards buried beneath subsequently formed deposits. Of these the most important is a great mass of reddish felsite which occupies a wide field in the northern part of Moose Island and probably extends beneath the bays in this neighborhood. Besides this extensive sheet there is another, of the same general character, seen in the hill crowned by the old earthwork fort near the middle of Moose Island. The latter sheet of felsite is apparently interbedded in slates of Silurian age.

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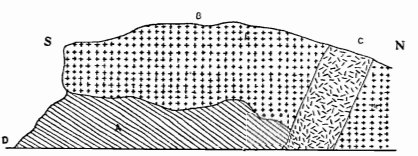

Section on shore N. of Red Island.

A, gray slabs and flags. B, greenish diorite. C, red felsite. D, high tide mark.

The felsites of this region also appear in dykes having a general north and south trend, which traverse all the other formations of this district; being perhaps the latest intrusions

which have taken place. These dykes are most extensively developed in the northern part of the Cobscook district, especially in the area about McMaster's Island and in the region to the westward as far as Deny's River. The felsites are, as is well known, found in the region about Lynn in Massachusetts. The Cobscook felsites do not however exhibit the same distinct flow lines as those from the more southern localities. They have not been observed in the clearly banded or ribboned form which they often exhibit in the region near Boston.

Besides these extensive extrusions of lavas belonging to the group of felsite porphyries, there is a larger series of other dyke stones and sheet lavas which exhibit a very great variety of appearance. Some of them are of a blackish, slaggy aspect, showing a tolerably distinct bedding, which seems to arise from successive flows. The best exhibition of these slaggy lavas is at the cape known locally as Denbo Point, the extremity of which is formed by them.

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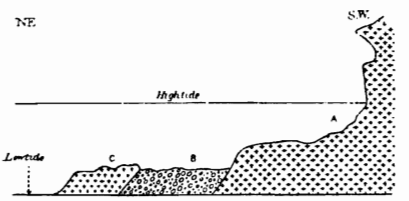


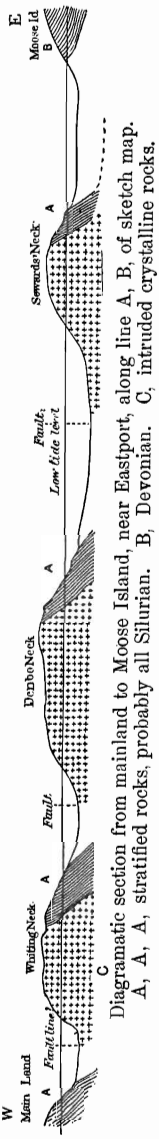
1½ miles south of Denbo Point.

A, greenish mottled trap. B, metamorphosed conglomerate. C, greenish amygdaloidal trap.

Besides the above mentioned lavas there are many other varieties of igneous rocks found in this district which are not classifiable by ordinary microscopic characters. These resemble in their general aspect the ordinary dykes of eastern New England. The classification of all these volcanic products must be left until they can be submitted to a careful lithological study.

The rocks of Silurian age are so cut up by these various intrusions that not more than one-third of the whole land area intersected by the arms of Cobscook Bay, is occupied by these strata. It seems likely that the sedimentary Paleozoic strata are extensively developed beneath the surface of the bays, the intervening ridges of land being occupied in the main by the harder volcanic rocks. That this is the case, is well shown by the fact that the stratified Paleozoic rocks are generally found as a fringe along the shores of the long, narrow capes which divide this bay into many inlets. These Paleozoic rocks are

clearly less resisting to the glacial action than those of igneous origin; they are not only softer, but their thin-bedded and much-jointed condition caused them to break up under the action of the ice or waves much more readily than the compact igneous deposits.



7. Diagramatic section from mainland to Moose Island, near Eastport, along line A, B, of sketch map. A, A, A, stratified rocks, probably all Silurian. B, Devonian. C, intruded crystalline rocks.

The greater part of these sedimentary rocks of the Cobscook series consist of very fine grained sandstones, and dark blue and blackish shales, which at certain points contain a good deal of lime, but rarely are pure limestones. At only two or three points are these beds sufficiently calcareous to be used in making commercial lime, and even at the best of these points, as in the beds exposed in Reynolds Cove, an effort to use them for lime failed, for the reason that in the greater part of the rock there was so much silex that it was apt to melt in the kiln. The siliceous element in the rock is larger than in any equally extensive section of these horizons known to me in this country, though at few points does it consist of pebbly matter; the only important exception being in certain conglomerates of a reddish color, apparently belonging to about the horizon of the Medina sandstone. These beds have so far been found only in or near the basin known as Mine Cove, an inlet near the head of great South Bay of Cobscook Bay. At many other points there are strata which contain small scattered fragments of hypogene rocks, presumably volcanic in their origin. These are particularly well shown in the extensive limestone section exposed at the head of Denbo Bay, the shallow fjord lying to the west of Leighton's Point.

