III.—NOTES ON THE GEOLOGY OF PRINCE EDWARD ISLAND, IN THE GULF OF ST. LAWRENCE.

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THE writer had the opportunity last summer, with Dr. B. J. Harrington as assistant, to re-examine the rock formations of Prince Edward Island, of which a notice was given in the second edition of his "*Acadian Geology*." The report of our reconnaissance, which has been published by the local government, with a map, sections, and figures of fossils, may be referred to for details; but I propose in this paper to notice a few points of general scientific interest not dwelt on in the report.

Prince Edward Island is crescentic in form, about 100 miles in length, and lies in the almost semi-circular bend formed by the southern shore of the gulf of St. Lawrence. It is one of the most populous and best cultivated portions of British America. Its surface, though low, is undulating and agreeably diversified with farm and forest, and beautiful arms of the sea. Its climate is comparatively mild and insular, and its soil of excellent quality; while the marly beds of decomposing oyster and mussel shells in its bays and creeks afford an apparently inexhaustible means of restoring the productiveness of the fields.

The prevailing formation is the Trias, which here, as in Nova Scotia and in Connecticut, is represented principally by bright red sandstone, sometimes mottled with white, and associated with occasional beds of grey and white sandstone. Subordinate to these sandstones are beds of red and mottled clay, of reddish concretionary and conglomerate limestone, sometimes dolomitic, and of reddish conglomerate with quartz pebbles and arenaceous cement. These beds undulate in low synclinals and anticlinals, having in general a north-east and south-west direction, and rise in some places to an elevation of 400 feet above the sea. They are probably about 500 feet in vertical thickness. The lower half of this thickness, which contains the limestone beds and also certain hard beds of conglomerate and concretionary calcareous sandstone, may be regarded as an equivalent of the Bunter sandstone; while the upper portion, consisting principally of soft red sandstone, with some beds of fine-grained conglomerate, may be regarded as corresponding to the Keuper.

In the little isolated spot named Hog or George Island, there occurs a limited mass of doleritic trap. It includes both the compact and vesicular variety, and the latter has its cavities filled with a white mineral, which Dr. Harrington ascertained to be Saponite. This trap, which was first noticed by Dr. Gesner in 1847, appears to be contemporaneous with the red sandstone, and is similar to that which occurs on a much larger scale in connexion with the Triassic sandstones of Nova Scotia and Connecticut.

The Triassic beds have afforded no distinct marine fossils, but in the lower beds some vegetable remains occur. One of these is a small cycadean stem presented to me by Mr. J. W. Taylor, F.G.S.,

and which I have described and figured as *Cycadoidea* (*Mantellia*) *Abequidensis*, the specific name being taken from the old Micmac appellation of Prince Edward Island—*Abequid*, "Lying in the water," Fragments were also found of coniferous wood belonging to a species of *Dadoxylon* (*Araucaroxyton*) allied to *D. Keuperianum* of Europe, and which I have named *D. Edvardianum*. The specimens of this tree, which were found by Dr. Harrington, had all been bored with minute cylindrical holes, similar to those now made by the crustacean *Limnoria terebrans*. These holes being filled with clear calcite, while the wood is of a reddish colour, give the trunks and branches the aspect at first sight of endogenous stems. Branches having the aspect of *Knorria* were also found, and obscure *Sternbergia* piths; and in some of the beds there are numerous cylindrical bodies of various sizes, perhaps stems of fucoids. These Triassic beds have also afforded the jaw of the remarkable reptile described by Dr. Leidy under the name of *Bathynathus borealis*, and which seems to have been a Dinosaur, probably allied to those which have left the gigantic trifold tracks on the red sandstone of Connecticut. We were not so fortunate as to find any additional remains of this creature.

The views which I stated in 1848, in the Journal of the Geological Society, as to the chemical nature and origin of the Triassic red sandstones of Nova Scotia, appear to be perfectly applicable to those of Prince Edward Island.¹ They appear to have been deposited in a shallow sea area, not improbably coincident with the Southern Bay of the Gulf of St. Lawrence, limited to the north by the Magdalen Islands and the banks in their vicinity, which represent an old Lower Carboniferous outcrop. Their materials were derived from the waste of red sandstones and marls of the Carboniferous, and have been thrown down with sufficient rapidity to prevent the coating of red oxide of iron from being removed by abrasion or by the chemical action of organic matter. The dolomitic character of some of the coarse limestones may either indicate the occurrence of occasional isolated basins and depositions of magnesia from sea-water,² or may have been connected with the outburst of igneous matter rich in magnesia, like the dolerite of Hog Island, near to which place the beds richest in magnesia were observed.

