

ART. XX.—*On some points in the Geology of Vermont*; by  
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It is proposed in the present communication, to state some facts with regard to the distribution of the paleozoic rocks of western Vermont, but before doing so it will be well to recall certain points in the geology of the province of Quebec. In this province, to the southeast of the St. Lawrence, there is displayed a great series of rocks to which Sir William Logan has given the name of the Quebec group. In the geology of Canada, published in 1863, this group was divided into two parts, an upper called the Sillery, and a lower the Levis formation, while some black limestones and shales occurring at the base of the latter were referred, doubtfully, to the Potsdam formation. These have, however, since been found to be paleontologically connected with the lower and fossiliferous parts of the Levis formation, as seen in the section on the island of Orleans near Quebec, the whole forming a natural division, which includes 4680 feet at Phillipsburg with the addition of the lower 1285 feet of the Orleans section, where the inferior measures of the group, seen at Phillipsburg, are not brought into view. To this portion of the Quebec group it has been found convenient to restrict the name of the Levis formation, while the succeeding part of what was at first called by that name, extending upward to the base of the Sillery, is distinguished as the Lauzon formation.

The entire thickness of the Levis, so far as known, is over 6,000 feet, and that of the Sillery about 2,000, while the Lauzon is extremely variable, ranging from a few hundred to more than 2,000 feet in thickness.

This middle division is characterized by two bands of magnesian and metalliferous rocks, one near its base, and the other at its summit. The latter band, for convenience of definition, has been united with the succeeding division or formation, and is represented on the geological map as forming the base of the Sillery. These two magnesian bands are of considerable economic importance, and contain interstratified deposits of copper, iron and chrome ores, together with dolomite, magnesite, steatite, serpentine, diorite, chloritic and epidotic rocks, associated with reddish and greenish shales and sandstones. The fauna of the upper divisions of the Quebec group is as yet limited to an *Obolella* and two species of *Lingula* in the Sillery, but the

Levis division has yielded a great number of organic forms which have been carefully studied by Mr. Billings and Prof. James Hall. The latter has described not less than fifty-one species of Graptolitideæ, which are figured in the second decade of Canadian Fossils, while most of the other species, including twenty-eight brachiopods, forty-two gasteropods, twenty cephalopods, and seventy-four crustaceans, have been described by Mr. Billings. The whole number of species described up to this time from the Levis formation, is 219; of these five have been detected in the Chazy and ten in the Calciferous, all the others being peculiar to the Quebec group, whose position is thus, it would seem, clearly defined as intermediate between the Calciferous and Chazy formations; none of its numerous species having been recognized in higher or lower rocks than these. The chief localities of these fossils are at Point Levis and Orleans island near the city of Quebec, and at Phillipsburg and Farnham near Missisquoi bay; but many of the characteristic forms are met with at numerous points between these two regions, the graptolites of the division in particular having been recognized among the cupriferous diorites on the St. Francis at Drummondville, and in the plumbaginous slates near the outlet of Lake Memphramagog.

This group of rocks appears in the province of Quebec along the southeast side of a great fault which has been traced from far below the City of Quebec to the line of Vermont on Missisquoi Bay. By this dislocation it is raised up along side of the rocks of the Trenton and Hudson river formations, and in one place is brought in contact with the Medina formation.

These higher strata, which are in some cases inverted along the line of fault, are often overlaid, and thus made to pass beneath the Quebec group. A little to the south of the province line this same fault brings up a still lower formation, the Red Sandrock of Vermont. This has been traced continuously from near Missisquoi bay to Shoreham, along the east side of the line of fault, while to the west appear the overturned and overlaid strata of the various formations from the Calciferous to the Hudson river formation inclusive. The line of fault is somewhat irregular, and where it has been affected by subsequent denudation, evidences of great overlapping are seen, the strata of the Hudson River formation, according to Sir William Logan, passing in some cases not less than a mile beneath the nearly horizontal layers of the Red Sandrock, which were by the earlier observers very naturally referred to the Medina formation, itself a red sandstone, and next in natural succession to the Hudson River formation in the New York series. In like manner the strata of the Quebec group, which, in Can-

ada, were found overlapping the Trenton limestone were regarded as belonging to the Hudson River formation until the study of their fossils led the way to a knowledge of their true age and relations.