The fossiliferous rocks of the Cobscook district are mostly thin-bedded, even the impure limestones, though sometimes appearing in massive form, being on the whole distinctly divided into strata of no great thickness. The general absence of detrital material derived from the land, as well as the nature of the organic contents of these rocks of the Cobscook series, favor the hypothesis that they were formed at some distance from the shore. It is generally

believed that the deep sea deposits have more continuity of structure, i. e., are less divided into layers, than those found near the shore. This is probably the case with the strata formed in many parts of the sea; still we know that the Devonian black

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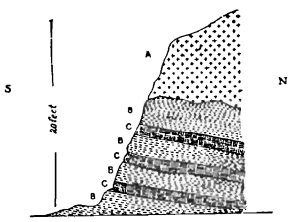

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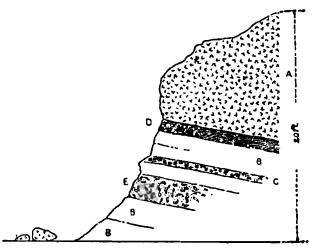

Fig. 8.—Section on Pembroke River, Cobscook Bay. A, massive trap 30 ft. thick. B, B, B, sandstones and shales. C, C, C, thin ash beds.

Fig. 9—Section 3 miles N.W. of Red Island. A, massive trap. B, B, red sandstone and shale. C, breccia, probably volcanic. D, irregular ash bed. E, vermiform concretions in sandstone (Scolithus tubes).

shales of the Ohio Valley termed in the Kentucky reports the Ohio shale, have a remarkable amount of stratification planes, though they were certainly formed in deep water in a position remote from the shore. We also know that any such disturbance as would be produced in the deep seas by an earthquake shock, would certainly cause a movement of the mud of the sea floor, thereby bringing about the formation of a stratification plane in the deposit. As this region was much subjected to volcanic action at the period when these sediments were depositing, we may well believe that earthquakes were common in this portion of the sea floor.

The great preponderance of siliceous and shaly beds and the remarkable absence of limestones in this district is a noteworthy feature. It is probably due in the main to the singular absence of corals and the infrequency of brachiopods and crinoids, which groups were the principal lime producers of the Paleozoic seas.

All the evidence goes to show that these rocks of the Cobscook series were in the main formed in water of moderate depth under circumstances, which, owing to some causes, were not very favorable to the development of organic life. In the latter regard this district is in striking contrast with the basin of the St. Lawrence, where during the same periods the seas contained a singularly abundant life, as is shown by the Upper Silurian deposits of the Island of Anticosti. I venture to suggest, as a possible cause of this peculiarity, the fact, that this

portion of the old sea, in which the fossils of the Cobscook section lived, was on the northeastern face of the old Appalachian Island, and thus by their position were cut off from the warm current which flowed from the southwest against the ancient shores of Central New York. This same life-giving current of warm water may have found its way along the western shores of the Appalachian island to the region of the St. Lawrence.

The action of the mountain-building forces on these sedimentary deposits of Cobscook Bay has been great but extremely peculiar in its effects. Everywhere within the field of my enquiry there are evidences of much pressure, except perhaps in the southern part of Whiting or Orange Bay; that the rocks have been subjected to strong compressive action, is shown by the general distortion of the fossils. This distortion is very general; it is doubtful if in any part of the basin the rocks have entirely escaped it. The amount of the distortion varies from an elongation which does not exceed one-twelfth of the diameter to a very extreme condition, where it is as much as one-half the diameter of the distorted object, i. e. where a circle of an inch in diameter lying in the plane of the movement would be changed to an ellipse having a length of an inch and a half. Possibly one of the results of this compression is the singularly close adhesion of the fossils and the matrix. In the many thousand specimens of fossils observed, none were found fairly separated from the rock in which they were preserved. The pressure seems to have welded the walls of the fossil to the matrix in a very perfect manner.

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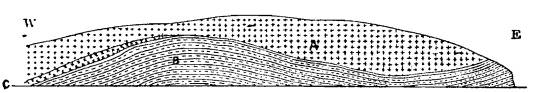

Shales and trap south end of Shakford Head.
A, overlying trap. B, dark colored shales. C, intrusive trap.