On the West coast of Prince Edward Island, and at Gallas Point and Governor's Island in Hillsborough Bay, the beds of the Upper Coal-formation appear rising in low anticlinals from beneath the Trias. As on the neighbouring coast of Nova Scotia, these beds scarcely differ in mineral character from those of the Trias, except in the somewhat darker colour of the red sandstones, and the greater frequency of shales, grey sandstones, and concretionary limestones. Their fossils indicate the highest zones of the Carboniferous next to the Permian, corresponding to the "Annularia" and "Fern" zones of Geinitz in Germany. The dips of these Carboniferous beds are not appreciably greater than those of the Trias resting on them, so that we have here the interesting fact of the conformable super-

¹ See also Acadian Geology, pp. 24 and 623.

² As explained by Dr. Sterry Hunt.

position of the Carboniferous on the Trias without the intervention of the Permian. This is the more remarkable, as in Nova Scotia the Triassic beds usually rest unconformably upon disturbed Carboniferous rocks. The anticlinals of the coal-fields of Nova Scotia and New Brunswick, however, flatten out very much towards the coast, and retaining the same attitude under Northumberland Strait, they present very gentle inclinations under Prince Edward Island. Hence only the higher beds of the Newer Coal-formation are seen, and the Permian age having no representative, fossils alone indicate the distinction of the Carboniferous and Triassic formations. The beds seen in Prince Edward Island thus represent only a small portion of the upper part of the Newer Coal-formation. They contain no beds of coal, though trunks of carbonized trees appear in the sandstones at Gallas Point; and judging from the arrangement observed in Nova Scotia, the upper coal-seams may be at a depth of from 500 to 2000 feet. These coal-beds nevertheless underlie the whole of Prince Edward Island, and may some day be reached.

The most abundant fossil in the Newer Coal-formation of Prince Edward Island is a coniferous tree of the genus *Dadoxylon* (*Araucaroxylon*), and which I identify with my species *D. materiarium*, which is extremely abundant in the upper sandstones of the Coal-formation of Nova Scotia. These trees are mostly silicified, but specimens also occur mineralized by carbonate of lime and per-oxide of iron, and in a carbonized condition. The cracks formed by decay in the silicified specimens are often filled with a red variety of sulphate of barium. In Nova Scotia a *Walchia* or *Araucarites* (*A. gracilis*) probably represents the foliage of this tree, and the same species occurs with it in Prince Edward Island, and also a second species of the same genus. These *Walchias* may be regarded as Permian in aspect; but it must be remembered that there is every reason to believe that the genus *Walchia* includes leafy branches of *Dadoxylon*: and the circumstance that in Europe the trunks are more characteristic of the upper coal-formation and the branches of the Permian is merely an accident of preservation.

The other fossils found in these beds are the following. Those marked with asterisks occur also in the upper coal-formation of Nova Scotia:—

- **Pecopteris arborescens*, Schlot.
- **P. rigida*, Dawson.
- **P. oreopteroides*? Brongt.
- P.* (allied to *P. Goepperti*, Brongt.)
- **Alethopteris nervosa*, Brongt.
- A. massilionis*, Lesqux.
- **Neuropteris rarinervis*, Bunbury.

- **Cordaites simplex*, Dawson.
- **Calamites Suckovii*, Brongt.
- **C. Sisti*, Brongt.
- C. gigas*, Brongt.
- C. arenaceus*? Jaeger.
- Trigonocarpum*, sp.

This may be regarded as on the whole an assemblage characteristic of the newest beds of the Upper Coal-formation. Several of the species are in Europe common to the Carboniferous and Permian; but none of them are exclusively Permian. The beds containing such fossils constitute the newest members of the Carboniferous both in Nova Scotia and in Europe.

The superficial deposits of Prince Edward Island consist of

Boulder-clay, stratified sand and gravel, and loose travelled boulders. The prevalent Post-pliocene deposit is a Boulder-clay, or in some places boulder-loam, composed of red sand and clay derived from the waste of the red sandstone. This is filled with boulders of red sandstone derived from the harder beds. They are more or less rounded, often glaciated, with striæ in the direction of their longer axis, and sometimes polished in a remarkable manner, when the softness and coarse character of the rock are considered. This polishing must have been effected by rubbing with the sand and loam in which they are embedded. These boulders are not usually large, though some were seen as much as five feet in length. The boulders in this deposit are almost universally of the native rock, and must have been produced by the grinding of ice on the outcrops of the harder beds. In the eastern and middle portion of the Island only these native rocks were seen in the clay, with the exception of pebbles of quartzite which may have been derived from the Triassic conglomerates. At Campbellton, in the western part of the Island, I observed a bed of Boulder-clay filled with boulders of metamorphic rocks similar to those of the mainland of New Brunswick.