The late Dr. Emmons supposed the Red Sandrock to include the Potsdam and Calciferous formations, though he at the same time completely misunderstood, as will be shown, its stratigraphical relations. Certain trilobites found in this formation by Prof. Adams in 1847 were recognized by Prof. Hall as belonging to the European genus *Conocephalus*, whose geological horizon was then undetermined, but which was afterwards shown to be a primordial type, and led Mr. Billings in 1861, to refer this sandrock to the Potsdam formation. (This Journal, II, xxxii, 232.) Subsequently the Rev. Zadock Thompson discovered in the slates of Georgia the trilobites which were by Emmons described as *Paradoxides*, but by Prof. Hall were recognized as a new genus *Olenellus*, of which he described two species, *O. Vermontana* and *O. Thompsoni*. Notwithstanding its designation, the Red Sandrock of Vermont consists in great part of a red or mottled granular dolomite associated with beds of fucoidal sandstone, conglomerate and slates.

This formation is well displayed in a section examined by Sir William Logan in Swanton, about two miles south of the boundary line between Quebec and Vermont, and described in the Geology of Canada, page 281. The thickness of the series here regarded as belonging to the Potsdam formation is 2,200 feet, intercalated in which, and about 500 feet from the base, occur 130 feet of gray and bluish-black slates, containing the two species of *Olenellus* noticed above, with *Conocephalites*, *Obolella*, *Orthisina*, &c. These slates have been traced southward to a locality in Georgia, where the same species of *Olenellus* occur in similar slates. The strata of the Potsdam formation in Swanton pass to the eastward beneath black shales and thin-bedded limestones holding the characteristic fossils of the Quebec group, and apparently representing the upper portion of the Levis formation. The superposition of these is well seen at Herrick's Mills, besides other places. The Levis formation may be traced northward around the extremity of the Potsdam rocks till it appears between these on the east, and the strata of the Trenton group on the west, forming a tongue which becomes narrower and disappears to the southward where the Potsdam comes directly up against the Trenton group. A little above this point, however, a section from Highgate Springs eastward takes us from the Trenton across a fault bringing up the Levis formation, followed at the distance of a mile farther eastward by a second dislocation by which the Potsdam is

brought up against the Levis, and again passes beneath it to the east, as in the Swanton section. By the second upthrow, a tongue of the Potsdam is carried northward a distance of about ten miles in the midst of the Quebec group. The details of this structure are fully given in the map and sections of this region by Sir William Logan, contained in the atlas accompanying the Geology of Canada. It is to be remarked that the lowermost beds of the Levis formation which are seen to the westward between the Trenton and the Potsdam, do not appear along the eastern limit of the latter, which is overlaid by beds belonging to the summit of the Levis, from which Sir William Logan conjectures a want of conformity between the two formations. The unconformability, in this vicinity, of the overlying rocks with the Potsdam is also to be inferred from the entire absence of the Calciferous from its place between the Potsdam and Levis formations in this locality, although in Newfoundland it appears in its proper position, and with a thickness of no less than 2,700 feet, resting upon more than 5,000 feet of rocks which are referred to the Potsdam group, and overlaid by the Quebec group, which there appears fully developed.

It happens then from the facts already set forth, that the Potsdam formation, which at its outcrop at the foot of the Adirondacks and Laurentides, includes only from 300 to 700 feet of sandstone, is represented a few miles to the eastward by not less than 2,000 feet of dolomites, sandstones and slates, and moreover that occupying a position between the Calciferous and Chazy formations, which are contiguous at their eastern outcrop, there becomes intercalated within this short distance, a fossiliferous group, several thousand feet in thickness. Sir William Logan explains these remarkable differences between the two regions in the following manner. At the beginning of the Silurian period, when the nucleus of the present continent was composed of Laurentian and Huronian rocks, partly rising into hills and in part forming a region of slight elevation, there were deposited in the surrounding seas the first fossiliferous beds of the period. To this succeeded a depression of the bed of the continent, upon the surface of which were then successively laid the shallow water deposits, which are known in New York as the Potsdam sandstone and the Calciferous Sandrock. Meanwhile strata characterized by a similar fauna to these, but having very different lithological character, were formed in the deeper waters which surrounded the continental plateau, this being submerged and elevated at intervals, became overlaid with beds which represent only in a partial and interrupted manner, the great succession of strata that were being

accumulated in the adjacent ocean, and which constitute to the eastward, the rocks of Quebec and Vermont, and in the west the great thickness of sediment contemporaneous with those which form the metalliferous series of Lake Superior.