The most curious feature in the attitudes of these rocks is, that few of their dislocations take the form of folds, only three examples of folding meet the eye, in the hundred and fifty miles of cliffs inspected. (These exceptional folds are shown in figs. 10, 11 and 12.) In nearly all cases the dislocations were effected by a system of principal faults extending in a general north-northeast and south-southwest direction, cut more or less nearly at right angles by less important transverse fractures.

So far none of these fractures, except in a few unimportant cases, have been observed in the form of simple faults; they seem in nearly all cases to have been made the pathway for extrusions of igneous matter thrown out at the time when the

faulting occurred. This fact seems to indicate that the source of supply of this volcanic material was very near the level of the rocks, so that no fissure of any size could form without giving exit to igneous matter. This may perhaps be explained by the

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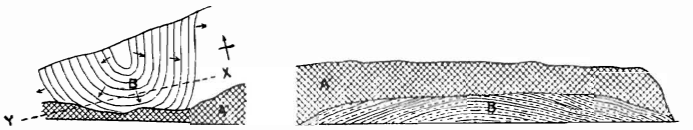


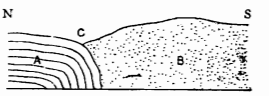
Horizontal and vertical section of small fold on shore 2½ miles N.W. of Red Island.

A, A, trappean rocks. B, B, reddish and greenish shales. X—Y, line of section 200 ft. long.

fact that the rocks of this region were very near the seat of extensive and long continued volcanic action which naturally led to the formation of a very large supply of rock matter in the state to be forced into every crevice which penetrated to it.

The almost invariable dip toward the east and southeast exhibited by the masses of stratified rocks in this district is a very remarkable feature in its structure, one for which I have no explanation to offer.

12.



Near N.W. end of Moose Island.

A, hard flaggy slates. B, volcanic ash. C, slickensided contact.

Extending our observations beyond the shores of Cobscook Bay, we find in the shores of Passamaquoddy Bay a considerable change of structure. The islands of Campobello and Deer Island have the general structure of anticlinals, the basin between them, known as Quoddy river, being distinctly synclinal in structure. These islands are in the main composed of a series of very compact and highly metamorphosed, non-fossiliferous schists, slates, and quartzites considerably cut by dykes, which in the main apparently belong to an older series of extrusions than those which intersect the fossiliferous rocks. These rocks, which for convenience may be termed the Campobello series, are clearly several thousand feet in thickness. They have disclosed no fossils, although a careful search has been made for them. An assistant of the present writer, Mr. G. H. Squier, a very acute observer, spent several months in a detailed study of the geology of the island of Campobello without finding the least trace of fossils in the abundantly exposed beds. The entire absence of limestones, or beds of a calcareous nature, is sufficient to show that they cannot be regarded as the metamorphosed equivalents of the Cobscook series. The general absence of lime from this Campobello series is

shown by the fact that there is very little calcareous matter in the numerous veins which are found in the rocks of this series.

13.

Ideal section through Deer Island anticlinal.

A, A, Campobello series. B, B, sandstones and conglomerates: Perry series?

It will be observed from the diagramatic section showing the general geological character of Campobello and Deer Island, that they are only obscurely anticlinal in structure; being, in fact, rather complicated upheavals of intermingled stratified rocks and igneous intrusions. After they had been elevated above the sea and much eroded an extensive series of sandstones and comglomerates, which are essentially like the ordinary rocks of the Perry section were deposited upon their flanks, or possibly over the whole of the Deer Island. A further development of these axes, together with much subsequent erosion, has caused the Perry beds to appear only in the downfold between these two anticlinals.

If the Cobscook series existed on the flanks of Deer Island and Campobello, as was almost certainly the case, its beds had been eroded before the Perry series of conglomerates was laid down.

It will require much further study to unravel the succession of upheavals and subsidences which have taken place during the deposition of these rocks. There is, however, the promise of abundant reward for this enquiry, for it may throw very important light upon the history of the development of this continent.

As yet the Campobello series has not been identified in place immediately below the Cobscook series. But at various points it is seen in positions which make it a fair inference that it underlies the whole of this district. On the cape known as Quoddy Head the Campobello series is well shown in a highly metamorphosed condition. This series is traceable for three miles to the westward; indications of it were found in the region to the west of Denys River with dips which would take it beneath the Cobscook series.

In the further search along this coast for the beds of the Cobscook series, it will be well for the observer to bear in mind the fact that the Cobscook series probably lies immediately upon the more ancient beds of the Campobello series. The series of rocks exposed on Campobello is probably well developed along the coast of Maine. Rocks essentially simi-

lar in appearance to those on Campobello abound about Frenchman's Bay, and at other points to the westward. Wherever these rocks occur it seems to me there is reason to hope for some traces of the overlying Cobscook series.