Striæ were seen only in one place on the North-eastern coast and at another on the South-western. In the former case their direction was nearly S.W. and N.E. In the latter it was S. 70° E.

No marine remains were observed in the Boulder-clay; but at Campbellton, above the Boulder-clay already mentioned, there is a limited area occupied with beds of stratified sand and gravel, at an elevation of about fifty feet above the sea, and in one of the beds there are shells of *Tellina Grœnlandica*.

On the surface of the country, more especially in the western part of the island, there are numerous travelled boulders, sometimes of considerable size. As these do not appear *in situ* in the Boulder-clay, they may be supposed to belong to a second or newer boulder-drift similar to that which we shall find to be connected with the Saxicava sand in Canada. These boulders being of rocks foreign to Prince Edward Island, the question of their source becomes an interesting one. With reference to this, it may be stated in general terms, that the majority are Granite, Syenite, Diorite, Felsite, Porphyry, Quartzite and coarse slates, all identical in mineral character with those which occur in the metamorphic districts of Nova Scotia and New Brunswick, at distances of from 50 to 200 miles to the South and South-west; though some of them may have been derived from Cape Breton on the East. It is further to be observed that these boulders are most abundant and the evidences of denudation of the Trias greatest in that part of the Island which is opposite the deep break between the hills of Nova Scotia and New Brunswick, occupied by the Bay of Fundy, Chiegnecto Bay and the low country extending thence to Northumberland Strait, an evidence that this boulder-drift was connected with currents of water passing up this depression from the South or South-west.

Besides these boulders, however, there are others of a different character; such as Gneiss, Hornblende schist, Anorthosite and La-

bradorite rock, which must have been derived from the Laurentian rocks of Labrador and Canada, distant 250 miles or more to the Northward. These Laurentian rocks are chiefly found on the North side of the island, as if at the time of their arrival the island formed a shoal, at the North side of which the ice carrying the boulders grounded and melted away. With reference to these boulders, it is to be observed that a depression of four or five hundred feet would open a clear passage for the arctic current entering the Straits of Belle Isle to the Bay of Fundy; and that heavy ice carried by this current would then ground on Prince Edward Island, or be carried across it to the Southward. If the Laurentian boulders came in this way, their source is probably 400 miles distant in the Strait of Belle Isle. On the North shore of Prince Edward Island, except where occupied by sand dunes, the beach shows great numbers of pebbles and small boulders of Laurentian rocks. These are said by the inhabitants to be cast up by the sea or pushed up by the ice in spring. Whether they are now being drifted by ice direct from the Labrador coast, or are old drift being washed up from the bottom of the gulf, which north of the island is very shallow, does not appear. They are all much rounded by the waves, differing in this respect from the majority of the boulders found inland.

The older Boulder-clay of Prince Edward Island, with native boulders, must have been produced under circumstances of powerful ice-action, in which comparatively little transport of material from a distance occurred. If we attribute this to a glacier, then as Prince Edward Island is merely a slightly raised portion of the bottom of the Gulf of St. Lawrence, this can have been no other than a gigantic mass of ice filling the whole basin of the gulf, and without any slope to give it movement except toward the centre of this great though shallow depression. On the other hand, if we attribute the Boulder-clay to floating ice, it must have been produced at a time when numerous heavy bergs were disengaged from what of Labrador was above water, and when this was too thoroughly enveloped in snow and ice to afford many travelled stones. Farther, that this Boulder-clay is a submarine and not a subaerial deposit, seems to be rendered probable by the circumstance that many of the boulders of sandstone are so soft that they crumble immediately when exposed to the weather and frost.

The travelled boulders lying on the surface of the Boulder-clay evidently belong to a later period, when the hills of Labrador and Nova Scotia were above water, though lower than at present, and were sufficiently bare to furnish large supplies of stones to coast ice carried by the tidal currents sweeping up the coast, or by the Arctic current from the North, and deposited on the surface of Prince Edward Island, then a shallow sand-bank. The sands with sea-shells probably belonged to this period, or perhaps to the later part of it, when the land was gradually rising. Prince Edward Island thus appears to have received boulders from both sides of the gulf of St. Lawrence during the later Post-pliocene period; but the

greater number from the South side, perhaps because nearer to it. It thus furnishes a remarkable illustration of the transport of travelled stones at this period in different directions; and in the comparative absence of travelled stones in the lower Boulder-clay, it furnishes a similar illustration of the homogeneous and untravelled character of that deposit, in circumstances where the theory of floating ice serves to account for it, at least as well as that of land-ice, and in my judgment greatly better.