Already, at this early period, movements were going on in the earth's crust, folding and dislocating the paleozoic sediments, within what we may call the oceanic area, while those of the continental plateau were at the same time left undisturbed. This Sir William Logan explains by the resistance offered by the solid continental gneiss. He says, "we may suppose that if a sufficient lateral pressure were applied to strata thus accumulated, and arranged, there would result a series of folds running in a direction at right angles to that of the force, with prevailing overturn dips toward the line of resistance. The solid crystalline gneiss offering more resistance than the newer strata, there resulted a break coinciding with the inclined plane at the junction of these with the gneiss. The lower paleozoic strata pushed up this slope would then raise and fracture the formations above, and be ultimately made to overlap the portion of those resting on the edge of the higher terrace, after probably thrusting over to an inverted dip, the broken edge of the upper formations. The shallow-water strata of the higher terrace relieved from the pressure by the break, would remain comparatively undisturbed, and thus the limit of the more corrugated area would correspond with the slope between the deep and shallow waters of the Potsdam period. The resistance offered by the buttress of gneiss would not only modify the main disturbance, but would probably also guide or modify in some degree, the whole series of parallel corrugations, and thus act as one of the causes giving a direction to the great Appalachian chain of mountains." (*Geol. of Canada*, p. 297.)

In further illustration of this view, I have to communicate a recent discovery which shows the progress of the change from the continental to the oceanic area, and demonstrates that at a point where the Potsdam had already assumed the character of the Red Sandrock, it was overlaid by all of the members of the New York series, up to the Hudson River group, inclusive. It is now some years since Mr. Billings of the Canada Geological Survey received from Messrs. C. H. Hitchcock and A. D. Hager, fossils apparently newer than the Quebec group, from a place to the east of the Potsdam in Sudbury, Vermont, and in 1866, the Rev. Augustus Wing, of Bridport in that state, correctly determined these to belong to the Trenton formation, and sent specimens of the fossils to Mr. Billings, who in April last, visited, and carefully examined the locality, with Mr. James Richardson. The following are the facts observed along a line

of section passing from Crown Point in New York across the head of Lake Champlain and through Bridport to Cornwall in Vermont. Passing from the Laurentian across the various members of the New York series, we reach the limestones of the Trenton group of the east shore of the lake and then encounter the Chazy formation which is brought up along a gentle anticlinal, and is succeeded by the Trenton, Utica, and Hudson River formation all sloping gently to the eastward until we come to the great fault which brings up the Red Sandrock. All the preceding details are shown on Mr. Hitchcock's map which accompanies the Geology of Vermont. This red sandrock which is here seen to overlap the Hudson River formation dips eastward at a small angle and is overlaid by a great mass of limestone holding the characteristic fossils of the Calciferous, among which, as determined by Mr. Billings, are *Ophileta complanata*, *Bathyurus conicus*, *Asaphus canalis*, and others too obscure to be identified. These fossils were first discovered by the Rev. Mr. Wing in Sudbury. At the summit of the formation, Mr. Billings was enabled to detect other obscure forms which resemble those of the Levis formation, and seem to indicate the first appearance of the Quebec group in its place between the Calciferous and Chazy formations. Next in ascending sequence, occurs a mass of limestones not less than 2,000 feet in thickness, and probably representing both the Chazy and the Trenton. From it the following Trenton species were obtained by Mr. Billings in Sudbury: *Stenopora fibrosa*, *Petraia corniculum*, *Glyptocrinus ramulosus*, *Ptilodictya acuta*, *Lepæna sericea*, *Strophomena alternata*, *Orthis testudinaria*, *O. pectinella*, *Pleurotomaria lenticularis*, *P. rotuloides* and *Trinucleus concentricus*.

To the east these limestones are cut off by a second dislocation, which brings up the Levis formation, with its characteristic fossils against the Trenton. A ravine marks the line of fault, which has been followed for a distance of more than twenty miles from the southern line of Sudbury northward to Weybridge, where it joins the great western fault. To the west of this line, fossils of the various divisions of the Trenton group are found in numerous localities, and to the east, the characteristic forms of the Levis formation, among which Mr. Billings has detected *Pleurotomaria Quebecensis*, *P. Missisquoi*, *Murchisonia Vesta*, *Ophileta bella*, *Maclurea matutina*, *M. ponderosa*, and *Bathyurus Saffordi*, besides which many large Orthoceratites are seen in section. These fossils are found in many localities in Sudbury, Cornwall, Middlebury, and Brookville. The limestones are for the most part bluish, but are closely associated with the white marbles quarried in these

localities. Thus at Brookville, Mr. Billings found Levis fossils immediately above and below the white marbles, clearly showing these beds of white crystalline limestone to belong to the lower portion of the Quebec group. This confirms the view expressed by me in this Journal for May, 1861, page 392, that these marbles represent a great development of calcareous matter in the Quebec group and are to be regarded as beds of chemically precipitated carbonate of lime, and not limestones of organic origin. Their great purity and crystalline texture depend upon original conditions of deposition, and not upon any subsequent alteration.