One of the most difficult problems in the section is to determine the relations of the Perry series of sandstones and conglomerates to that of Cobscook Bay; at no point as yet has the former series been found in contact with the latter. But in the valley of Sipps Bay we find a series of red shales and sandstones, which has a thickness of over fifteen hundred feet, and probably belongs to the Perry series. These beds have the same general dip as those of the Cobscook series, where the latter series is shown about a mile farther to the south. It is likely that a careful search in this part of the field may reveal a contact of these two sets of beds.

On the mainland just north of Moose Island, and thence up to the town of Perry, similar sandstone and conglomerate beds are shown, with a strike which would place them above the beds of the Cobscook series of that island. But in this Perry district the section of red shales and sandstones lies apparently on the denuded edges of the granitic and syenitic rocks which form a yet lower series than those which furnish the floor of the red conglomerates and shales of Deer Island. That is to say, while the Perry series of Deer Island lies on the old slates of the Campobello series, in the more northern exhibition of the beds they are directly on the rocks of presumably Laurentian age. The Perry series of rocks appears to be much less cut up by dykes than the underlying Cobscook series; no intrusions of igneous matter were observed in the outcrops which were studied. This makes it probable that the time of most intense volcanic action had passed away before the Perry series was deposited.

Thus this district seems to contain the following more or less well indicated series of stratified rocks. At the base a series whose thickness is unknown, consisting of gneissoid syenitic and granitic rocks and some mica schists; of this series little is known: it is the prevailing series of crystalline rocks along the coast of Maine, and is probably of Laurentian age.

Above these series lies a second which for convenience we have termed the Campobello group, comprising a set of dark greenish and grayish siliceous and argillaceous rocks containing very little lime.

This Campobello series has a thickness of at least four thousand feet and may be thicker; the rocks appear to be entirely destitute of fossils though they are not so much metamorphosed as necessarily to lose by this change all trace of fossils if they had once contained them. This section may be equivalent to

the slates of the Cambridge district in Massachusetts, and generally of the Cambrian slates about Boston, which they resemble in a general way, especially in the remarkable absence of lime in their composition. This Campobello series probably rests immediately on the subjacent older series of Laurentian age, and may represent the lower Cambrian section, but the phenomena of contact with the underlying beds are unknown. Above these Cambrian layers, and without observed contacts with them but with scant place for any intermediate deposits, lie the beds of the Cobscook series. This series has a thickness in all of not less than four thousand feet, and on careful study may be found to have much more than this depth. Although the contact between this series and the Campobello group is not known, the facts justify us in saying that an extensive elevation and erosion of the last named deposits took place before the deposition of the Cobscook series was begun or after they were formed, for they were not present on the Deer Island anticlinal or on the banks of the St. Croix river, where the Perry series was laid down. The presumption is that they were originally in place on these surfaces, but were worn away during the interval between the close of the Cobscook series and the formation of the Perry beds.

Last in this succession of deposits we have the coarse red sandstones, conglomerates and reddish shales of the Perry series. This deposit is certainly over two thousand feet in thickness. It differs very widely from those which occupy a lower level in this district; nearly all the other deposits seen are mainly if not entirely made up of materials such as may be laid down in a tolerably deep sea. The Perry section was clearly formed in shallow water in immediate proximity to the land.

If the lower part of the section at Perry should turn out to be upper Devonian or Sub-carboniferous, as seems not improbable, then the evidence will be to the effect that a period of erosion occurred in the interval between the close of the middle Devonian section and the formation of the Perry beds. This is especially interesting, as it would seem to show that this portion of the continent was above the sea during a part of the Devonian, or of the Sub-carboniferous period. Moreover, the character of the sediments which formed the Perry series favors this view. Those are clearly materials which were derived from neighboring lands. If we could assume with Sir A. C. Ramsay that all such red sandstones as are found in the Perry section were formed in fresh or brackish water, then this series would perhaps indicate a time when the shore line was at or near its present position. This view is rendered quite probable by the fact that the Perry beds have yielded a certain number of land

plants, and so far has furnished no trace of fossils which could have been formed in marine deposits. I do not propose at present to consider the age of the Perry series, as the problem is one of peculiar difficulty and requires a much more extended study than I have been able to give to it.