The modern deposits observed were extensive beds of Peat, Oyster-beds, or "mussel mud," Dunes or sand-hills, Shore Ridges or "shooting-dykes."

Of the Peat deposits examined, the most important was that of "Black bank" in Cascumpec Bay, which is reported by Dr. Harrington as having an area of nearly three millions of square yards, and an average depth of fifteen feet. It presents a steep front to the bay, the waters of which are now gradually removing it; and a little below low-water mark it has a layer of roots of trees which indicate a forest surface now under the level of the sea. Similar evidences of modern subsidence were observed in other places. At Gallas Point, for example, there is a layer of stumps five feet below high-water mark.

The common American oyster, *Ostrea Virginiana* and var. *Borealis*, occurs abundantly on the coast, and large accumulations of its shells with those of the mussel, *Mytilus edulis*, have been formed in some of the bays and river estuaries. I was informed by Mr. W. H. Pope, who has given much attention to this subject, that some of these beds are fifteen feet or more in thickness. They consist of dead shells, and in many places no living shells occur even at the surface, the animals having been killed by the gradual approach of the beds to the surface of the water, exposing them to the action of the frost and ice and to invasion of sandy sediment. These beds of dead oyster and mussel shells, with the mud filling the interstices, constitute one of the most valuable deposits on the Island. Under the name of "Mussel Mud," this material is taken up in great quantity by ingenious dredging machines, worked from rafts in summer or from the ice in winter, and is applied as a manure to the soil with the most excellent effects. It supplies lime and organic matter, besides small quantities of phosphates and alkalies.

The shells in these old beds are all of the long narrow form (*O. Virginiana*), and Mr. Pope informs me the round form (*O. borealis*) occurs at the surface in many places where the long narrow form is found only a few inches below. It also appears that the modern oysters procured in the upper parts of the rivers and on muddy bottom tend to the long form, while those in more salt water and on hard bottom are round.

"Dunes," or mounds of drifted sand, are extensively developed along the outer or north-west shore, where they extend in long lines across the bays and parallel to the coast. In all they extend in length about 45 miles, and are sometimes more than 40 feet high. Though usually held together by the roots of coarse grasses, they are liable

to frequent changes, which are much promoted by the cropping of the grass by the cattle or by any artificial or accidental breaking of the surface. At St. Peter's I saw an old entrance used in the early French times quite filled up with the blown sand; and I was told that a hill 40 feet high had been removed within a few years, and had disclosed the remains of an old blacksmith's forge under its base. The sand in these hills is derived from the waste of the red sand-stones; and, when left dry by the tide, is blown up by the wind. The attrition to which it has been subjected has removed the coating of red oxide of iron from the siliceous grains of sand, so that, though derived from red rocks, these sands are nearly white. Where the sand-hills run along the coast, a long narrow channel often occurs between them and the shore, and they often block up streams, forming lagoons, in which deposits very different from those of the open gulf are produced.

Mr. Pope kindly pointed out to us on a creek near Grand River, and on Ives Creek, the mounds known locally as "shooting-dykes," in allusion to their use by sportsmen as a shelter in duck-shooting. These are somewhat regular banks or dykes of soil fringing the creeks, and having almost the appearance of artificial earth-works, which they have indeed been supposed to be. Some of them are six feet in height and ten feet wide at base. I believe them to be of the same nature with the Lake Ridges of Nova Scotia described in my *Acadian Geology*,¹ and that they have been produced by the expansion or driftage of the ice, which forms in the creeks in winter. They constitute a sort of "Moraine" deposit, which, on a larger scale and in a more hilly country, might readily be mistaken for the work of glaciers. Those that we saw were entirely composed of soil intermixed with vegetable matter. Some of them showed evidence of formation by successive increments of material. Their steepest sides were next the land, and they were highest opposite the most exposed and widest portions of the creeks.

IV.—THE SUCCESSION OF THE CRAGS.

By ALFRED BELL.

ALL geologists, especially those who, like myself, are interested in the study of the Upper Tertiaries, are indebted to Mr. Prestwich for the valuable memoir upon "The Structure of the Crag-beds of Suffolk and Norfolk."² As the views propounded therein are somewhat novel, I purpose examining some of the points brought forward in their support.

The presence of Diestien fossils in the Suffolk Crag, and the cause of their being there, appears to me to be susceptible of a simpler explanation than has been given. Mr. Lankester considers them to be the remains of an older formation, which was broken up by the Crag Sea. This will not account for all the phenomena noticed, and I shall venture upon a few words concerning the older Pliocene deposits. Between the Falunian (Upper Miocene) and

¹ Page 35.

² Quarterly Journal Geol. Soc. London, 1870 and 1871.