In this connection it may not be out of place to notice some of the views of the late Dr. Emmons which have lately been resuscitated, with certain modifications, by the Rev. J. B. Perry, in a communication to the Boston Society of Natural History in December last. Dr. Emmons conceived the Red Sandrock to be the base of the Silurian system, and to rest upon an older and unconformable series of rocks, to which he gave the name of the Taconic system. His views, though rejected by all American geologists, have been supported by Mr. Jules Marcou, who, however, differs from Dr. Emmons in including the Red Sandrock in the Taconic system, in which he is followed by Mr. Perry. For an exposition of the views of Dr. Emmons and of Mr. Marcou's curious misconception of them, the reader is referred to this Journal, II, xxxii, 427, and xxxiii, 135, 281.

According to Mr. Perry, the slaty rocks which appear to the east and west of the Red Sandrock, belong to two older formations or divisions, which he describes as Lower and Middle Taconic. In the latter he includes the Georgia slate with its primordial species and the Swanton slate considered to be still lower, with graptolites and *Atops trilineatus* Emmons, while he refers to the Lower Taconic, the slates, limestones and conglomerates of the Quebec group. This Middle Taconic is made up of three distinct series of black and brown shales, none, however, older than the Potsdam :

1st. His Swanton slates. These are the Utica and Hudson River formations which are distinctly overlapped by the Potsdam at various points along its western border, as at Sharpshins and Appletree Point, near Burlington, where the superposition is clearly seen, and where *Triarthrus Beckii* (*Atops*), is found in the underlying Hudson River slates. An excellent section, showing the superposition of the Potsdam to the Hudson River formation at St. Albans, is given by Mr. Hitchcock in the Geology of Vermont, page 374.

2d. The Georgia slates which are but an interstratified part of the Potsdam, as appears from the section at Swanton. The

*Conocephalites Teucer* Billings, cited by Mr. Perry as characteristic of these supposed lower slates, is, according to Mr. B., common to the slates and to the associated Red Sandrock.

3d. The black slates to the east of the Potsdam which belong to the Levis formation, and afford its characteristic fossils at various points all along their outcrop. We have seen that the Levis formation with its graptolitic slates had been at an early date confounded with the Utica and Hudson River formations in Canada, and all of these have now been confounded with the Georgia slates to make up the Middle Taconic. Finally, it remains to be said that this view consigns to a still more remote period, the lower Taconic, the great mass of the Quebec group which lies between the lines of fault already alluded to and the Green mountains, including the white marbles or Eolian limestones with their associated fossils, the Orthoceratites, Maclureas and other fossils already named, which no paleontologist would think of assigning to a horizon below the Potsdam.

To sum up in a few words—all the evidence, paleontological and stratigraphical, as yet brought forward, affords no proof of the existence in Vermont of any strata (a small spur of Laurentian excepted) lower than the Potsdam formation, which the present advocates of the Taconic system regard as forming its summit. The supposed more ancient Middle and Lower Taconic clearly consists in part of Potsdam, in part of Utica and Hudson River, and in part of the Quebec group, which also constitutes the Lower Taconic. To the upper portion of the Quebec group, the Geological Survey of Canada have already referred the gneiss of the Green mountains, assigning to this chain a synclinal structure, nor does there yet seem to be any reason to believe otherwise.

That strata still older than the Potsdam of New York and Vermont were deposited in some portions of the oceanic area, is apparent from the existence in New Brunswick of the St. John's slates holding a primordial fauna older than the Potsdam, and it is not impossible that their equivalents may underlie the Potsdam formation of Vermont. No such rocks have, however, as yet, been detected either in Vermont or Canada, and to preserve the name of the Taconic system as the designation of a series of rocks older than the Potsdam and lying unconformably beneath it, is simply to perpetuate an unfortunate mistake which I believe Dr. Emmons, if now living, would, with the paleontological evidence at present before the world, be the first to acknowledge.