We shall see in the subjoined account of the fossils from several horizons of the Cobscook series that what appear to be the uppermost beds of that series contain an assemblage of forms which belong in the Devonian section. These fossils are in a very thick section of blackish slates resembling in certain features the Devonian black shales of the Mississippi valley and the basin of the great lakes. These beds, like their presumed western equivalents, probably were deposited in the waters of a deep sea at a considerable distance from the main land, yet in a time that cannot be very far separated from these Moose Island shales, as I have termed the black shales of this series. The Perry sandstones were deposited in conditions that show that they were made on the mainland or in an estuary basin. Thus the elevation which followed the deep subsidence occurring in the time of the Moose Island black shale, appears to have brought this part of the continent above the sea level, while in the Ohio basin it only served to shallow the water and bring the shore nearer than it was before.*

Although these conclusions as to the divisions of the rocks in the regions near Eastport must be subject to review after a more thorough knowledge of this district is attained, they are sufficient to show that the oscillation of levels of this district and the data attainable from the composition of the sediment, will afford some important clues to the geological history of the continent. It should be said that these divisions of the rocks in and about the Cobscook district are presented with much hesitancy; although it may be found in the end to be extremely imperfect, it will at least serve as a basis on which to build a more critical study of the rocks of this region.

Fossiliferous Horizons of the Cobscook series.

We turn now to the problems connected with the stratigraphic equivalency of the various divisions of the Cobscook series. It has also been noticed that the very great amount of igneous injections and the extensive erosion to which this district has been subjected has made it very difficult to determine the stratigraphical relations of the fragmentary sections which remain. This problem is still further complicated by the difficulty which is found in using the fossils contained in the rocks

* It may be incidentally suggested that the conglomerates and sandstones of the Perry series should be compared with the deposits of the Catskill period of the Hudson district.

as data for the identification of their age. Of the hundred or so species of fossils which have already been approximately determined, the greater part are either distinctly unlike those obtained elsewhere, or belong to forms which have a wide vertical range in the rocks of other districts. A number of the most interesting forms are so far novel that they offer no evidence of value as to the age of the beds in which they occur. Moreover, judging from the other known deposits of middle Paleozoic age on the Atlantic slope, those of Newfoundland, New Brunswick, and Nova Scotia, the typical divisions of the New York section or of the Mississippi valley, do not retain their limits on the eastern shore of the continent. The Silurian deposit of Anticosti cannot be precisely paralleled with those of the interior basin and much the same lack of definite relation to the western section is found in all the horizons which are represented on the Atlantic coast basins. This difficulty is one which might fairly be expected. The faunal divisions in contemporaneous strata of the Paleozoic rock though less clearly marked were hardly less numerous than those of the present day, i. e., the faunal areas whether determined by the difference between deep sea and shallow water, or by the difference between the sides of a barrier such as separated the Paleozoic deposits of the continental basin from the Atlantic coast were as numerous as those in the existing seas.

Although these divisions were nearly as distinct in the Paleozoic era as found at the present time, there was, it is true, no such delimitation of zoological or botanical provinces as at present; no such difference as those which now separate the Australian from the American province existed in the Paleozoic time, but the lesser differences of faunal divisions, though not so much accented, were something like as numerous as at present. It is therefore by no means surprising that we find difficulty in determining the relations between the deposits of the Cobscook series and those of the typical western series of the continent.

The Cobscook series presents us with the several sets of beds which in their physical characters and their organic contents seem to indicate separate horizons. By far the richest horizon yet found in this series is that which is shown on the west side of Orange or Whiting Bay about half a mile south of Ball's Mill. At this point the fossiliferous strata are seen with a thickness of about twenty feet. On the west they are cut off by an extensive series of dykes and in the east they dip below the level of the bay.

These beds are only exposed below high tide mark which fact made collecting in the few hours on two days when the

locality was visited, very difficult. The rock is a very dense, much jointed, siliceous limestone; the fossils are less distorted than any others yet found in this basin. They appear on the fracture faces of the rock with great clearness of outline and are extremely abundant. From about five hundred pounds of material selected from the upper ten feet of this section, careful dissection with hammer and chisel developed the fifty or more species from which the position of the group has been preliminarily determined. It is probable from the results obtained that at least one hundred species may be obtained from this point. The next most important locality which is as a horizon to be separated from the Orange Bay section is that exposed in Denbo or Leighton's Bay, about two miles to the northwest of Denbo Point.

This locality exhibits at least two hundred feet of shales and impure limestones. These beds are barren of fossils in the lower parts, but in the upper hundred feet contain about thirty species of fairly well preserved fossils. At this point the beds are much distorted, the fossils having an average elongation of one-fourth their original measurements. The strata are much softer and thinner bedded than those of the preceding section, to which is perhaps due their greater distortion from pressure. None of the species from this and the preceding locality are precisely identical, though there are certain species common to the two localities which are closely allied to each other.

The third locality which gives hopes that it may prove the basis for a separate horizon is that shown about one mile northeast of Dennysville. As yet this locality has been imperfectly studied: the beds appear some distance below the water line in very solid ledges which will require a considerable use of powder before they will freely yield their fossil contents. The small amount of material gathered seems to indicate that the deposits are closely related to those of the Orange Bay section, but probably represent a separate and inferior horizon.

On the eastern shore of Seward's Neck near the north end of Roger Island, and again at Reynolds' Cove, there are considerable exposures of compact, thick-bedded limestone which distinctly differ in their general aspect from the other horizons of the series; there are only a few species of fossils in this section and these are very imperfectly preserved.

On the Denbo shore, i. e., the western shore of Great South Bay at about one and one-half miles south of Denbo Point, there is a locality exhibiting very massive beds of limestone having a rich brachiopodal fauna. The contained fossils have been very much modified by pressure, being very greatly extended in the northeast and southwest axes. The outcrop of these strata consist of singularly smooth "roches moutonées," from which

only small quantities of the rock could be detached. The fossils promise to afford a series very nearly connected with those in Leighton's Bay and probably of the same age but representing a different association of fossils. On the west shore of Straight Bay there is another set of rocks affording a section over one hundred feet in thickness containing a limited but peculiar fauna.

The last of these important sections is that exhibited on Moose Island, on which Eastport stands. This consists in a great thickness of shales of a generally dark carbonaceous look, reminding the observer, as has already been remarked, of the Devonian black shale of the Ohio valley and western New York.

The Moose Island series is rather thicker bedded than the ordinary Devonian shale; its upper part is composed of dark, siliceous flags, with occasional interbeddings of what will probably prove to be volcanic ash deposits. The section as a whole is decidedly like the Devonian black shale. The series, as far as exhibited, has a thickness of about one thousand to fifteen hundred feet, but neither its superior or inferior limits are seen.

The Orange Bay section, being that which is richest in its fossil contents may, in the determination of these various horizons advantageously be used as a datum level. If its stratigraphic position can be approximately determined, the other sections can then be grouped about it. This seems a more feasible way of approaching the problem than by trying to make separate identifications for each section in the basin.

The following list of fossils from this last named horizon, with the comments given therewith, will serve to show the data which are now in hand for determining the geological age of the beds.

List of Species.

Mollusca.

Orthoceras perstriatum.
" tenui-annulatum.
Holopea antiqua, var.
Platystoma depressum.
Platyceras lamellosum.?
" platystomum, var.
Loxonema allied to L. Fitchii.
Anatina sinuata?
Avicula allied to A. manticula.
" " A. securiformis.
" " A. communis.
Megambonia allied to M. lata.
" " M. ovata.
Spirifer modestus?
" perlammelosus.

Spirifer cyclopterus ?
" octocostatus.
Rhynchonella mutabilis.
" abrupta.
" vellicata, var.
" formosa.
Rhychonella æquivalvis, var.
Rennselæria allied to R. ovalis (doubtful)
Leptocœlia allied to L. fimbriata.
" " L. concava.
Atrypa reticularis (extremely abundant)
Orthis pedunculosa, var.
" planoconvexa, var.
Strophodonta planulata, var.
" Beckii, var.
Trematospira allied to T. Deweyi.

Articulata.

Dalmanites closely allied to D. micrurus.
Tentaculites irregularis, var.

In this and the following lists of species no revision of the generic and specific names has been attempted.

The thirty-three species of fossils which are named in the preceding list, have been in the main determined from casts of the exterior or interior, of the shells or other hard parts; this being the form in which the remains are commonly preserved in the beds of this locality. The species from the equivalent New York strata have generally been described and figured from specimens which show the substance of the hard parts. Any one who has undertaken identifications under these circumstances, must have remarked the difficulties involved in such comparisons. Despite these hindrances to complete determination, the identification may perhaps be taken as sufficiently accurate to serve the needs of the problem in hand.

There can be little doubt that these species prove the beds from which they came to be, in a general way, the equivalent to the Lower Helderberg group of New York, but it does not seem possible, at least at present, to refer the deposit to any particular division of that series of beds. It should also be noticed that there remain at least twenty species of fossils from this locality, which are as yet unidentified many of which may hereafter be found to belong to other geological horizons; moreover nothing like a complete collection of the fossils contained in the deposit has yet been secured.

Although the species given in the above list are in most cases closely related to the forms to which they have been referred, it must not, for the reason before given, be assumed

that complete specific identities have been proved; that degree of accuracy in the determination cannot be secured until much more extensive comparisons are made.

It should be noticed that there are many genera of fossils which are commonly represented in the deposits of Lower Helderberg age, which have not as yet been found in this series of rocks. So far the abundant collections have shown no Lingulas, no distinct Meristas, no Nucleospiras, no Trematospiras, no Leptænas of the *L. depressa* type and very few species of the genus Orthis. There is scarcely a trace of corals or crinoids; no Bryozoa have been found.

The next locality of importance is that near Dent's Point, at the head of what is locally known as Leighton's Cove. The physical character of the rocks differs considerably from that of the Orange Bay deposits, before described. The Leighton's Cove series consists in the main of shales generally thin-bedded and containing but little lime. About two hundred feet in thickness of beds is exposed, but of this only the upper half is fossiliferous. The fossils are well preserved, but have been subjected to a considerable distortion from pressure; the elongation being in a general northeast and southwest direction. Thirty species have been found in these beds, of which the following have been approximately determined.

List of Species.

Dalmanites limulurus. Clinton.
Beyrichia symmetrica. Niagara.
Orthoceras imbricatum.
Orthis allied to O. elegantula } as usual these two forms blend
" O. hybrida } together. Niagara.
Atrypa cuneata, var. Niagara.
Chonetes allied to C. cornuta, but much larger and with finer ridges. Clinton.
Orbicula squamiformis, var. Niagara.
Lingula oblata. Clinton.
Avicula allied to A. textilis. Lower Helderberg.
" emacerata. Niagara.
" rhomboidea. Clinton.
Modiolopsis sublatus. Niagara.
" ovatus, var. Clinton.
Orthonota curta, var. "
Cyclonema ventricosa. "
Murchisonia subulata. "

The greater part of these species are represented by abundant but poorly preserved specimens. Although the identifications are not perfectly satisfactory, they serve to show the relation of these beds to the horizons of the Clinton and

Niagara in New York. The dozen or more, less well determined forms, the names of which are not given in this list, probably belong in the same series of strata.

As the collections made at this locality came from about one hundred feet in thickness of beds and contain several thousand specimens, they may fairly be taken to represent the general nature of the life of the Clinton and Niagara epochs in the sea of this region. It is interesting to note the fact that several very important and elsewhere abundant genera and families of animals are not represented here. Not a trace of a coral and no bryozoan has been found in the collection. Crinoids are extremely rare and are represented by a few small fragments of stems. Among the Brachiopoda the Strophomenas are represented by only one obscure species, and the characteristic Strophodontas do not appear; the genus Orthis is very scantily represented. The most abundant group in number of species is that of the Lamellibranchiata.

So far not one of the species in this locality has proved to be clearly identical with those collected at the previously described locality in Orange Bay, but it is not impossible that among the undetermined forms some species common to both may be found.

The next set of beds in order of importance, which permit of approximate identification, are those which are exposed at a point about one mile northeast of Dennysville. These beds are scantily exposed in the belt below the high tide level, where they appear in the form of low glacially worn ridges. The specimens collected from this locality probably represent in a very inadequate way the fauna found in the rocks.

The total number of species collected is about twenty, of which the following are approximately identified.

List of Species.

Pleurotomaria percarinata, var. Trenton.
Atrypa nitida, var. Niagara.
" aprinis, var. Niagara.
Spirifer crispus, } not distinctly separable. Niagara.
" bilobus. }
Syringopora multicaulus? Niagara.
Heliolites spinipora. Niagara.

All the unidentified forms from the preceding locality seem to be related to Niagara species. Thus, as far as this limited evidence goes, these beds are to be taken as belonging to the Niagara limestone, or at least having a close relation to the beds of that horizon.

By far the most important section of the paleozoic series of rocks as regards its thickness or its geological significance

which is exhibited in this district is that which is found on the western side of Moose or Eastport Island. As before noted I propose to term this section the Moose Island series for the reason that the beds are most abundantly developed on that island, it being indeed doubtful if they occur elsewhere in this district. These deposits consist mainly of black and dark gray shales and slates. They are exhibited at several points along the western shore of Moose Island from north of Shackford Head to near Eastport. The total thickness of the section is not known as neither its superior nor its inferior limits are disclosed. It is evident, however, that at least one thousand or one thousand five hundred feet of beds are shown in the several exposures, or indicated as in existence between the outcrops.

The dark color and the shaly nature of these beds will remind any one familiar with the aspect of the Devonian shales of Western New York and the Ohio Valley; the deposit which has been termed the Ohio shale in the Reports of the Kentucky Survey. Although fossils abound at Shackford Head and Princess Cove, they belong to few species and are not very well preserved, having been somewhat distorted by the considerable pressure to which the beds have been subjected. The following species are fairly recognizable.

List of Species.

Modiomorpha, allied to M. subulata.
" sp. undetermined.
Murchisonia desiderata.?
Beyrichia, species not determined.
Lingula, a species not determined.
Discina, two species.

The total number of species recognizable in the large collections made at this point does not exceed ten, though the individuals amount to many thousand. Though these forms taken alone afford slender ground for identification of the deposits, still they are entirely consistent with the supposition that the series is equivalent to the Ohio shale.

It is much in favor of this view that the beds occupy a position where we might fairly expect to find the Devonian series of rocks. Thus though it is not safe to affirm that this series belongs to the Ohio shale it is undoubtedly the most reasonable supposition that can be applied to the facts.

If it should in the end be found that these beds represent the great Devonian shale it will add a new interest to that remarkable deposit: so far this series of the Ohio shale has not been clearly traced in the section east of the central Appalachian axis. If these beds at Eastport belong to the Devonian

shale it had an extension to the east which must carry it beneath the Atlantic Ocean. The exact determination of the age of these beds is one of the most interesting matters for future research afforded by the geology of the Cobscook region.

Besides the above mentioned localities where organic remains have been found there are many others, a score or more in number, scattered along the great length of shore of this region, which to my preliminary study yielded too few and altogether too imperfect fossils to make it profitable to undertake the determination of their age. It seems possible that among these beds there may be found traces of the fauna of the lower Silurian, especially of the Trenton and Hudson River groups. If these faunæ are represented at all, it is clear that they are shown in a very imperfect manner, still the search has as yet been so inadequate that much may yet reward the careful explorer. There is reason to believe that these fossil-bearing Cobscook rocks extend much farther to the west than they have yet been followed. It is also probable that they may be found considerably to the north of the points where my explorations were carried.

From the foregoing summary of my observations in this region it will be seen that it affords a large field for profitable study. It seems likely that at least three hundred species of fossils may be gathered from the localities exposed along the cliffs of the Cobscook fjord system, many of them are undescribed forms, and in all cases they depart in an interesting manner from the types found elsewhere.

The problems now are to compare these species with those from the classical localities of New York and elsewhere, so as to determine how far the horizons accepted in those regions may be recognized in the Cobscook district. This task cannot well be undertaken until the topographic representation of this district is on a satisfactory basis. Such is the complexity of the topography as well as of the geological accidents that nothing in the way of final work can be done until a good map is secured. As the parties of the United States Coast Survey expect to be working in this region in 1887 we may hope to have the basis for a good map before 1890, it may be well to postpone the delineation of the geology until that time. In the meanwhile the more important parts of the geological work, all that relates to the assimilation of the deposits to those of other districts, can be carried on.

It seems to me that it will be well to extend the search for the beds of the Cobscook series to the shore line both to the east and west of the region treated of in this preliminary report. It is not likely that they have been preserved on this portion of the shore alone. Their general character shows that

with the exception of the Perry beds they were deep sea deposits and therefore presumably covered all this part of the coast. They may fairly be expected to appear both in the southern part of New Brunswick and along the Maine shore to the westward.

It is particularly important that they should be sought for elsewhere for the reason that in the Cobscook series it is evident that not one-twentieth part of the total fossiliferous section is revealed. The greater portion is completely covered by the extruded rocks, or is buried beneath the glacial drift, or is hidden by the waters of the bay. If the beds are found elsewhere there is reason to hope that these hidden portions of the section may there be exposed to view. In this way we may hope to complete the stratigraphic as well as the paleontological series of the district.

Nearly every exposure of fossiliferous strata which occurs in this region manifestly owes its preservation from glacial and other wear, which would have eroded the beds to below the sea level or removed them altogether, to the protection afforded by the dense and erosion-resisting covering of lava which lies upon it, or has only recently been worn away. This points to the conclusion that in searching for these deposits in the neighboring parts of the coast it will be well to examine every point where stratified rocks appear beneath the cliffs of igneous rock; such being the position in which these relatively soft beds are most likely to have survived the destructive effects of glacial and marine erosion, both of which causes have acted with peculiar energy along this shore.

It should be borne in mind that these fossiliferous horizons have an especial interest from the light they may throw on the position of the shore line in past times. Therefore not only the organic remains which they contain but also the detrital matter of which the rocks are formed is of much importance. The occurrence of a conglomerate apparently of the Clinton or Niagara age in the section on the western shores of South Bay seems to show that the shore in this district was not far away during a portion of the time when the Cobscook series was forming. The general character of the pebbles in this bed indicates that the ancient shore was composed of the hypogene rocks, syenites, etc., which now constitute the principal materials exposed to erosion in this part of the continent. Again in the age of the Perry section we have evidence that the shore line was near its present position and that the rocks exposed to erosion were principally of Laurentian age. Thus it is evident that we may reasonably hope, from the study of this field, to find our way to conclusions of great value to American geology.